APPENDIX G

AQUATIC PLANT CONTROL OF THE LAKE

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APPENDIX G AQUATIC PLANT CONTROL OF THE LAKE

CHAPTER I FAUNA AND FLORA IN THE STUDY AREA

1.1 Fauna and Flora in the Basin

The Study Area is highly developed for livestock farming and upland crop cultivation. Gentle slope forest area was cleaned off for cultivation. Pine and fast growing *Eucalyptus globulus* (Eucalyptus) are planted in the forest area, and *Salix humboldtana* (Willows) are planted mainly along irrigation channel. Bush communities were cleaned off for livestock farming and habitats for animals were lost. Diversity of the fauna is poor due to low diversity of flora. A wide area of the lake swamp gives habitats for animals.

1.1.1 Fauna

A study on the fauna in the Study Area was done in 1979, however, it was limited to birds and animals. The study identified 65 species of birds and 12 species of animals as shown in Table G.1.1.

The Study Team observed again the existing fauna in the Study Area during April to May, 1999. However, the observation area was limited to the surrounding of the Lake Fuquene due to security problems. The observation covered birds, mammals, reptiles and amphibians, fish, crustacea, arachinid and insect. The observed species are shown in Table G.1.2.

The Study Team reconfirmed 24 species of birds and 10 species of mammal in the surrounding area of the Lake among the birds and mammal species identified by the previous survey. Two (2) new species of mammal were identified through interview to the local people. They are *Dasypus novemcinctus* (Armadillo) and *Didelphis sp*.

Further, this time survey identified four (4) species of reptiles and amphibians, four (4) species of fish, one (1) species of crustacea, one (1) species of arachinid and fourteen (14) species of insects.

1.1.2 Flora

The survey on the flora in the Study Area was conducted in 1979, 1986 and 1997 one (1) time each. However, the survey covered only aquatic plants in the Lake. For the observed species of aquatic plants, see Chapter II, Table G.2.3.

The Study Team observed the existing flora in the Study Area. However, the study was limited to along the roads and the surrounding areas of the Lake due to security problems. The survey results are shown in Table G.1.3.

Diversity of the flora is poor due to the intensive cultivation development in the Study Area. Some species listed in the above table is still being confirmed. No endangered species are identified by this survey.

1.2 Plankton, Fish and Aquatic Animals in the Lake

The Study Team surveyed the existing species of fish, plankton and aquatic animals during April to May, 1999. The results are described below.

1.2.1 Plankton

The existing species of plankton in the Lake Fuquene were surveyed in 1977, 1981 and 1982. However, the surveys were limited to phytoplankton. The observed species of phytoplankton are shown in Table G.1.4. The Study Team has observed the exiting species of both phytoplankton and zooplankton during April and May, 1999. For the results, see Appendix E.

1.2.2 Fish

Four (4) species are found in the Lake. Names of the species are as follows.

Native species *Eremophilus mutisii*, *Grundulus bogotensis*

Exotic species *Cyprinus carpio*, *Carassius auratus*

It is reported that *Carassius auratus* (Gold fish) is a new exotic species identified by the Environment Agency of the Cundinamarca Province.

Salmo gairdneri (Trout) is bred at the deepest part of the Lake. There is no more natural Trout in the Lake. They shifted their habitats from the Lake to the connecting rivers due to the water pollution in the Lake. This shifting of Trout to the connecting river reduced predator pressure to the native fishes.

1.2.3 Aquatic Animals

(1) Invertebrates

(a) Turbellaria

It is reported that Snails (Gastropoda, Planorbidae family) were found on *Egeria densa* (Brazilian elodea) in the Lake. However, the snails were not found during this survey. The snail is known as a host of Schistosoma haemation. This related disease was not confirmed through the interview to the local people.

(b) Crustacea

Decapoda consists of shrimps, crayfish and crabs. This survey identified only crabs in the Lake. This identification was confirmed through the interview to the local people. The identified species during this survey is *Hipolobocera macropa* (Freshwater crab). It was found at root of *Scripus californicus* (Burlush).

(c) Macroinvertebrates

Oligochaeta (Worms) and Hirudinaea (Leeches) are found among roots of *Eichhornia crassipes* (Water hyacinth).

(d) Insects

The previous surveys show the following insects.

Order	Suborder	Family	Species
Coleoptera	Adephaga	Dytiscidae	*Rhantus sp., Platynectes sp., Bidessus sp.*
	Polyphaga	Gyrindae	*Gyrinus sp.*
		Hyddrophilidae	*Tropisternus laleralis, Tropisternus sp., Enochrus sp.*
		Psephanidae	
		Elimidae	

However, the above insects were not all found during this time survey. Only two (2) species of Coleoptera, three (3) species of Odonata, one (1) species of Ephemeroptera, one (1) species of Mesoveliidae, one (1) species of Hydrometridae, two (2) species of Veliidaae(Pond-skater), one (1) species of Corixidae, one (1) species of Chironomidae, one (1) species of Tipulidae (Cranefly) and one (1) species of *Loxablemmus sp.* were found. Further, lava of dragonfly was also found.

(2) Vertebrates

(a) Birds

All the confirmed birds in the Study Area were also found in or around the Lake. For the species of the birds, see Table G.1.2.

(b) Mammals

Cavia procellus, *Sylvilagus brasilensis*, *Dasypus novemcinectus* and *Pteronura brasiliensis* were confirmed in or around the Lake through interview to the villagers. *Dasypus novemcinctus* (Armadillo) and *Pteronura brasiliensis* (Otter) were newly identified during this survey.

(c) Reptiles and Amphilians

Anura is present in the Lake. A limited number of adult anura were found during this survey. Two (2) tadpoles are found (Hyla labialis). One (1) species of snake was found around the lake (Atractus crassicaudatus).

CHAPTER II AQUATIC PLANTS IN THE LAKE

2.1 Historical Change of Aquatic Plants

2.1.1 Change of Lake Morphology and Aquatic Plants

(1) Lake Morphology

Bathymetric survey in the Fuquene Lake was undertaken four (4) times, namely, in 1962, 1980, 1984 and 1997. The survey results/bathymetric maps in 1984 and 1997 are available, which are shown in Figs. G.2.1 and G.2.2 respectively. The areas for lake bed elevation in 1984 and 1997 are tabulated in Tables G.2.1 and G.2.2 respectively.

In the Fuquene Lake, the deeper potions are found in east of the Lake, south of the island (El Santuario) and central part of the lake. These deeper portions (deeper than El. 2,536 m) might have become narrower and shallower during 1984 to1997, while the remaining wide shallower portions (shallower than El.2,536 m) shows no big change in depth and area.

The maximum and average water depths of the Lake are estimated to be 6.0 m and 1.5 m measured from the water level of 2,539.0 m respectively.

(2) Aquatic Plants

Aerial photos of the Fuquene Lake can be obtained from the Geographic Institute "Agustin Codazzi". The photos of the Fuquene Lake were taken 12 times since 1940 as tabulated below.

No.	Date	Series No.	Scale	Remark
1	1940/Nov.29	A-208	1/25,000	Not Complete
2	1940/Dec.11	A-211	1/25,000	
3	1955/Jan.27	M-45	1/60,000	
4	1955/Feb.16	M-47	1/60,000	
5	1956/Jan.20	M-52	1/30,000	
6	1962/Feb.21	C-1054	1/20,000	
7	1963/Feb.21	C-1056	1/20,000	
8	1978/Feb.2 to 4	C-1822	1/27,000	
9	1982/Jan.20	C-2050	1/20,000	
10	1983/Jan.09	C-2072	1/20,000	
11	1989/Nov.11	C-2378	1/30,000	
12	1993/Dec.24-26	C-2525	1/40,000	

The last aerial photo was taken six (6) years ago (1993/Dec.). However, it is not considered to show the real existing features of the Lake due to the recent high growth of aquatic plants in the Lake. Therefore, the JICA Study Team took a new aerial photo in May 15, 1999.

In consideration of the photo taking intervals, seven photos, namely, 1940 (Dec. 11), 1955 (Jan. 27), 1963 (Feb. 21), 1978 (Feb. 2-4), 1983 (Jan. 9), 1989 (Nov. 11) and 1999 (May 15) are used to analyze the historical change of aquatic plants in the Lake.

Followings are the conclusions of GIS analyses made in cooperation with the CAR based on the aerial photos.

(a) Existing Aquatic Plant Distribution

Fig. G.2.3 indicates existing (May 15 1999) aquatic plant distribution in the Fuquene Lake classifying the plants into five (5) categories, namely, (1) Bulrush (*Scirpus Californicus*), (2) Cattail (*Typha angustifolia*), (3) Water hyacinth (*Eichornia crassipes*) and other floating plants, (4) Water hyacinth and Brazilian elodea (*Egeria densa*) and (5) Brazilian elodea.

Following table tabulates existing areas of each aquatic plants mentioned above and water surface.

Classification	Area (ha.)	Percent (%)
Bulrush	842.2	52.8
Cattail	56.7	3.6
Water hyacinth & other floating plants	545.7	34.2
Water hyacinth & Brazilian elodea	151.2	9.5
Sub-total (covered area by aquatic plants)	1,595.8	100.0
Brazilian elodea (submerged)	804.4	
Pure water surface	558.8	
Sub-total (water surface area)	1,363.2	
Total	2,959.0	

The area of Brazilian elodea in the above table is limited to the area where Brazilian elodea emerges to the water surface and were taken by the photo. Therefore, the total area of Brazilian elodea including the submerged one covers much wider area than the above.

(b) Historical Propagation of Aquatic Plants

Fig.G.2.4 indicates historical propagation of aquatic plants (emergent and floating leaf/floating plants) obtained from the eighth (8) aerial photos and the following table tabulates the decrease of water surface due to the expansion of aquatic plants.

No.	Date	Water Surface Area (ha)	Expanded Plant Area (ha)	Accumulated Plant Area (ha)
1	1940/Dec.11	3,071	-	-
2	1955/Jan.27	2,806	265	265
3	1963/Feb.21	2,376	430	695
4	1978/Jan.04	2,211	165	860
5	1983/Jan.09	2,036	175	1,035
6	1989/Feb.16	1,881	155	1,190
7	1993/Dec.25	1,603	278	1,468
8	1999/May 15	1,363	240	1,708

Fig.G.2.5 indicates the water surface decreasing rate during 59 years from 1940 to 1999. From this figure, the decreasing rate has changed after the year of 1989. Before 1989, decreasing rate was 24.5 ha/year, while after 1989 decreasing rate has doubled to 50.4 ha/year.

(c) Historical Propagation of Bulrush

The present area of Bulrush in the Fuquene Lake is 842.2 ha, which has expanded for 58.5 years since Dec. 1940 and therefore, the average increasing rate of Bulrush during the same period was 14.4 ha/year.

An emergent plant, Bulrush is considered to play a definitive role for dry-up process of the present Fuquene Lake because rhizomes tie in a permanent way to the substrate and stalks accelerate deposition of organic/inorganic matters. It may be said that at the beginning of invasion of aquatic plants to water body, they were composed of floating/floating leaf plants and then have changed to Bulrush after a long time.

In order to analyze the time necessary for Bulrush to become dominant in the littoral zone of the Fuquene Lake, the existing Bulrush area is overlaid on the historical propagation of aquatic plants as shown in Fig.G.2.4. From this overlaid figure, the historical expansion of Bulrush area is calculated as tabulated below.

Period	Expanded Plant Area (ha)	Expanded Bulrush Area (ha)	Percent to Total Area (%)	Percent to Expanded Plant Area (%)
1940 to '55	265	188	22.3	70.9
1955 to '63	430	281	33.4	65.3
1963 to '78	165	159	18.9	96.4
1978 to '83	175	117	13.9	66.9
1983 to '89	155	35	4.2	22.6
1989 to '93	278	2	0.2	0.7
1993 to '99	240	60	7.1	25.0
Total	1,708	842	100.0	49.3

As shown in the above table, the expanded aquatic plant area (165 ha) during 1963-1978 has been completely converted to Bulrush area (96.4%). The expanded aquatic plant areas during 1940-1955 and 1955-1963 are also considered to have been completely converted to Bulrush area. The aerial photo taken in 1999 did not identify Bulrush in some parts of the expanded plant areas during 1940-1955 and 1955-1963 because the Bulrush in such areas had already been replaced by pasture.

From the above discussions, it is concluded that the floating/floating leaf plant areas in 1978 has been completely converted to Bulrush growing areas in 20 years (1978 to 1999). Hence, the conversion time from the existing floating/floating leaf plants to Bulrush is roughly estimated to be 20 years.

2.1.2 Change of Species

The aquatic plants in the Lake have been surveyed four (4) times since 1979. They are the surveys in 1979, 1986, 1997 and 1999 (survey of this Study). The identified species of the aquatic plants by the four (4) times surveys are listed in Table G.2.3. The plant classification of 1986 survey was different from that of the other surveys and therefore, the classification was changed to conform to the others in the above table.

The aquatic plants are classified into four (4) categories: submerged plant, floating leaf plant, floating plant and emergent plant.

A submerged plant of *Egeria densa,* (Brazilian elodea) was first officially reported in 1997 survey although it has widely been recognized by the local people since the beginning of 1990s.

A submerged plant of Ranunculaceae Family, *Ranunculus sp*. was identified by the 1986 survey as shown in Table G.2.3. On the other hand, *Egeria densa* is classified as Hydrocharitaceae Family. However, they have nearly same shape and flower. *Ranunculus sp*. has not been found in the later surveys in the Lake as well as in the upstream rivers. Hence, it is supposed that *Egeria densa* was classified as *Ranunculus* sp. in 1986 survey and *Egeria densa* had already invaded into the Lake as of 1986.

A floating leaf plant *Potamogeton illinoensis* (Pondweed) and floating plant of *Eichornia crassipes* (Water hyacinth) have continuously been confirmed through all the surveys.

The emergent plant of *Scirpus californicus* (Bulrush), *Bidens laevis* and *Ludwigia peplides* have also been continuously confirmed through all the surveys. *Typha angustifolia* (Cattail) was not identified in 1986 survey, however, it probably existed in the Lake since it is strong. New species of emergent plant *Pseadoraphis* sp., *Hydrocatyle ranunculoides, Juncus bogotensis*, *Scripus* sp. and *Begonia cucullata* were found around the Lake in 1999 (this time survey). *Hydrocotyle ranunculoides* is reported in 1979 survey only. It probably has become extinct.

2.2 Existing Aquatic Plants

2.2.1 Submerged Plants

The existing submerged plant in the Lake is *Egeria densa* (Brazilian elodea) only. *Potamogetan illinoensis* is classified into floating leaf plant in this Report. It is considered that *Egeria densa* appeared in the Lake before 1986 as mentioned in the above Section. It is distributed over the water surface area with a water depth of 1.9 m – 3.8 m according to the field survey. It does not grow in the shallower area than 1.9 m depth since the area is covered by emergent and floating plants. It also does not exist in the deeper area than 3.8 m due to the lack of photosynthesis effects.

It covers approximately 90 % of the water surface area (about 1,400 ha) of the Lake. It will grow even in deeper areas than 3.8 m if water turbidity is low enough so that sunlight can reach the bottom.

It does not exist in the inflow river of the Lake: Ubate River, however, abundant in the outlet river: Suarez River. This is considered due to the difference in water turbidity, river flow velocity and water depth in dry season (Ubate River is dried up in dry season). Further study is necessary to reach the final conclusion.

Branches sprout from “double nodes” located at intervals along the stems. Slender roots extend to attach the bottom soils from the nodes located in the lower part of the stems. Generally, its height is said to be about 1.0 m, however, it extends up to 3.0 m at maximum in this Lake.

The stems are provided with dense bright green leaves. Length of the leaves is 2 - 3 centimeters. Small and white flowers bloom above water surface. In densely growing area, some plants change the color white and many hairy roots grow from the main roots. It absorbs nutrient from water and soils through leaves, stems and roots.

The plant reproduces by the spread of plant fragments or grows from the stems cut by machine. Two (2) cutting machines are deployed in the Lake, which cut weeds from 1.5 m below water surface. It is reported that Elodea will completely recover in a short time after cutting.

2.2.2 Floating Leaf Plants

The existing floating leaf plant in the Lake is *Potamogeton illinoensis* (Pond weed) only. *Potamogeton illinoensis* (Pond weed) is reported to have been prevailing before invasion of *Egeria densa* (Brasilian elodea). It grows from bottom up to water surface in the area shallower than 4.0 m. It makes no large community and coexists with *Egeria densa.*

Water lily was not found during this Study in the Lake, however, one (1) species is found in irrigation drainage channel entering the Suarez River.

2.2.3 Floating Plants

There are four (4) species of floating plants in the Lake: *Eichornia crassipes*, *Lemna polyrrhiza*, *Lemna minor* and *Azolla filicuoides.* Among them, the most prevailing plant is *Eichornia crassipes* (Water hyacinth), and *Lemna polyrrhiza*, *Lemna minor* and *Azolla filicuoides* exist in some limited areas. *Eichornia crassipes* has already been identified in 1979 survey. It makes thick and hard mattresses in the sallow areas than 1.9 m according to the field survey. In the deeper areas, *Eichornia crassipes* makes a floating island together with emergent plants, of which diameter sometimes exceeds 10 m.

2.2.4 Emergent Plants

There are 12 species of emergent plant in the Lake: *Scirpus californicus, Typha angustifolia, Bidens laevis, Cyperrus rufus, Ludwigia peploides, Polygonum hidropiperoides, Myriophyllum aquzticum, Juncus bogotensis, Hydrocatyle ranunculoides, Pseudoraphis sp, Scripus* sp. and *Begonia cucullata.*

Among them, the major plants in the Lake are *Scirpus californicus and Typha angustifolia*. They are tall, grow up to approximately 2.5 – 3.0 m in height and coexist with such small emergent plants as *Ludwigia peploides, Polygonum hydropiperoides, Myriophyllum aquaticum and Biden laevis*. *Scirpus californicus* is called as Junco in local name.

Polygonum hydropiperoides grows up to about 1.5 m in the case that it coexists with tall *Scirpus califonicus and Typha angustifolia.*

Ludwigia peplides and Polygonum hydrpiperoides grow in two (2) forms – floating leaf form and emergent form. *Scirpus californicus and Typha angustifolia* have big roots with light leaves and stems, and can grow in water. During the field survey, *Scirpus californicus and Typha angustifolia* was found at such deep water depths of 0.9 m and 2.6 m, respectively.

2.3 Biomass Survey

A biomass survey was carried out for *Egeria densa* (Brazilian elodea) of submerged plant, *Eichornia crassipes* (Water hyacinth) of floating plant, and *Scirpus californicus* (Burlush) and *Typha angustifolia* (Cattail) of emergent plants. The sampled biomass was measured in wet weight.

2.3.1 Submerged Plant

Brazilian elodea covers a wide area in the Lake. The plant propagation is controlled by machine cutting. The biomass measurement was carried out in the area where the plants were not recently cut to avoid the effects of machine cutting.

(1) Sampling Method

Elodea is sampled by harvesting by a scythe at 22 plots covering the lake areas with different water depth. The test plots in 3 m x 3 m size each are enclosed by a fish net to prevent the harvested Elodea to float away.

The biomass at each plot was measured with the breakdown into two (2) portions: water surface to 1.0 m depth and 1.0 m depth to bottom. The weight measurement was done in wet condition.

(2) Results of Sampling Survey

The survey results are shown in Fig. G.2.6. The biomass density decreases in inverse proportion to water depth. No significant Elodea was identified in the areas deeper than 3.8 m. The average density in wet weight by water depth is summarized as follows.

Water Depth	Density (kg/m^2) in Wet Weight		
	Upper 1.0 m	From 1.0 m to Bottom	Total
less than 2.00 m	14.46	4.44	18.89
2.01 m - 2.50 m	11.58	4.56	16.14
2.51 m – 3.00 m	11.59	2.70	14.29
3.01 m – 3.80 m	4.25	7.52	11.77
More than 3.8 m	0.00	0.00	0.00

Sampling location is shown in Fig. G.2.7.

(3) Estimation of Biomass

The existing water surface area (including Elodea) is delineated as shown in Fig. G.2.3. On the other hand, the water surface area (excluding emergent and floating plants area) by water depth is delineated by using the bathymetric map in 1984. There are two (2) bathymetric maps of 1984 and 1997 surveys are available. However, the 1984 map is used since it covers a wider area of the Lake than 1997 map and no significant change is identified in the lake bed topography of both maps.

The existing water surface area by water depth is calculated by overlapping both figures as shown in the following table. Elodea is growing in the water surface area shallower than 4.0 m in the following table.

Water Depth (m)*	Water Surface Area (ha)	Elodea Growing Area (ha)
Less than 2.0	518	518
2.01 – 3.00	601	601
3.01 – 4.00	85	85
4.01 – 5.00	99	0
More than 5.01	60	0
Total	1,363	1,204

*: Water level is assumed at 2,539.0 m.

The total quantity of Elodea in the Lake is estimated at 197,300 ton in wet weight with the following break down.

Portion	Wet Weight (ton)	Average Density (kg/m^2)
Upper 1.0 m depth	147,400	12.24
1.0 m depth to bottom	49,900	4.14
Total	197,300	16.38

2.3.2 Floating Plant

The prevailing floating plant in the Lake is Water hyacinth. Most of Water hyacinth form floating islands together with various species of the other floating plants and emergent plants. The mixed major species of floating and emergent plants are *Lemnar minor, Bidens laevis, Ludwigia peplides and Polygonum hidropy peroides.*

The sampling measurement for the biomass of floating plant was made at 20 plots of the floating islands. The sampling lot covers an area of 9 m^2 (3 m x 3 m) each. The biomass of Water hyacinth and other mixed plants were separately measured in wet weight.

The floating plants forming islands grow in the lake area with a water depth shallower than 3 m. The average biomass density of the total floating plants is estimated to be 109.11 kg/m^2. The biomass dendity of the total floating plants decreases according to the increase of the mixed plants due to mutual competition as shown below. Especially, mixing of higher emergent plants much reduces the biomass density of the total floating plants.

Mixed Plants Biomass (kg/m^2)	Total Biomass (kg/m^2)
0.00	119.09
0.01 - 0.50	114.94
0.51 – 1.50	109.17
More than 1.51	47.12

On the other hand, the existing floating plant area is estimated to be 696.9 ha (see, Sub-section 2.1.1). Accordingly, the total existing biomass of the floating plants is roughly estimated at 690,000 ton in wet weight as shown below.

Plant	Area (ha)	Density (kg/m^2)	Wet Weight (ton)
Water hyacinth with other floating/emergent plants	545.7	109.11	595,400
Water hyacinth with Elodea	151.2	62.75*	94,900
Total	696.9		690,300

*: Average density of Water hyacinth (109.11 kg/m^2) and Elodea (16.38 kg/m^2)

The sampling survey results are shown in Table G.2.4. For sampling location, see Fig. G.2.7.

2.3.3 Emergent Plant

There 12 species of emergent plant in the Lake of which two (2) tall emergent plants: Burlush and Cattail are prevailing. These two (2) tall emergent plants coexist with the other small emergent ones. Cattail usually grow offshore of Burlush.

The sampling measurement of biomass was made at 20 plots for Burlush mixed with other small emergent plants and at 10 plots for Cattail mixed with other small emergent plants. The sampling lot covers an area of 9 m^2 (3 m x 3 m) each. The biomass was measured by dividing the following three (3) portions: (i) leafs/stems above water surface, (ii) leafs/stems under water, (iii) roots.

Burlush mostly grows in the lake area shallower than 1.5 m, on the other hand, Cattail exists offshore of Burlush with a water depth of 0.9 – 2.5 m.

The average biomass density of the two (2) emergent plants are shown below along with the mixed species of other emergent plants.

Plant	Biomass Density ((kg/m^2)			Total
	Leaf/Stem above Water Surface	Leaf/Stem under Water	Root	
Burlush	7.87	10.23	12.14	30.22
Cattail	8.46	8.60	90.65	107.70

The existing Burlush and Cattail areas are estimated to be 842.2 ha and 56.7 ha respectively (see, Sub-section 2.1.1). Accordingly, the total existing biomass of the emergent plants is roughly estimated at 315,600 ton in wet weight with the breakdown of Burlush (254,500 ton) and Cattail (61,100 ton).

The sampling survey results are shown in Table G.2.5. For sampling location, see Fig. G.2.7.

2.4 Reproduction Experiment of Brazilian Elodea

2.4.1 General

Brazilian Elodea reproduces by striking plant fragments into soil or by sprouting from the stems harvested by machine. Elodea of the Lake grows at a high speed. It is said to reproduce up to the original height in a short period when it is harvested, leaving roots and some portion of the stem on the lake bed. However, the reproduction rate of Elodea is unknown when it is completely harvested, leaving no roots and stems on the lake bed.

A field experiment was tried for the purpose of analyzing the reproduction rates of Elodea under the following two (2) different conditions. The test started mid June, 1999 with cooperation of CAR.

2.4.2 Reproduction after Machine Harvesting

The reproduction experiment was done at the following five (5) locations: (A) northern fringe of Isla Santuario, (B) southern fringe of Isla Santuario, (C) near Isla Santuario, (D) near the mouth of Q. Monroy and (E) near the mouth of Naranjitos canal. The existing Elodea in each experimental location was harvested by machine by 1.5 m depth from the water surface, leaving roots and some portion of stems on the lake bed. The experimental lots were not enclosed by protector and then, invasion of Elodea fragments from outside was allowed.

The experimental conditions and results at the five (5) locations are summarized below.

Loca-tion	Water Depth (m)	Case	Starting Date	Initial Vol. (kg/m^2)	Measurement Time	Measured Vol. (kg/m^2)	Reproduction Vol. (kg/m^2)
A	1.90	A-1	Jun. 17, 1999	0.46	-	-	-
		A-2			After 49 days	0.52	0.06
		A-3			After 78 days	0.53	0.07
		A-4			After 120 days	0.70	0.24
		A-5			After 195 days	2.36	1.90
B	2.55	B-1	Sep. 23, 1999	0.81	-	-	-
		B-2			After 30 days	1.51	0.70
		B-3			After 97 days	5.44	4.63
C	2.50	C-1	Oct. 28, 1999	0.22	-	-	-
	2.34	C-2			After 32 days	0.28	0.06
	1.90	C-3			After 63 days	0.22	0.00
D	2.54	D-1	Oct. 28, 1999	0.44	-	-	-
	2.28	D-2			After 32 days	4.56	4.12
	1.91	D-3			After 63 days	4.00	3.56
E	3.10	E-1	Oct. 28, 1999	0.94	-	-	-
	2.57	E-2			After 32 days	0.22	0.00
	2.60	E-3			After 63 days	4.44	3.50

Note: Original biomass before harvesting: Location A: 11.51 kg/m^2, Location B: 14.29 kg/m^2

The reproduction rate of Elodea after machine harvesting was still small during the experiment period of this time. The experiment must be continued to obtain the final conclusion. Because the reproduction rate may make a rapid increase after Elodea grows to a certain height where photosynthesis capacity is large.

2.4.3 Reproduction after Complete Removal

The reproduction experiment was done at the northern fringe of Isla Santuario with a water depth of 2.0 m. The existing Elodea in the experimental lot was completely removed by dredging, leaving no roots and stems on the lake bed. The experiment was done for five (5) lots of which four (4) experimental lots were enclosed by net to prevent invasion of Elodea fragments from outside and the remaining one (1) lot was not enclosed by net, allowing invasion of Elodea fragments. Further, some of the above enclosed lots were artificially planted with Elodea fragments to observe the growth rate of Elodea fragments stricken into the bed.

The above experiment started on July 17, 1999. The experimental conditions and results at the five (5) lots are summarized below.

Lot	Water Depth (m)	Protect -ion	Artificial Planting	Measurement Time	Reproduction Vol. (kg/m^2)	Shoot Sprouting	Root Sprouting
A*-1	2.45	by net	13 fragments	After 32 days		1-2 cm	5 cm
A*-2	2.20	by net	13 fragments	After 63 days	0.05	max. 60 cm ave. 30 cm	max. 30 cm ave. 15 cm
A*-3	2.34	by net	13 fragments	After 165 days	1.38		
A*-4	2.46	by net	No planting	After 165 days	0.90		
A*-5	2.40	None	No planting	After 122 days	0.22		

Note: Original biomass before removal: 11.51 kg/m^2

The above table shows that Elodea may not recover easily once it is completely removed by dredging.

CHAPTER III AQUATIC PLANT CONTROL MEASURES

3.1 Necessity of Aquatic Plant Control

3.1.1 Projection of Future Aquatic Plant Area

The future aquatic plant area of the Lake is projected as follows based on the analysis in Chapter II, Sub-section 2.1.1.

(1) The total aquatic plant area of the Lake (covering emergent and floating plant areas but excluding submerged plant area) has increased by 1,708 ha during 59 years of 1940 to 1999. The expansion speed during 1940-1989 was 24.5 ha/year on average, however, it has accelerated to 50.4 ha/year during the recent 10 years of 1989-1999.

(2) This expansion has always been initiated by formation of floating aquatic islands and thereafter, the floating islands have gradually been replaced by emergent plants. According to the interpretation of the historical aerial photographs, the expanded floating plants have completely been replaced by emergent plants after 20 years. Hence, all the existing floating plant areas are assumed to become the emergent ones after 20 years in the future.

(3) On the other hand, the habitat of emergent plants is limited to wet-lands or shallow water areas. They generally grow in the water areas of the Lake shallower than 1.5 m. According to the bathymetric map of the Lake in 1984, the lake area shallower than 1.5 m (measured from the elevation of 2,539.0 m) is estimated to be 1,603 ha. Hence, the emergent plant area in the water of the Lake will not exceed 1,603 ha in the future.

(4) The existing aquatic plants of the Lake in 1999 are distributed as follows.

Classification	Area (ha)	(%)	Remarks
Emergent Plant	898.9	30.4	Burlush (842.2 ha), Cattail (56.7 ha)
Floating Plant	696.9	23.6	Water Hyacinth and others
Sub-total	1,595.8	54.0	Total aquatic plant area
Submerged Plant	1,204.0	40.7	Growing in water area shallower than 4.0 m
Pure Water Area	159.2	5.3	Water area deeper than 4.0 m
Sub-total	1,363.2	46.0	Total water area
Total	2,959.0	100.0	Total lake area

(5) The total emergent and floating plants area will reach 2,654.2 ha in 2020 if it continues expanding at a speed of 50.4 ha/year in the future. The emergent plants will cover 1,595.8 ha of the total area of 2,654.2 ha in 2020 if the existing floating plant area is completely replaced by emergent plants. For this assumption, see Chapter II, Subsection 2.1.1 (c). The future aquatic plants in the Lake will distribute as shown below in 2020.

Classification	Area (ha)	(%)	Remarks
Emergent Plant	1,595.8	53.9	Burlush, Cattail
Floating Plant	1,058.4	35.8	Water Hyacinth and others
Sub-total	2,654.2	89.7	Total aquatic plant area
Submerged Plant	145.6	4.9	Growing in water area shallower than 4.0 m
Pure Water Area	159.2	5.4	Water area deeper than 4.0 m
Sub-total	304.8	10.3	Total water surface area
Total	2,959.0	100.0	Total lake area

(6) The future aquatic plants distribution in 2010 (target year of this master plan study) is interpolated between those of 1999 and 2020. In this interpolation, the total area of emergent and floating plants is assumed to linearly increase from 1,595.8 ha in 1999 to 2,654.2 ha in 2020. The floating plant is assumed to increase at a constant growth rate every year, referring to a basic concept in the previous study report [1)] as follows.

$$Vt = Vo\ (1 + r)^{t}$$

Where, Vt: volume of t year, Vo: initial volume, r: annual growth rate, t: elapsed year

The floating plant of the Lake increases at a high rate every year, on the other hand, some part is replaced by the emergent plant. Then, it will increase from 696.9 ha in 1999 to 1,058.4 ha in 2020 at an apparent growth rate (net growth rate) of 2% per annum.

The future aquatic plants in the Lake in 2010 will distribute as shown below.

Classification	Area (ha)	(%)	Remarks
Emergent Plant	1,284.0	43.4	Burlush, Cattail
Floating Plant	867.0	29.3	Water Hyacinth and others
Sub-total	2,151.0	72.7	Total aquatic plant area
Submerged Plant	649.0	21.9	Growing in water area shallower than 4.0 m
Pure Water Area	159.0	5.4	Water area deeper than 4.0 m
Sub-total	808.0	27.3	Total water surface area
Total	2,959.0	100.0	Total lake area

3.1.2 Problems Caused by Excessive Aquatic Plants

The following major problems will be caused by the above mentioned excessive growth of aquatic plants in the future.

(1) Reduction of Storage Capacity of the Lake

Aquatic plants remove water, resulting in reduction of storage capacity of the Lake and those in the shallow areas reduce its effective storage capacity. Reduction of the effective storage capacity of the Lake is estimated as follows.

The existing area, average density and biomass of the aquatic plants in the Lake are summarized below.

Plant	Area (ha)	Average Density (kg/m^2)	Total Biomass (ton)	Under Water Biomass (ton)	Reduced Effective Storage (m^3)*
Emergent	899	35.11	315,600	244,700	244,700
Floating	697	99.04	690,300	345,200	345,200
Submerged	1,204	16.38	197,300	197,300	147,400
Total	2,800		1,203,200	787,200	737,300

*: specific weight of aquatic plants is assumed to be nearly 1.0 ton/m^3.

In the above table, the underwater biomass of emergent plant is estimated by field observation. The underwater biomass of floating plant is assumed to be half of the total biomass since the lower portion of floating plants are submerged under water.

The underwater biomass of emergent plants is assumed to fully reduce the effective storage capacity since they grow in the shallow water areas. It is evident that the underwater biomass of floating plants fully reduces the effective storage capacity. With regard to submerged plants, the biomass in the upper layer of 1.0 m depth (75% of total biomass) is assumed to actually reduce the effective storage capacity. Reduction of the effective storage capacity at present is also shown in the above table.

Reduction of the effective storage capacity in the future is also estimated in the same way as the present. It is shown below.

Plant	Area (ha)	Average Density (kg/m^2)	Total Biomass (ton)	Biomass under Water (ton)	Reduced Effective Storage (m^3)*
Emergent	1,596	35.11	560,400	435,100	435,100
Floating	1,058	99.04	1,047,800	523,900	523,900
Submerged	146	16.38	23,900	23,900	17,900
Total	2,800		1,632,100	982,900	976,900

*: specific weight of aquatic plants is assumed to be nearly 1.0 ton/m^3.

As mentioned above, the effective storage capacity of the Lake will further decrease by 240,000 m^3 by the year of 2020 due to the growing aquatic plants when no control measures are taken.

(2) Deterioration of Lake Water Quality

Excessive growth of aquatic plants makes the lake water anaerobic due to the following effects.

(a) Decomposition of withered aquatic plants consumes oxygen in the lake water.

(b) Coverage of aquatic plants on the water surface shades sunlight, resulting in prevention of the photosynthesis of plants.

(c) Coverage of aquatic plants on the water surface reduces natural aeration of the lake water (input of oxygen from air into the lake water).

The lake water has already become anaerobic in the areas with densely growing aquatic plants, emitting a toxic substances of H_2S, especially under the floating islands. In such areas, the lake water is colored black and emits a bad odor. Further, the entire lake deposits are under an anaerobic condition, allowing no lives in the deposits. See, Appendix E. Chapter I, 1.4.

The water quality will further worsen in the future according to the growth of aquatic plants. It will cause fatal damages not only on the aquatic lives in the Lake but also on the water uses in the surrounding areas.

Such deteriorated lake water may not allow benthos, fishes and other aquatic lives at all. Treatment of such water for human use may not be difficult, however, groundwater recharged from the Lake may decay roots of the pastures in the surroundings of the Lake.

(3) Blocking of Water Flow

Excessive aquatic plants in the Lake block the outlet of the Lake and those in the Suarez River also block the water flow in the River. This blocking may result in flood damages on the surrounding low areas of the Lake and damages on the water uses in the downstream of the Suarez River.

3.2 Possible Control Measures

The following five (5) control measures are enumerated as the possible ones; (i) Reduction of inflow nutrients, (ii) Dredging of the lake bed, (iii) Harvesting of submerged plants, (iv) Removal of floating plants and (v) Aquatic plant control by grass carp.

3.2.1 Reduction of Inflow Nutrients

Aquatic plants grow up by absorbing various kinds of nutrients from the bed soil and water through the roots, stems and leaves. Nitrogen (N) and phosphorus (P) are the most essential nutrients. The Lake is currently much eutrophicated and contains a large quantity of N and P in the water and bed deposits as shown below.

Item	N	P
Average Water Quality (mg/l)	1.83	0.07
Average Bed Deposit Quality (mg/dry-kg)	4,600	150

Reduction of the inflow nutrients (N, P) into the Lake is not considered effective as described below although the cut of nutrient sources may theoretically curb the growth of aquatic plants.

(1) Most of the inflow nutrients (N, P) to the Lake come from the non-point sources including livestock, lands (farmland, pasture and shrub/forest) and households in rural area. Those from the point sources of sewerage and industries are limited. Percentage of the existing annual inflow of nutrients by source are shown below (see, Appendix E, Chapter III, Sub-section 3.2.2).

Pollutant Source	N (%)	P (%)
Sewerage	21.1	20.0
Industry	0.8	2.3
Livestock	61.9	76.2
Land	16.1	1.5
Household	0.1	0.0
Total	100.0	100.0

Currently, there is no practical way to control N and P of the livestock and lands. Treatment of N and P in the above sewerage and factories is technically possible. However, it requires a large cost, hence, it is considered economically infeasible.

(2) Highly concentrated nutrients (N, P) are accumulated in the deposits of the entire lake bed as shown above. A large quantity of nutrients (N, P) are continuously released from the lake bed into the water. (see, Appendix E, Chapter III, Sub-section 3.4.3). The lake bed has a large nutrient potential sources which can grow aquatic plants for a long time.

(3) Aquatic plants are said to grow even in an oligotrophic lake.

3.2.2 Dredging of the Lake Bed

Dredging of the lake bed will decrease the photosynthesis capacity of Elodea. The lake bed must be dredged to maintain the water depth of more than 4 m to completely control the growth of Aquatic plants. The required dredging works covers 1,900 ha (lake area shallower than 4.0 m excluding emergent plant area) and an earth volume of 43 million m^3. Hence, the possible dredging will be limited to such critical areas as the front zone of Bulrush.

Dredging of the front-zone of Bulrush may contribute to the control of the expansion of Bulrush area since its habitat is usually limited to the wetlands or shallower water areas than 1.5 m.

3.2.3 Harvesting of Submerged Plants

CAR and Cundinamarca Prefecture are currently harvesting submerged plants (mainly Elodea) by machines every day. The machines harvest only the upper portion of Elodea (1.5 m from the water surface), leaving the lower part of stems and roots on the lake bed. As a result, Elodea is said to reproduce itself to the original conditions in a short period after the harvesting.

This harvesting is endless. Then, CAR and Cundinamarca Prefecture are troubled with disposal of the harvested Elodea. Use of the harvested Elodea is considered to be the key for the successful implementation of this control measures.

According to the questionnaire survey, approximately 50% of the total number of farmers in the Study Area are interested in using Elodea as fertilizer. Then, use of the harvested Elodea as green fertilizer for the surrounding pasturelands of the Lake or as compost for the farmlands is considered to be one of the most possible uses.

3.2.4 Removal of Floating Plants

The total existing floating plants (mainly Water hyacinth) cover approximately 700 ha which mostly form aquatic floating islands. The floating islands of Water hyacinth are mixed with other floating plants/small water resistant emergent plants and withered Elodea. The total floating plant area is extending at a high rate every year.

Removal of these floating plants is also urgent. However, an adequate disposal system of the removed floating plants should be developed since the required disposal quantity is large. Composting of the removed floating plants for agricultural use is considered to be the most possible disposal system.

3.2.5 Aquatic Plant Control by Grass Carp

The Grass Carp (*Ctenopharyngodon idellus*) is indigenous to those rivers of North Vietnam, China and Russia that flow into the Pacific Ocean. It has been introduced into more than 50 countries throughout the world for aquatic plant control and fish cultivation. The grass carp is polyphagous, however, it prefers aquatic plants and it grows fast in warm water. Its taste is similar to that of ordinary carp.

It has been cultivated in the ponds of China, Taiwan and South East Asian countries for human consumption from old times. It is said that natural spawning of the grass carp is generally difficult except in the large rivers/lakes of the original countries and in some limited rivers of Japan. It never spawns in artificial ponds. Therefore, the grass carp cultivation is usually performed by releasing fingerlings produced by artificial spawning.

However in USA, wide-scale use of the grass carp had been limited or regulated due to fears about its reproduction and negative impact on sport fish until 1984 when a non-reproductive grass carp was developed. The newly developed grass carp is a sterile triploid one with a chromosome number (3N), on the other hand, the natural grass carp is diploid with a chromosome number (2N). The aquatic plant control capability of the triploid grass carp is the same as the diploid one.[2)]

The grass carp can live in a water temperature of 0 ^{o}C to 35 ^{o}C [3)], however, it eats more grasses under warm water. According to the experiment of R. V. Khambi and W. R. Robinson, [4)] grass carp consumed grasses even in a cold water of 12.8 ^{o}C although its consumption volume was small. It consumed 5 times of 12.8 ^{o}C case under a water temperature of 18.3 ^{o}C to 29.4 ^{o}C. In Japan, the grass carp is said to grow well under a water temperature of 20 ^{o}C to 30 ^{o}C [5)] .

In Japan, grass carp generally becomes an adult fish in more than 3 to 4 years and the body weight of an adult fish is in the range of 5 kg and 20 kg. Yoshio Sakurai roughly assumed the growth rate curve of a grass carp based on the previous experimental data as follows, in the study for the control of aquatic plants by grass carp in the Lake Nojiri of Japan. [6)]

Age (year)	Body Weight (kg)	Age (year)	Body Weight (kg)
1	0.6	5	12
2	3.0	6	15
3	6.0	7	18
4	9.0	8	20

According to the experiences in USA, the grass carp may grow at a rate of two (2) pounds (0.91kg) or more per one (1) month in warm water when sufficient vegetation is available. In Florida, some fish have grown to 40 ponds (18 kg) with an apparent life span of approximately 10 years.[2)]

The grass carp prefers submerged plants and the soft tips of young tender plants. When, the preferred food is not available, this fish feeds on terrestrial vegetation hanging over the surface of the water. The approximate order of grass carp's preference on the aquatic plants in Florida is shown below. [2)]

Order	Name	Order	Name	Order	Name
1	Hydrilla	8	Pondweeds	15	Tapegrass or Eel-grass
2	Musk-grass	9	Coontail	16	Parrott-feather
3	Southern Maiad	10	Torpedograss	17	Water Hyacinth
4	Brazilian Elodea	11	Cat-tail	18	Water-lettuce
5	Water-meal	12	Water-aloe	19	Water-lilies
6	Duck Weeds	13	Watercress	20	Spatterdock
7	Azolla or Water-fern	14	Eurasian Watermilfoil		

According to Vergin B. V., V. Nguen and D. Nguen, [7)] a grass carp eats as heavy grass (in wet weight) as 1.0-1.5 times of body weight per one (1) day when the grass is a favorite aquatic plant and 30 - 60% of its body weight even when the grass is a terrestrial plant.

In Florida, aquatic plants have been successfully controlled by grass carps in many ponds, lakes and canals. [2)] In Japan, Kazuo Nakamura decreased the aquatic plants to 30% of the original quantity in a pond during one (1) year (Nov. 1955 – Oct. 1956) by releasing grass carps of 16 kg/ha in weight. [8)]

In the Lake Nojiri of Japan, the local people released 5,000 fingerlings (approximately 5 cm) of grass carp to control the excessive submerged and floating plants on the littoral zone of the lake in November 1978. The submerged and floating plants have completely disappeared by August, 1982. On the other hand, this extinction of the aquatic plants caused damages on the production of shrimps. Thereafter, the grass carps were collected from the lake to recover the shrimp production. This failure was clearly due to the excessive stocking density of the grass carps. [6)] Salient features of the Lake Nojiri are shown below.

Elevation	654 m above sea level
Lake Area	Lake Area: 390 ha, Shallower Water Area than 5 m: 80 ha, Aquatic Plant Growing Area: 20 ha
Water Depth	Max. Water Depth: 38 m, Average Water Depth: 21 m
Water Quality	pH: 7.3-8.4, Transparency: 4.5 m, DO: 9.7 mg/l, COD_{Mn}: 1.7 mg/l, T-N: 0.17 mg/l, T-P: 0.005 mg/l, Temperature: 1.3 – 25.0 ^oC

The Lake Nojiri is oligotrophic. The average monthly water temperature is shown below.

Month	Water Temp. (^oC)	Month	Water Temp. (^oC)	Month	Water Temp. (^oC)
Jan.	1.9	May	13.6	Sep.	20.9
Feb.	1.8	Jun.	19.0	Oct.	15.2
Mar.	1.3	Jul.	21.9	Nov.	8.9
Apr.	7.1	Aug.	25.0	Dec.	4.3

From the above previous studies, the aquatic plant control, especially the control of Brazilian Elodea, in the Lake Fuquene by grass carp is considered effective. However, the efficiency of the control can not be estimated from the previous studies because the water temperature of the Lake is not warm enough (17 ^{o}C). The growth rate and food consumption rate of a grass carp in the Lake Fuquene was estimated through a field experiment as described in the following Section.

3.3 Field Experiment of Aquatic Plant Control Measures

3.3.1 Experiment for Use of Elodea as Green Fertilizer

(1) Experimental Methodology

A field experiment was performed to evaluate the effectiveness of the use of Elodea as a green fertilizer for the pasture lands with cooperation of CAR. The experiment was conducted for approximately eight (8) months during late May, 1999 to mid January, 2000.

The experiment was performed for the following two (2) experimental lots with different kinds of soils, located on the western coastal plain of the Lake near by the port.

Lot	Condition
Block-1	High content of organic matter (higher than 9%)
Block-2	Low content of organic matter (less than 2%)

For each experimental lot, the following five (5) cases of experiments were conducted.

Case	Condition
1	Covered with 75 cm thick Elodea
2	Covered with 50 cm thick Elodea
3	Covered with 25 cm thick Elodea
4	Chemical fertilizer only
5	Neither Elodea nor chemical fertilizer

The effects of the experiments were evaluated in terms of the production of pasture (species: Kikuyo) per unit land area.

(2) Results of the Experiment

(a) Initial Soil Condition of Experimental Land

The physical and chemical properties of the soils in the experimental pasture lands were analyzed before commencement of the experiment. Those are summarized below.

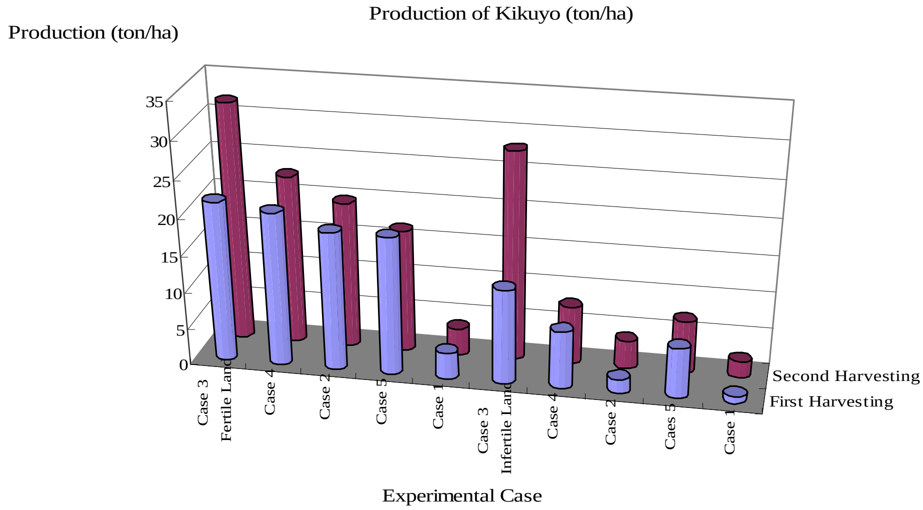
Classification	Soil Property	Block-1 (Fertile Land)	Block-2 (Infertile Land)
Physical Property	Sand (%)	36	16
	Silt (%)	18	52
	Clay (%)	46	32
Chemical Property	pH	4.2	5.5
	Organic Matter (%)	9.95	1.22
	Ca (meq/100g)	6.05	3.75
	Mg (meq/100g)	1.34	1.18
	K (meq/100g)	0.34	0.31
	Na (meq/100g)	0.15	0.11
	P (mg/kg)	8.3	3.3

(b) Production of Pasture (Kikuyo)

Green fertilizer of Elodea decomposes, improving soil conditions slowly over a long period. Generation of the effects as fertilizer is slow, different from chemical fertilizer. Therefore, the effects of Elodea as green fertilizer were confirmed through two (2) stages of pasture harvesting. The production of pasture in the two (2) harvesting stages are shown below.

Block	Experimental Case	First Harvesting (ton/ha)	Second Harvesting (ton/ha)
B-1 (Fertile Land)	Case 3 (25cm Elodea)	21.67	32.00
	Case 4 (Chemical Fertilizer)	20.81	22.83
	Case 2 (50cm Elodea)	18.71	19.82
	Case 5 (Nothing)	18.70	16.61
	Case 1 (75cm Elodea)	3.57	3.67
B-2 (Infertile Land)	Case 3 (25cm Elodea)	12.84	28.23
	Case 4 (Chemical Fertilizer)	7.85	7.95
	Case 2 (50cm Elodea)	1.94	3.87
	Case 5 (Nothing)	6.83	7.24
	Case 1 (75cm Elodea)	0.97	2.24

The above unit productions of pasture are illustrated in the following figure.



According to the above figure, pasture production of each block are summarized below.

(c) Evaluation of the Experimental Results

(i) The production of pasture of Case-1 (75 cm thickness) and Case-2 (50 cm thickness) are smaller than Case-3 (25 cm thickness) in both stages of harvesting. The production of Case-1 and Case-2 were delayed in exhibiting their capacity possibly due to shading of sunlight from pasture. Hence, Case-3 is more efficient than Case-1 and Case-2.

(ii) In the fertile land, Case-3 did not produce so much effect compared to Case-5 (nothing) in the first harvesting stage. However, it produced two (2) times of Case-5 in the second harvesting stage. It means that the green fertilizer may display the effects slowly.

(iii) In the infertile land, the effects of the green fertilizer was much larger than those in the fertile land. Case-3 produced two (2) times of Case-5 (nothing) in the first stage and four (4) times in the second stage.

(iv) The green fertilizer of Elodea displays a considerable effects on pasture production. The effects are larger for infertile land than for fertile land. However, the green fertilizer use of Elodea may be limited to the surrounding fertile pasturelands of the Lake since the infertile land is mostly distant from the Lake.

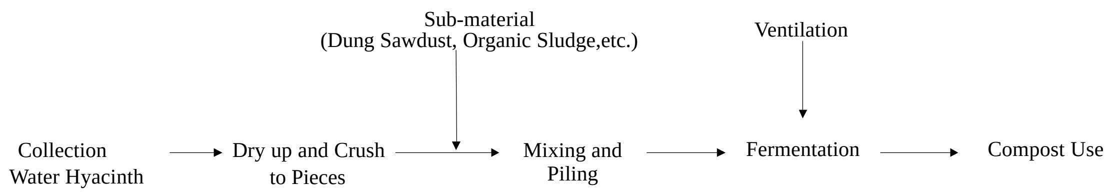
(v) More experimental studies may be necessary to conclude the effects of the Elodea green fertilizer quantitatively for the fertile surrounding lands of the Lake.

For detailed results of the above green fertilizer experiment, see Annex I.

3.3.2 Experiment for Composting of Aquatic Plants

(1) General

Compost has been used throughout the world as fertilizer, soil conditioner, landfill material, and horticultural medium on parkland. Compost is often mixed with chemical fertilizers to make the nutrient concentration suitable for crop growth. The organic matter from compost is an excellent soil conditioner because it has been stabilized, decomposes slowly, and thus remains effective over a long period of time. Compost of aquatic plants has also widely been used. The compost is usually produced through the following processes.



Compost made of aquatic plants is generally suitable for flower and green vegetables (spinach, lettuce, etc.) due to its comparatively low concentration of phosphorus (P).

(2) Previous Studies and Application of Aquatic Plants Compost

Compost of aquatic plants has been experimented or actually applied in Japan and other countries. Some representative examples of such experiments and applications are shown below.

No.	Country	Location	Aquatic Plants	Objective	Scale	Composting Period (Month)	Objective Crop
1	Japan	L. Teganuma [9)]	Floating	F&S	310 ton/yr.	5	Spinach, etc.
2	Japan	L. Abashiri [10)]	Submerged	F&S	30 ton/ha*	1	Radish
3	Japan	Experiment [11)]	Floating	F	-	1	-
4	Japan	Experiment [12)]	Floating	F	-	1-2	-
5	Japan	Okayama [13)]	Floating	F	-	0.5	Paddy
6	Thailand	Experiment [14)]	Floating	F	-	3	-
7	Myanmar	Whole Country [15)]	Floating	F	5 carts/acre	-	Paddy
8	Egypt	Nile River Basin [16)]	Floating	F&S	50,000 ton/yr.	-	Upland Crop
9	India	Experiment [17)]	Floating	F	15 ton/ha.	-	Paddy

Note: 1) F&S: fertilizer and soil conditioner 2): F: fertilizer 3) *: estimated by Study Team

The following factors are considered important for production of compost: (i) required period of composting, (ii) atmospheric temperature and (iii) sub-materials to facilitate fermentation.

(a) Required Period for Composting

The period for composting generally varies depending on property of raw materials {water content, fiber characteristics, carbon and nitrogen ratio (C/N)}, ventilation effects, kind and quantity of sub-materials, and magnitude of composting mass. However, according to the above mentioned previous experiments and applications, the period for composting of Water hyacinth is in the range of 0.5-5 months. Then, five (5) months are considered long enough to complete composting of Water hyacinth in general.

(b) Atmospheric Temperature

Compost of aquatic plants can be produced under only a high temperature. However, it does not mean that a high atmospheric temperature is necessary for compost production. In the process of compost production, sub-materials are firstly decomposed, resulting in rising of the inner temperature of a mass of compost materials. Usually, the inner temperature rises up to 60-70℃. This high inner temperature easily ferments the compost raw materials to produce compost.

Hence, the atmospheric temperature does not so much affect the production efficiency of compost. In fact, compost production has been successful even in Hokkaido, Japan where the atmospheric temperature is lower than that of the Lake Fuquene Area.

(c) Sub-materials

In the previous experiments and applications, saw dusts, chaff, withered leaves, cow/pig dung, etc were used as sub-materials. In this Study Area, cow dung and remnants of sugar production which have a higher fermentation effect are available.

(3) Required Standard Quality for Compost Use

Colombian Agricultural Institute (ICA) issued a technical manual for compost use [18]. According to this manual, the required compost quality of nutrients and heavy metals are summarized below.

(Dry Weight)

Item		Unit*	Target Quality	Remarks
Nutrients	Organic Matter	(%)	25	
	N	(%)	1.0	
	P_2O_5	(%)	1.0	Equivalent P = 0.43
	K_2O	(%)	1.0	Equivalent K = 0.83
	Moisture Content	(%)	40	
	90% Passage Size	(cm)	2.5	
Heavy Metals	Cd	(mg/kg)	10	
	Cu	(mg/kg)	450	
	Ni	(mg/kg)	120	
	Pb	(mg/kg)	150	
	Zn	(mg/kg)	1,100	
	Hg	(mg/kg)	7	
	Cr	(mg/kg)	400	

(4) Experiments for Aquatic Plants Composting in Lake Fuquene

(a) Experimental Methodology

The experiment was done for the following 20 cases.

No.	Material for Composting	Additive	Condition
1	Mainly Elodea	None	(1)
2	Mainly Water Hyacinth	None	(1)
3	Mainly Bulrush	None	(1)
4	Mixture of Elodea and Water Hyacinth	None	(1)
5	Mixture of Elodea, Water Hyacinth and Small Emergent Plants	None	(1)
6	Mainly Elodea	Cow Dung: 5%	(1)
7	Mainly Water Hyacinth	Cow Dung: 5%	(1)
8	Mainly Bulrush	Cow Dung: 5%	(1)
9	Mixture of Elodea and Water Hyacinth	Cow Dung: 5%	(1)
10	Mixture of Elodea, Water Hyacinth and Small Emergent Plants	Cow Dung: 5%	(1)
11	Mainly Elodea	Cow Dung: 10%	(1)
12	Mainly Water Hyacinth	Cow Dung: 10%	(1)
13	Mainly Bulrush	Cow Dung: 10%	(1)
14	Mixture of Elodea and Water Hyacinth	Cow Dung: 10%	(1)
15	Mixture of Elodea, Water Hyacinth and Small Emergent Plants	Cow Dung: 10%	(1)
16	Mainly Elodea	Cow Dung: 10%	(2)
17	Mainly Water Hyacinth	Cow Dung: 10%	(2)
18	Mainly Bulrush	Cow Dung: 10%	(2)
19	Mixture of Elodea and Water Hyacinth	Cow Dung: 10%	(2)
20	Mixture of Elodea, Water Hyacinth and Small Emergent Plants	Cow Dung: 10%	(2)

Note: (1): aerated by ventilation pipe
(2): aerated by mixing the materials

The experiment was conducted with cooperation of CAR by putting the above composting materials into 20 storage boxes (1.0 m^3 each) with a drain each in the neighborhood of the port. The experimental materials in the boxes was kept under aerobic condition for shortening of composting period. For this purpose, the boxes of No. 1 – No. 15 were provided with a ventilation pipe each, on the other hand, the boxes of No. 16 – No. 20 were aerated by mixing the materials every day.

The following physical and chemical factors were measured through the experiment to evaluate the composting effects.

Measurement Item	Measurement Time
Volume	At the commencement of experiment and every one (1) month
Weight	At the commencement and end of experiment
pH	At the commencement of experiment and every one (1) month
Water Content	At the end of experiment
Ash Quantity	At the end of experiment
C Content	At the end of experiment
N Content	At the end of experiment
P Content	At the end of experiment
Bacteria Number	At the end of experiment
K Content	At the end of experiment
Mg Content	At the end of experiment

The experiment was conducted for three and half (3.5) months of early September in 1999 to mid December in 1999 with the following detailed dates: harvested in September 10-11, put into compost bin in September 19-21 and completed in 17 December.

(b) Results of the Experiment

(i) Chemical Characteristics of Aquatic Plants

Chemical characteristics of the aquatic plants are analyzed as follows.

(Dry Weight)

Item	Unit*	Elodea	Water Hyacinth	Bulrush
Moisture Content	(%)	92.2	91.0	76.9
Ash Content	(%)	20.8	16.8	7.4
N	(%)	2.85	1.84	1.03
P	(%)	0.23	0.13	0.05
N/P Ratio	-	12.4	14.2	20.6
K	(%)	2.81	1.91	0.97
Ca	(%)	1.21	1.09	0.11
Mg	(%)	0.17	0.18	0.05
Fe	(%)	1.10	1.86	0.01
Pb	(mg/kg)	N.D.	N.D.	N.D.
Hg	(mg/kg)	0.45	0.45	0.71
Cr	(mg/kg)	0.74	1.75	0.47
Cu	(mg/kg)	6.4	7.3	2.0
Zn	(mg/kg)	137.3	47.9	20.2
As	(mg/kg)	1.4	1.5	1.1

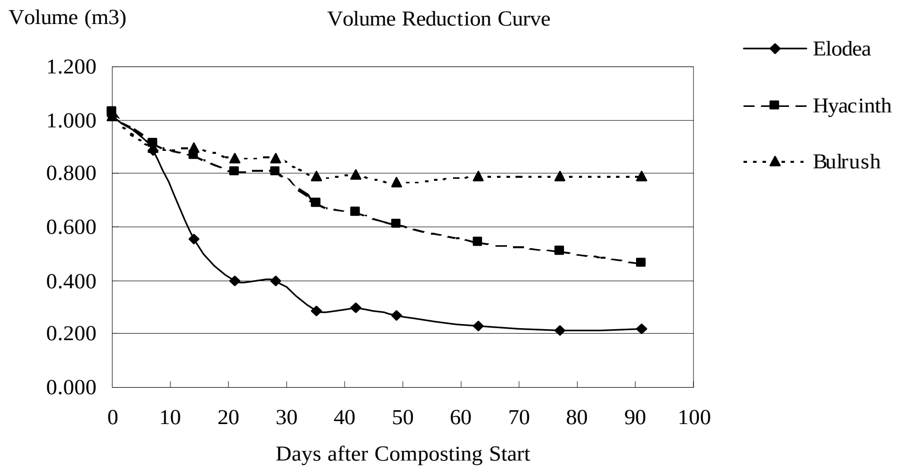
Note: N.D.: Not detected

(ii) Reduction of Volume and Weight

The average volume and weight of the aquatic plants were reduced as shown below through the composting process.

Item	Aquatic Plant	At Initial Time of Composting (%)	At Completed Time of Composting (%)
Volume	Elodea	100	22
	Water hyacinth	100	45
	Bulrush	100	78
Weight	Elodea	100	32
	Water hyacinth	100	57
	Bulrush	100	46

Further, the volume reduction curves of the three (3) aquatic plants are shown below.



As shown in the above figure, reduction of the volume of Elodea finished in 70-80 days after the start of composting. It means that decomposition of Elodea was almost completed during this period. However, the volume of Water hyacinth was still under reduction even at the final stage of this composting experiment. It will require more time to attain a satisfactory decomposition.

On the other hand, reduction of the volume of Bulrush finished in 30 days after the start of composting. The reduction rate is small and no more decomposition is expected. It is considered due to its high fibrous characteristics.

For detailed results of the above composting experiment, see Annex II.

(5) Conclusion

The following conclusions can be reached from the previous experiences in Japan and other countries, and the field experiment of this Study.

(a) Compost of Elodea and Water hyacinth can be produced in the Study Area regardless of the low atmospheric temperature. However, composting of Bulrush is difficult.

(b) Composting of Elodea and Water hyacinth can be completed within three (3) months and five (5) months respectively.

(c) Sufficient preparatory works of crushing/squeezing of aquatic plants before composting works will further reduce the initial compost weight/volume and required composting period. A large piling of compost raw materials will generate a higher inner temperature than the small scale experiment of this time, resulting in further reduction of the composting period.

(d) Compost production of Elodea and Water hyacinth to satisfy the standard quality of ICA is possible. Only the concentration of phosphorus (P) is smaller than the standard, however, this shortage can be met by adding a little chemical fertilizer with a high concentration of P. The concentration of heavy metal is very small compared to the standards.

3.3.3 Experiment for Aquatic Plant Control by Grass Carp

(1) General

For the experiment, 547 sterile triploid grass carps with a chromosome number (3N) were imported from USA with permission of the Ministry of Environment in September 29, 1999. They were temporarily stocked in the quarantine tank of the Lake Neusa for inspection of the National Agricultural and Livestock Planning Institute (INPA). Thereafter, they were released into the experimental cage and yard in the Lake Fuqene in October 11, 1999. During the inspection period, 17 grass carps were dead. Among the remaining 530 fishes, 271 were released into the cage and 259 were released into the yard.

The experiment is being done for the following two (2) cases with cooperation of CAR.

(2) Experimental Methodology

(a) Experiment in Cage

One (1) floating cage made of nets with a size of length (6 m) x width (6 m) x depth (3 m) was installed near by the Isla del Santuario. The water area at the site is 6.0 m deep with no growing aquatic plants.

This experiment is being done to analyze the characteristics of grass carp such as sequence of food preference, growth rate, grass consumption rate, disease, etc. The above consumption rate and growth rate will increase with elapse of time. Therefore, the experiment is scheduled to be continued for more than two (2) or three (3) years.

(b) Experiment in Yard

Four (4) experimental yards were set up on a shallow site (water depth: 2.0 m) near by the Isla del Santuario where Brazilian Elodea densely grows. Each yard was enclosed by nets with a size of length (15 m) x width (15 m) x depth (4.0m including allowance). Elodea within the yard was harvested along the nets in five (5) m width, then, the actual Elodea growing area within the yard is 10 m x 10m. The experimental yards are provided with aerators to maintain necessary oxygen.

This experiment is being done to establish the growth rate of grass carp and consumption rate of Elodea under the existing natural conditions. The grass consumption rate is measured by harvesting the remained Elodea in the yard. The experiment was started with the first yard. The experiment will be continued by shifting the grass carps to the second yard and thereafter, to the third and fourth yards in every measurement time.

These experiments will be continued for more than two (2) or three (3) years since the growth rate and consumption rate will increase at a high rate with the elapse of time.

(3) Results of the Experiment

(a) Experiment in Cage

Small 271 fingerlings with an average size of 10.0 cm (16.0 g) were released into the cage in October 11, 1999. The water quality in the cage was observed in November 10, 1999 as shown below.

	Surface	1.0 m below Surface	Remarks
pH	7.6	7.6	Time: 10:40 a.m
Temperature (^{o}C)	19.3	18.5	Weather: cloudy with no rain
DO (mg/l)	7.7	7.9	

Thereafter, 49 fishes were dead during the period of November 8 to November 25. Therefore, the remaining fishes except one (1) fish were returned to the quarantine tank of the Lake Neusa. Further, 37 fishes were dead immediately after the transfer to the Lake Neusa. The alive 184 fishes are still being stocked in the quarantine tank of the Lake Neusa.

On the other hand, the one (1) fish left in the Lake Fuquene is still alive.

The above mentioned death may be attributable to the abnormally high turbidity of lake water caused by the flood occurred during November. The flood is reportedly the biggest in the recent history.

In January 12, 2000, size and weight of the grass carps being stocked in the quarantine tank of the Lake Neusa were measured. The results are shown below, compared to those at the starting time of the experiment.

Date	Average Size (cm)	Average Weight (g)
Oct. 11, 1999	10.0	16.0
Jan. 12, 2000	10.24	11.47

(b) Experiment in Yard

Comparatively large 259 fingerlings with an average size of 15.0 cm (75.0 g) were released into the first yard in October 11, 1999. The water quality in the yard was observed in November 10, 1999 as shown below.

	Surface	1.0 m below Surface	Remarks
pH	7.4	7.4	Time: 10:30 a.m
Temperature (^oC)	18.5	18.4	Weather: cloudy with no rain
DO (mg/l)	10.4	10.3	

Out of 259 fishes, 62 fishes were dead until December 7, 1999. However, no death has occurred thereafter. At present, 197 fishes are inhabiting in the yard. This death is also considered due to the abnormally high turbidity of lake water caused by the flood.

In January 11, 2000, size and weight of the grass carps in the first yard were measured. The results are shown below, compared to those at the starting time of the experiment.

Date	Average Size (cm)	Average Weight (g)
Oct. 11, 1999	15.0	75.0
Jan. 11, 2000	20.5	95.3

In the same day, the remaining Elodea of 100 m^2 in the first yard was harvested. The harvested quantity was 641 kg (6.41 kg/ m^2). On the other hand, the original Elodea density is estimated to be 18.89 kg/ m^2. Then, the consumed Elodea by the grass carps is calculated to be 1,248 kg (12.48 kg/ m^2).

Further, the grass carps in the first yard were shifted to the second yard to continue the experiment.

From the above data, the average unit consumption rate during the three (3) months of October 11, 1999 to January 11, 2000 is estimated to be as follows.

Unit Consumption Rate = 1,248 kg / 90 days / 197 fishes = 70 g/day/fish

It is generally said that an adult grass carp eats as much grass as its body weight every day if sufficient favorite grass is available and young one eats more. The above consumption rate of the experiment is considered reasonable, taking into consideration to the disadvantage of low water temperature in the Lake.

The experiment must be further continued to reach the final conclusion of unit consumption rate of Elodea. However, control of Elodea by grass carp is considered possible.

3.4 Selection of Optimum Use of Aquatic Plants

3.4.1 Use of Harvested Submerged Plants (Elodea)

Three (3) alternative uses of Elodea: (i) green fertilizer use for pastureland (ii) compost use for flower farming and (iii) compost use for potato cultivation are compared as follows.

(1) Green Fertilizer Use for Pastureland

The harvested Elodea is used as green fertilizer for the pastureland in the surrounding areas of the Lake.

The required works include harvesting by machine, transportation by boat and unloading at the shore. Elodea will be unloaded at as many shore sites as possible for the convenience of farmer’s use. It is assumed that the farmers will transport the unloaded Elodea to their pasturelands from the nearest unloading site by themselves. The required cost including harvesting, transportation on lake and unloading is estimated to be 15,300 Col$/ton in wet weight with the break-down of 8,900 Col$/ton for O&M cost and 6,400 Col$/ton for equipment depreciation cost.

As discussed in the previous Sub-section 3.3.1, the green fertilizer of Elodea may produce a considerable extent of effects on the growth of pasture in the surrounding areas of the Lake. However, it is doubtful that the farmers are willing to share the harvesting cost of Elodea at this moment. Then, all the cost is assumed to be borne by CAR in this Study.

(2) Compost Use for Flower Farming

Some kinds of compost is used for the flower farming of approximately 4,000 ha in the metropolitan area of Bogota (mainly Zipaquira region). According to the interview survey, some big farm uses only compost for flower cultivation with no supplementary chemical fertilizer. Unit compost consumption of the above farm is estimated to be 65 ton/ha/year with the following break-down: 44 ton/ha before cultivation and 7 ton/ha in every three (3) months. Then, the maximum potential compost demand in the metropolitan area of Bogota is roughly estimated at 260,000 ton/year. The compost is sold at 120,000 Col$/ton in Bogota and 140,000 Col$/ton in the suburban areas at present.

Feasibility of the use of composted Elodea for the flower farming is studied as follows.

The nutrient contents of this compost are shown below comparing with those of Elodea.

Component	Compost being Used (%)	Elodea (%)	
	Compost Weight	Dry Weight	Compost Weight
Humidity	29.92	0.00	30.00
T-N	0.82	2.85	2.00
T-P	0.40	0.23	0.16
K	1.52	3.39	2.37

The compost made of Elodea is sufficient in T-N and K but short of T-P. The shortage of T-P is 2.4 kg per one (1) ton of Elodea compost. Some additive is necessary to supplement T-P of Elodea compost. An additive of chemical fertilizer (Di-ammonium Phosphate) is available in Bogota at a market price of 550 Col$/kg. This chemical fertilizer contains 20% of T-P in dry weight. Hence, the chemical fertilizer of 12 kg needs to be added to the Elodea compost as per one (1) ton.

The unit production cost of Elodea compost including harvesting, composting, transportation and additive costs is estimated at 187,200 Col$/ton in compost weight with the following break-down. In this cost estimate, the transportation distance is assumed to be 60 km between Lake Fuquene and flower farming area (Zipaquira).

Item	Unit Production Cost of Elodea Compost (Col$/ton)
Harvesting O&M	62,600
Composting O&M	30,000
Equipment/Compost Yard Depreciation	70,000
Transportation	18,000
Additive	6,600
Total	187,200

(3) Compost Use for Potato Cultivation

The composted Elodea is used for potato cultivation as an alternative of chemical fertilizer.

Approximately 16,933 ha of potato is cultivated in the Study Area of which 14,350 ha or 85% is in Carmen de Carupa (3,500 ha), Tausa (3,000 ha), Suesca (1,550 ha), Villapinzon (1,800 ha), Lenguazaque (3,000 ha) and Saboya (1,500 ha). For the above potato cultivation, the farmers usually use chemical fertilizer at present.

The chemical fertilizer being used for potato cultivation has very high nutrient contents compared to those of Elodea as shown below.

Component	Chemical Fertilizer (%)	Elodea (%)	
	Dry Weight	Dry Weight	Compost Weight
Humidity	0.00	0.00	30.00
T-N	15.00	2.85	2.00
T-P	6.54	0.23	0.16
K	12.45	3.39	2.37

As shown in the above table, Elodea compost of 7.5 ton is necessary to provide the same quantity of T-N contained in the chemical fertilizer of one (1) ton. Further, additive of chemical fertilizer (Di-ammonium Phosphate with T-P content of 20% in dry weight) needs to be added to supplement T-P. The required additive is calculated to be 267 kg as per the Elodea compost of 7.5 ton.

The cost of Elodea compost (7.5 ton) required to substitute for chemical fertilizer of one (1) ton is shown below. In this cost estimate, the transportation distance is assumed to be 40 km between Lake Fuquene and major potato cultivation area.

Item	Elodea Compost Production Cost to Substitute for Chemical Fertilizer (Col$)
Harvesting O&M	469,500
Composting O&M	225,000
Equipment/Compost Yard Depreciation	525,000
Transportation	90,000
Additive	146,850
Total	1,456,350

On the other hand, the market price of the chemical fertilizer of one (1) ton being used for potato cultivation is 510,000 Col$/ton at Bogota. The cost on farm gate is estimated to be 534,000 Col$/ton by assuming the transportation distance between Bogota and the major potato cultivation area as 80 km.

As evident from the above cost comparison, the use of Elodea compost as an alternative of chemical fertilizer is economically infeasible. Further, farmers need 7.5 times labor force in fertilization works compared to chemical fertilizer.

(4) Conclusion

As discussed in the above, compost use for potato cultivation is definitely infeasible. Then, green fertilizer use and compost use for flower farming are compared from the financial view point of CAR as follows.

The unit production cost of compost for flower farming at the market place (including transportation cost to Zipaquira) is estimated to be 187,200 Col$/ton (compost weight). On the other hand, the present selling price at the market is 140,000 Col$/ton (compost weight). The compost production company can bear 112,000 Col$/ton (compost weight) if the company's profit is assumed at 20% of the selling price. In this case, CAR must bear the remaining cost of 75,200 Col$/ton (compost weight), equivalent to 10,700 Col$/ton (wet weight).

On the other hand, CAR must bear 15,300 Col$/ton (wet weight) for the use of green fertilizer as mentioned before.

From the above financial cost comparison of CAR, compost use for flower farming is recommended.

3.4.2 Use of Removed Floating Plants (Water hyacinth)

It is considered difficult to use Water hyacinth as green fertilizer for the surrounding pasturelands of the Lake since Water hyacinth contains much cellulose which is not easily decomposed. Then, two (2) alternative uses: (i) compost use for flower farming and (ii) compost use for potato cultivation are compared as follows.

(1) Compost Use for Flower Farming

The nutrient components of Water hyacinth are compared with those of the compost being used for flower farming as follows.

Component	Compost being Used (%)	Water hyacinth (%)	
	Compost Weight	Dry Weight	Compost Weight
Humidity	29.92	0.00	30.00
T-N	0.82	1.84	1.29
T-P	0.40	0.13	0.09
K	1.52	2.30	1.61

The compost of Water hyacinth is also sufficient in T-N and K but short of T-P. Then, additive of chemical fertilizer ((Di-ammonium Phosphate with T-P content of 20% in dry weight) needs to be added to supplement T-P. The required additive is calculated to be 15.5 kg as per the Water hyacinth compost of one (1) ton.

The islands of Water hyacinth are removed in a different way from Elodea. They are cut into several pieces by cutting equipment and trawled by boat to the port.

The unit production cost of Water hyacinth compost including removal, composting, transportation and additive costs is estimated at 110,100 Col$/ton in compost weight with the following break-down. In this cost estimate, the transportation distance is assumed to be 60 km between Lake Fuquene and flower farming area (Zipaquira).

Item	Production Cost of Water hyacinth Compost (Col$/ton)
Removal O&M	17,600
Composting O&M	30,000
Equipment/Compost Yard Depreciation	36,000
Transportation	18,000
Additive	8,500
Total	110,100

(2) Compost Use for Potato Cultivation

Use of the composted Water hyacinth for potato cultivation as an alternative of chemical fertilizer is studied as follows.

The chemical fertilizer being used for potato cultivation has very high nutrient contents compared to those of Water hyacinth as shown below.

Component	Chemical Fertilizer (%)	Water hyacinth (%)	
	Dry Weight	Dry Weight	Compost Weight
Humidity	0.00	0.00	30.00
T-N	15.00	1.84	1.29
T-P	6.54	0.13	0.09
K	12.45	2.30	1.61

As shown in the above table, Water hyacinth compost of 11.6 ton is necessary to provide the same quantity of T-N contained in the chemical fertilizer of one (1) ton. Further, additive of chemical fertilizer (Di-ammonium Phosphate with T-P content of 20% in dry weight) needs to be added to supplement T-P. The required additive is calculated to be 275 kg as per the Water hyacinth compost of 11.6 ton.

The cost of Water hyacinth compost (11.6 ton) required to substitute for chemical fertilizer of one (1) ton is shown below. In this cost estimate, the transportation distance is assumed to be 40 km between Lake Fuquene and major potato cultivation area.

Item	Water hyacinth Compost Production Cost to Substitute for Chemical Fertilizer (Col$)
Harvesting O&M	204,160
Composting O&M	348,000
Equipment/Compost Yard Depreciation	417,600
Transportation	208,800
Additive	151,250
Total	1,329,810

On the other hand, the cost of chemical fertilizer on farm gate is estimated at 534,000 Col$/ton.

As evident from the above cost comparison, the use of Water hyacinth compost as an alternative of chemical fertilizer is economically infeasible. Further, farmers need 11.6 times labor force in fertilization works compared to chemical fertilizer.

From the above discussions, compost use for flower farming is recommended.

CHAPTER IV PROPOSED AQUATIC PLANT CONTROL PLAN

4.1 Proposed Aquatic Plant Control Works

4.1.1 Dredging of the Lake Bed

The emergent plants (mainly Bulrush) grow in the shallow area along the lake shore and they are expanding toward the lake center. The existing emergent plant area of 899 ha is projected to extend to 1,596 ha in the future (2020) at an average extension rate of 33 ha/year (see, Chapter III Sub-section 3.1.1). The average movement speed toward the lake center is roughly estimated at 10 m/year by assuming the perimeter length of the plant growing zone as 30 km.

On the other hand, the habitat of Bulrush is usually limited to wet-lands or shallower water areas than 1.5 m. Then, dredging of the front zone of Bulrush is proposed to stop the expansion of Bulrush.

The dredging is proposed for the following priority areas in consideration to the above mentioned historical expansion of Bulrush area.

(1) Eastern coastal area of Isla del Santuario (distance: 3 km)

(2) East-north bay area (distance: 3 km)

(3) Eastern and western coastal areas of Suarez River outlet (distance: 3 km)

(4) Eastern and western coastal areas of Ubate River mouth (distance: 3 km)

For location of the dredging zones, see Fig. G.4.1.

The proposed dredging works are summarized below.

Item	Quantity	Remarks
Dredging Zone Distance	12,000 m	
Dredging Width	20 m	
Dredging Depth	2.0 m	Water Depth: 3.0 m, Datum Water Level: 2,539 m
Dredging Volume	480,000 m^3	

In this Study, the excavated soil is assumed to be dumped on the neighboring pasturelands, especially the low-lying lands where are prone to habitual inundation. This land reclamation will release the lands from flood problems. The land reclamation area is roughly estimated to be approximately 50 ha when the reclamation depth is assumed at 0.3-0.5 m.

However, a pilot project is considered necessary prior to the proposed full scale dredging project to confirm the effectiveness of the dredging. The pilot project will check the following subjects: (i) effectiveness to stop the expansion of Bulrush, (ii) burying of the dredged site, (iii) topographic deformation of the surrounding lands and (iv) recovery of land use of the soil dumping site.

The pilot project will be performed at some location in the neighboring areas of the Ubate River mouth where an effective check of the above mentioned problems can be made. The dredging works of the pilot project are shown below.

Item	Quantity	Remarks
Dredging Zone Distance	300 m	
Dredging Width	20 m	
Dredging Depth	2.0 m	Water Depth: 3.0 m, Datum Water Level: 2,539 m
Dredging Volume	12,000 m^3	

The pilot project will be implemented as early as possible and the full scale project will start several years after completion of the pilot dredging works.

4.1.2 Harvesting/Removal and Composting of Aquatic Plants

(1) General

The existing submerged plants (Elodea) and floating plants (Water hyacinth) are harvested or removed along with control by grass carp. The harvested Elodea and removed Water hyacinth are composted for the use of flower farming.

To complete the use of aquatic plants, the following four (4) stages of work are necessary: (i) harvesting/removal of aquatic plants, (ii) composting of harvested/removed aquatic plants, (iii) transportation of compost to farmland (iv) spreading of compost on farmland including adding additives. The former two (2) stages of work: harvesting/removal and composting of aquatic plants are included in this aquatic plant control project. However, the latter two (2) stages of work are excluded from this project and they will be implemented by farmers themselves.

Technical viability on the use of Elodea and Water hyacinth composts for flower farming was confirmed based on the field experiment and previous studies. However, some pilot project may be necessary prior to the implementation of full scale project so that farmers can actually accept the composts of the Elodea and Water hyacinth for flower farming. The implementation schedule is assumed as follows.

The pilot project will be implemented for three (3) years during 2001-2003 and actual operation of the full scale project will start in 2005.

(2) Harvesting/Removal of Aquatic Plants

(a) Removal of Water hyacinth

The existing Water hyacinth covers 697 ha with an average density of 100 kg/m^2. They are extending at a high rate in some part, on the other hand, they are being replaced by Bulrush in other part. As described in Chapter III Sub-section 3.1.1, the total area of Water hyacinth and Bulrush will increase in a linear way and Water hyacinth area will increase at 2% per year in case of without project. The Water hyacinth and Bulrush areas without project in 2020 are given below again, compared to those in 1999.

Plant	Year 1999 (ha)	Year 2020 (ha)
Burlush	899	1,596
Water hyacinth	697	1,058
Total	1,596	2,654

On the other hand, Water hyacinth area will extend to 1,755 ha (=2,654-899) in 2020 at an annual rate of 4.5% if expansion of Bulrush area now completely stops and Water hyacinth area is not replaced by Bulrush any more. Therefore, if the proposed dredging project for the front zone of Bulrush is completed in 2010, the Water hyacinth area will increase at 2.0% per year until 2010 and at 4.5% after 2011.

Water hyacinth area in the future is projected as follows for the cases of without project and with only dredging project.

(unit: ha)

Water hyacinth	Project	1999	2005	2010	2015	2020
Area (ha)	Without	697	785	867	957	1,058
Area (ha)	Only Dredging	697	785	867	1,080	1,346

For details, see Table G 4.1.

Control of Water hyacinth by grass carp is generally difficult since the fish does not prefer to Water hyacinth. In this Study, all Water hyacinth is mechanically removed. The Water hyacinth area is decreased to approximately 50% of the existing one (697 ha) in the target year of the Study (2010) and to almost zero in the year 2015 under the following conditions.

(i) Pilot project will be implemented for three (3) years during 2001-2003. The removal quantity of Water hyacinth during this period is 5 ha/year (5,000 ton/year in wet weight).

(ii) Actual operation of the full scale project will start in 2005.

(iii) Dredging for the front zone of Bulrush area will be completed by 2010.

(iv) Annual increasing rate of Water hyacinth area is 2% until 2010 and 4.5% after 2011.

For this purpose, Water hyacinth needs to be removed by 75 ha (equivalent 75,000 ton in wet weight) every year. In this case, Water hyacinth area or biomass (wet weight) in the future is projected as follows.

Water hyacinth	Project	1999	2005	2010	2015	2020
Area (ha)	Without	697	785	867	957	1,058
Area (ha)	Dredging and Removal	697	694	376	58	0
Weight (wet ton)	Dredging and Removal	697,000	694,000	376,000	58,000	0

For details, see Table G 4.1.

The removal works consists of cutting floating islands by equipment, trawling by boat to port and unloading at port.

(b) Harvesting of Elodea

According to the field experiments, the reproduction rate of Elodea after machine harvesting was still small during the experiment period of this time (2-6 months). However, the reproduction rate is considered to make a rapid increase after the plant grows to a certain height where sufficient sunlight is available. In this Study, it is assumed to recover the original biomass one (1) year after machine harvesting.

Elodea grows under the entire water surface area (lake area not covered by Bulrush and Water hyacinth) shallower than 4.0 m. The total area is estimated at 1,204 ha as of 1999. Elodea is considered to immediately die when covered by Bulrush or Water hyacinth and to soon reproduce when Bulrush or Water hyacinth are removed. Then, this area will increase or decrease according to the change of Bulrush and Water hyacinth areas in the future. The Elodea area in the future is projected as follows for the cases of without project, with only dredging and with dredging plus Water hyacinth removal.

Elodea	Project	1999	2005	2010	2015	2020
Area (ha)	Without	1,204	902	649	398	146
Area (ha)	Only dredging	1,204	902	649	436	170
Area (ha)	Dredging and Removal*	1,204	993	1,140	1,458	1,516

*: Removal of Water hyacinth

For details, see Table G 4.1.

The above Elodea is controlled by machine harvesting and/or grass carp. It may be all controlled by only grass carp if the consumption rate of grass carp is large enough. However, the consumption rate in the Lake Fuquene is still not clear.

The consumption rate of grass carp in the Lake Fuquene is roughly estimated to be 6 kg/fish/day for a fish of 5-year age and 10 kg/fish/day for a fish of more than 8-year age if the rate is assumed to be half of that in Japan, considering the low water temperature of the Lake Fuqune. In this case, 56,000 fingerlings needs to be released in 2003 at the latest (immediately after completion of the on-going experimental study) to clear the whole Elodea by the target year 2010.

However in this Study, a combination of machine harvesting and grass carp is proposed to control Elodea from the following reasons.

(i) Machine can harvest Elodea according to the priority sequence of harvesting area. On the other hand, grass carps will feed on grass as they like and they do not approach the lake area under anaerobic condition.

(ii) Effectiveness of aquatic plant control by grass carp for the Lake Fuquene is still being checked at present. Some more time may be necessary before the final confirmation of the effectiveness.

(iii) Colombia has no experience in aquatic plant control by grass carp.

In this Study, a combination of machine harvesting and grass carp is proposed to control Elodea. Approximately 20% of the existing Elodea area (240 ha) is harvested by machine and the remaining areas are controlled by grass carp in the target year 2010 under the following conditions.

(i) The pilot project of Elodea harvesting will be implemented for three (3) years during 2001-2003. The harvesting quantity of Elodea during this period is 30 ha/year (about 5,000 ton/year in wet weight, Elodea density: 16 kg/m^2).

(ii) Actual operation of the full scale project will start in 2005.

For this purpose, Elodea needs to be harvested by 240 ha/year (equivalent to about 38,000 ton/year in wet weight) every year. In this case, Elodea area or biomass (wet weight) in the future is projected as follows.

Elodea	Project	1999	2005	2010	2015	2020
Area (ha)	Dredging + Removal* + Harvesting**	1,204	753	900	1,218	1,276
Weight (wet ton)	Dredging + Removal* + Harvesting**	193,000	120,000	144,000	195,000	204,000

*: Removal of Water hyacinth, **: Harvesting of Elodea, Elodea density: 16 kg/m^2

For details, see Table G 4.1.

The harvesting works consists of harvesting by machine, transportation by boat to port and unloading at port.

(3) Composting of Aquatic Plants

(a) Physical and Chemical Properties of Compost

The unloaded Elodea and Water hyacinth are stocked in compost yard for compost production. Based on the field experiments and previous reports, the physical property, chemical quality and required production time of the composts are assumed as below along with those of raw aquatic plants.

Item	Elodea	Water hyacinth
Raw Aquatic Plants		
Water Content (%)	90	90
Apparent Specific Volume after Harvesting (m^3/ton)	7.0	7.0
Apparent Specific Volume after Cutting/Squeezing (m^3/ton)	2.33 (=7/3)	2.33 (=7/3)
T-N Content (%) in Dry Weight	2.85	1.84
T-P Content (%) in Dry Weight	0.23	0.13
K Content (%) in Dry Weight	3.39	2.30
Compost		
Water Content or Humidity (%)	30	30
Apparent Specific Volume at Starting Time (m^3/ton)	2.33 (=7/3)	2.33 (=7/3)
Apparent Specific Volume after Completion (m^3/ton)	---------	--------
T-N Content (%) in Dry Weight and Compost Weight	2.85 (2.00)	1.84 (1.29)
T-P Content (%) in Dry Weight and Compost Weight	0.23 (0.16)	0.13 (0.09)
K Content (%) in Dry Weight and Compost Weight	3.39 (2.37)	2.30(1.61)
Production Period (month)	3	5

Note: Figures in parentheses are nutrient contents in compost weight which are equivalent to those of dry weight.

(b) Compost Production Quantity

As shown in the above table, the humidity of the produced compost is assumed at 30%. Then, one (1) ton of compost is produced from seven (7) tons of raw aquatic plants. Annually, 16,100 ton of compost will be produced from the harvested /removed Eolodea and Water hyacinth of 113,000 ton (wet weight) with the following break-down.

Item	Harvested/Removed Plants (ton/year in wet weight)	Produced Compost (ton/year in compost weight)
Elodea	38,000	5,400
Water hyacinth	75,000	10,700
Total	113,000	16,100

(c) Required Compost Yard

The required net compost yard area for Elodea and Water hyacinth are estimated as follows by assuming the piling depth of Elodea and Water hyacinth in stock bin is 3.0 m.

Elodea: 38,000 ton/yr. x 2.33 m^3/ton /3 m /4 times/yr. = 7,400 m^2

Water hyacinth: 75,000 ton/yr. x 2.33 m^3/ton /3 m /2.4 times/yr. = 24,300 m^2

Then, 16 compost stock bins with each size of width (50 m) x length (40 m) x depth (3 m) are proposed. The gross compost yard is proposed to be 45,000 m^2. For layout of the stock yard, see Fig. G.4.2.

4.1.3 Control by Grass Carp

(1) Elodea Consumption of Grass Carp

Grass carp is generally said to consume grass as much as its own body weight per one (1) day. On the other hand, growth rate of grass carp varies depending on the water temperature. Dr. Yoshio Sakurai assumed the average growth rate of grass carp in Japan [6)] as described in Chapter III Sub-section 3.2.5. In this Study, the growth rate of grass carp in the Lake Fuquene is assumed to be half of that in Japan, taking into consideration the comparatively low water temperature of the Lake Fuquene. The assumed growth rate is shown below.

Age (year)	1	2	3	4	5	6	7	8	10	20
Body Weight (kg)	0.3	1.5	3.0	4.5	6.0	7.5	9.0	10.0	10.0	10.0

As mentioned before, the entire Elodea area is cleared together with machine harvesting in the target year 2010 under the following conditions.

(a) The machine harvesting controls Elodea 30 ha/year (5,000 ton/year in wet weight) during the pilot project stage (2001-2003) and 240 ha/year (38,000 ton/year in wet weight) during the full scale project stage (after 2005).

(b) Grass carp will consume Elodea as much as its own body weight per one (1) day.

(c) The control by grass carp will start in 2003 immediately after completion of the on-going experimental study.

To attain the above target, 44,000 fingerlings of grass carp needs to be released in the Lake. Yearly consumption of Elodea by grass carps in the future is estimated as follows.

Yearly Consumption	1999	2005	2010	2015	2020
Weight(ton/year)	0	24,100	144,500	160,600	160,600
Equivalent Area (ha/year)	0	151	903	1,004	1,004

In the above table, the equivalent consumed area is calculated by assuming the density of Elodea as 16 kg/m^2. For details, see Table G.4.2.

Elodea area or biomass (wet weight) in the future is projected as follows.

Elodea	Project	1999	2005	2010	2015	2020
Area (ha)	Dredging + Removal* + Harvesting** + Grass Carp	1,204	602	0	247	272
Weight (wet ton)	Dredging + Removal* + Harvesting** + Grass Carp	193,000	96,300	0	39,500	43,500

*: Removal of Water hyacinth, **: Harvesting of Elodea, Elodea density: 16 kg/m^2

For details, see Table G.4.1.

(2) Construction of Fish Barrier

A fish barrier is constructed in the upper reaches of the Suarez River to block the grass carps swimming downward from the Lake. Usually, the following two (2) kinds of fish barriers are employed: (i) Net with dust removal screen and (ii) Electrical fish barrier.

Net with dust removal screen is considered unpractical, taking into consideration a large quantity of floating aquatic plants in the river. An automatic dust removal equipment needs to be installed, resulting in a large cost requirement. Further, it may dam up the river water when proper maintenance is lack.

Hence, electrical fish barrier is proposed in this Study. This system consists of two (2) or more metal electrodes (plus and minus) installed in water with a voltage applied between them. Electric current passing between the electrodes, via the water medium, produces an electric field in the river section. This electric field gives a shock to the fishes which try to pass through the electric field. Hence, fishes do not approach or enter the electric field.

This electrical fish barrier has been developed and applied in many countries: Japan, USA, France and others to block fish swimming or guide swimming direction.

For the layout of the proposed fish barrier, see Fig.G.4.2.

4.2 Cost Estimate

4.2.1 General

The investment cost and O&M cost for the proposed aquatic plant control works are estimated based on the following assumptions.

(1) The costs are estimated based on the prevailing unit prices of material, equipment and labor as of October, 1999.

(2) Exchange rate of currency is assumed to be 1 US$ = 106 ¥en = 1,920 Col$ (Colombian peso) prevailing as of October, 1999.

(3) Civil works such as dredging, construction of compost yard and installation of electrical fish barrier are executed on contract basis.

(4) Necessary equipment for harvesting or removal of aquatic plants and compost production are directly procured by CAR.

(5) Operation and maintenance is directly performed by CAR.

(6) Pilot projects are performed for the lake bed dredging, and harvesting/removal and composting of aquatic plants, prior to their full scale implementation.

(7) The procured equipment and constructed facilities for the pilot project of the harvesting/removal and composting of aquatic plants are employed for the full scale implementation to the maximum extent

(8) Harvesting/removal works include harvesting, transportation by boat to port and unloading at port. Composting works include crushing and squeezing, transportation to compost yard and piling in stock bin. Transportation of the completed compost to farmlands is not included in this project.

(9) Value added tax (IVA) is not included in this cost estimate.

4.2.2 Dredging Cost of the Lake

(1) General

The dredging cost is estimated based on the following assumptions.

(a) The total dredging volumes of the pilot project and full scale project are 12,000 m^3 and 480,000 m^3 respectively.

(b) Dredged soil is dumped on the surrounding low-lying pasture lands of the Lake where are prone to habitual flooding. The required dumping area for the full scale project is estimated at approximately 50 ha by assuming the land reclamation depth as 0.3-0.5 m.

(c) Land compensation cost is considered for the soil dumping area to compensate the milk production loss of the pastureland for one (1) year.

(d) No operation and maintenance works are considered necessary.

(2) Pilot Project

The costs for dredging of 12,000 m^3 are estimated as below.

Work Item	Unit Cost	Amount (million Col$)	Remarks
1. Construction Cost	26,700 (Col$/$m^3$)	320.4	
Preparatory Works	1,500 (Col$/$m^3$)	18.0	
Dredging Boat Operation	13,200 (Col$/$m^3$)	158.4	
Supporting Boat Operation	2,000 (Col$/$m^3$)	24.0	
Soil Transportation Pipe O&M	3,600 (Col$/$m^3$)	43.2	
Water Pollution Control	1,500 (Col$/$m^3$)	18.0	
Soil Transportation Pipe Const.	1,900 (Col$/$m^3$)	22.8	
Land Reclamation	3,000 (Col$/$m^3$)	36.0	
2. Land Compensation	175 (Col$/$m^2$)	2.0	
3. Engineering/Administration Cost		64.5	(1.+2.) x 20%
4. Physical Contingency		32.2	(1.+2.) x 10%
5. Total		419.1	
Total (million US$)		(0.22)	

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

(3) Full Scale Project

The costs for dredging of 480,000 m^3 are estimated as below.

Work Item	Unit Cost	Amount (million Col$)	Remarks
1. Construction Cost	26,700 (Col$/m^3)	12,816.0	
Preparatory Works	1,500 (Col$/m^3)	720.0	
Dredging Boat Operation	13,200 (Col$/m^3)	6,336.0	
Supporting Boat Operation	2,000 (Col$ /m^3)	960.0	
Soil Transportation Pipe O&M	3,600 (Col$/m^3)	1,728.0	
Water Pollution Control	1,500 (Col$/m^3)	720.0	
Soil Transportation Pipe Const.	1,900 (Col$/m^3)	912.0	
Land Reclamation	3,000 (Col$/m^3)	1,440.0	
2. Land Compensation	175 (Col$/m^2)	89.0	
3. Engineering/Administration Cost		2,581.0	(1.+2.) x 20%
4. Physical Contingency		1,291.0	(1.+2.) x 10%
5. Total		16,777.0	
Total (million US$)		(8.74)	

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

4.2.3 Cost for Harvesting/Removal and Composting of Aquatic Plants

(1) Pilot Project

The harvesting or removal quantity of aquatic plants and produced compost quantity by the pilot project are assumed as follows.

Item	Harvested Plants (ton/year in wet weight)	Produced Compost (ton/year in compost weight)
Elodea	5,000	700
Water hyacinth	5,000	700
Total	10,000	1,400

(a) Investment Cost

Both Elodea and Water hyacinth are harvested by the existing harvesting machine (boat) of CAR, transported by barge with tugboat to the existing port and unloaded by belt conveyor. The unloaded Elodea and Water hyacinth are crushed and squeezed through hopper, transported by dump truck to the compost yard and piled by tractor shovel in the compost stock bin. Further, some additives to facilitate the fermentation of compost are purchased and mixed into the aquatic plants.

The compost yard is assumed at a location within 2-3km distance from the port. The compost yard consists of two (2) stock bins with each size of width (50 m) x length (40 m) x depth (3.0 m). These will be used as part of the full scale project. Approximately 0.8 ha of land needs to be acquired for the construction of the compost yard of the pilot project.

For layout of the stock yard, see Fig. G.4.2.

The costs for the equipment procurement and compost yard construction are estimated as follows.

Item	Cost (million Col$)	Remarks
1. Procurement of Equipment	603.0	
(1) Aquatic Plant Harvesting	313.6	Barge (2), Tugboat (1), Belt Conveyor (2)
(2) Compost Production	289.4	Hopper (1), Dump Truck (1), Tractor Shovel (1)
2. Construction of Compost Yard	499.0	
3. Land Acquisition	24.0	0.8 ha
4. Engineering/Administration Cost	164.9	1. x 10% + (2.+3.) x 20%
5. Physical contingency	112.6	(1+2+3) x 10%
6. Total	1,403.5	
Total (million US$)	(0.73)	

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

For details, see Table G.4.3.

(b) O&M Cost

The O&M cost includes fuel cost of equipment, personnel expense, repairing cost of equipment and management cost. The annual O&M costs of the pilot project are shown below.

Item	Cost (1,000 Col$/year)
Harvesting of Elodea and Water hyacinth	110,199
Compost Production	99,803
Total	210,002
Total (1,000 US$/year)	(109)

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

For details, see Table G.4.4.

(2) Full Scale Project

The harvesting or removal quantity of aquatic plants and produced compost quantity by the full scale project are assumed as follows.

Item	Harvested/Removed Plants (ton/year in wet weight)	Produced Compost (ton/year in compost weight)
Elodea	38,000	5,400
Water hyacinth	75,000	10,700
Total	113,000	16,100

(a) Investment Cost

Elodea is harvested by harvesting boat, transported by barge with tugboat to the port and unloaded by belt conveyor. Floating island of Water hyacinth is cut into pieces and transported to the port by trawl boat, and unloaded by crawler crane.

The unloaded Elodea and Water hyacinth are crushed and squeezed through hopper, transported by dump truck to the compost yard and piled by tractor shovel in the compost stock bin. Further, some additives to facilitate the fermentation of compost are collected and transported by dump truck to the compost yard, and mixed into the Elodea and Water hyacinth.

For the above works, the existing harvesting boat and equipment procured by the pilot project are fully employed and the necessary additional equipment are procured.

The compost yard of the pilot project is extended. The compost yard consisting of 14 stock bins with each size of width (50 m) x length (40 m) x depth (3.0 m) are additionally constructed. Additionally 3.7 ha of land is acquired for the construction of the compost yard of the full scale project.

For layout of the stock yard, see Fig. G.4.2.

The costs for the additional procurement of equipment and extensional construction of compost yard are estimated as follows.

Item	Cost (million Col$)	Remarks
1. Procurement of Equipment	5,472.3	
(1) Elodea Harvesting	2,147.4	Harvesting Boat (2), Barge (6), Tugboat (1), Belt Conveyor (2)
(2) Water hyacinth Removal	1,014.6	Trawl Boat (2), Crawler Crane (1)
(3) Compost Production	2,310.3	Hopper (3), Dump Truck (7), Tractor Shovel (3)
2. Construction of Compost Yard	2,749.0	
3. Land Acquisition	111.0	3.7 ha
4. Engineering/Administration Cost	1,119.2	1. x 10% + (2.+3.) x 20%
5. Physical contingency	833.2	(1+2+3) x 10%
6. Total	10,284.7	
Total (million US$)	(5.36)	

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

For details, see Table G.4.5.

(b) O&M Cost

The O&M cost includes fuel cost of equipment, personnel expense, repairing cost of equipment and management cost. The annual O&M costs of the full scale project are shown below.

Item	Cost (1,000 Col$/year)
Harvesting of Elodea	338,242
Removal of Water hyacinth	188,322
Compost Production	483,055
Total	1,009,619
Total (1,000 US$/year)	(526)

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

For details, see Table G.4.6.

The annual compost production of Elodea and Water hyacinth are 5,400 ton/year and 10,700 ton/year as assumed above. Then, the unit O&M cost for the harvesting (or removal) and compost production of the aquatic plants are calculated as follows.

Item	Elodea	Water hyacinth	Average
			(Col$/ton in compost weight)
Harvesting (or Removal)	62,637	17,600	32,706
Compost production	30,003	30,003	30,003
Total	92,640	47,603	62,709
Total (US$/ton)	(48.3)	(24.8)	(32.7)

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

4.2.4 Cost for Aquatic Plants Control by Grass Carp

(1) Investment Cost

Approximately 44,000 fingerlings of sterile triploid grass carp are released in the Lake. An electrical fish barrier is constructed at the upper section of the Suarez River to block the grass carps swimming downward from the Lake.

The investment cost includes installation of electrical fish barrier and procurement of grass carp fingerlings. The installation of the electrical fish barrier consists of civil works (electrodes supporting structures, guard fence, etc.) and electric equipment installation (electrodes, electric wire, transformer, control panel, etc.).

For layout of the electric fish barrier, see Fig.G.4.2.

The investment cost is estimated as follows.

Item	Cost (million Col$)	Remarks
1. Installation of Fish Barrier	730.0	one river section
Civil works	20.0	
Electric Equipment	710.0	
2. Procurement of Grass Carp	850.0	44,000 fishes
3. Land Acquisition	-	
4. Engineering and Administration	316.0	(1.+2.+3.) x 20%
5. Physical Contingency	158.0	(1.+2.+3.) x 10%
6. Total	2,054.0	
Total (1,000 US$)	(1.07)	

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

(2) O&M Cost

O&M cost is required only for the electrical fish barrier and it includes electric charge and others. The required O&M cost is estimated as follows.

Item	Cost (1,000 Col$/year)	Remarks
Electric Charge	46,297	35 kw
Other Expense	3,703	Inspection, etc.
Total	50,000	
Total (1,000 US$/year)	(26)	

Exchange Rate: 1 US$ = 106 ¥ = 1,920 Col$

4.3 Implementation Program

The aquatic plant control project will be implemented based on the following schedule.

(1) Dredging of the Lake

The pilot project will be implemented in 2002. Detailed design of the full scale project will be completed within 2006. The dredging works of the full scale project will be executed for four (4) years during 2007-2010.

(2) Harvesting/Removal and Composting of Aquatic Plants

The pilot project will be performed for three (3) years during 2001 – 2003. Procurement of the equipment and construction of the compost yard for the pilot project will be implemented in early stage of 2001. The operation of the pilot project will start immediately after completion of the procurement and construction.

The full scale project will start in 1994. Procurement of the equipment and construction of the compost yard for the full scale project will be completed within 2004. The operation of the full scale project will start in 2005.

(3) Aquatic Plants Control by Grass Carp

The project will start in 2003 immediately after completion of the on-going experimental study. The procurement of grass carp and installation of the electrical fish barrier will be completed within 2003. Fingerlings of grass carp will be released immediately after completion of the fish barrier.

The implementation and cost disbursement schedules of the above aquatic plants control project are shown in Table.G.4.7.

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Table G.1.1 Previous Fauna Survey Result

Birds	1979 Survey Scientific Name	Condition
	Ixabrychas exilis	C
	Pandion hallaecus	M
	Porphyriops melanops	QC
	Actitis macularia	QC
	Gallinago (nobilis ?)	QC
	Phaetusa simplex	R
	Columbina	M
	Cyspeloides rutilus	R
	Coccyzus emericanus	C
	Coccyzus melacoryphus	M
	Tyto alba	R
	Otus choliba	C
	Colibri coruscans	C
	Metallua tyrianthina	QC
	Lesbia victoriae	QC
	Eriocnemis vestitus	QC
	Synallaxis subpudica	C
	Veniliovnis fumigatus	QC
	Tyrannus tyrannus	C
	Tyrannus melancholicus	A
	Contopus cinereus	QC
	Myiodynastes maculatus	M
	Serpophaga cinerca	C
	Elaenia pallatangae	R
	Necocerculus leucophrys	C
	Notiochelidon murina	A
	Riparia riparia	QC
	Hirundo rustica	C
	Chistethorus platensis	C
	Troglodytes aedon	A
	Troglodytes solstitialis	C
	Mimus gilvus	C
	Catharus ustulatus	R
	Turdus fuscater	QC
	Molothrus bonariensis	C
	Agelaius icterocephalus	A
	Seiurus nove oracensis	R
	Setruhara Ruticilla	M
	Dendroica fusca	C
	Vermivora peregrina	C
	Parula pitiayumi	QC
	Basileuterus higrocristatu	C
	Basileuterus leuteoviridis	QC
	Confirustrum rufim	QC
	Diglossa lafresmayii	C
	Pipraeidea melanonota	C
	Thraupis cyanocephala	QC
	Pheucticus aureoventris	A
	Catamenia malis	A
	Sicalis luteola	A

Birds	1979 Survey Scientific Name	Condition
	Zonotrichia capensis	A
	Spinus spinescens	A
	Spinus psaltria	C
Following birds are present but not confirmed during 19 and 26 April.		
	Colinus cristatus	
	Botaurus pinnatus	
	Nycticorax nycticorax	
	Hydranassa tricoior	
	Dendrocygna bicolor	
	Anas georica	
	Anas discors-Pato (Chisgo o Careto)	
	Anas cyanoptera	
	Oxyura jamaicensis	
	Oxyura dominica	
	Athyaafinis	
	Cairina moschsta	

A = Abundant
C = Common
QC = Quite common
R = Rare
M = Migrant

Mammals	1979 Survey Scientific Name
	Didelphis albiventris
	Anoura geoffroyi
	Phyllostomidae
	Nasua nasua
	Mustels frenata
	Conepatus semistriatus
	Dusicyon culparus
	Sylvilagus brasilensis
	Mus musculus
	Cricetidae
	Cavia procellus
	Mazama sp.

Source : ESTUDIO DE LAGUNA DE FUQUENE, 1979

Table G.1.2 Fauna Survey Result

	Family	Scientific Name
Birds	Rallidae	*Porphirio martinica*
		Fulica americana
		Oxyura jamaicencis
		Tringa solitaria
	Emberizidae	*Zonotrichia capensis*
	Falconidae	*Falco sparverius*
	Tytonidae	*Tyto alba*
	Columbidae	*Zenaida auriculata*
		Turdidae fuscater
	Icteridae	*Icterus crysater*
		Carduelis spinescens
	Arcticora	*Nycticora nycticorax*
		Casmerodius alba
		Angelaius icterocephalus
		Butorides striatus
		Colibri coruscans
	Cuculidae	*Crotophanga major*
		Melanerpes rubricapilius
		Thraupis episcopus
		Bubulcus ibis
		Buteo magnirostris
	Alaudidae	*Alauda arvensis*
	Hirundinidae	*Tachycineta sp.*
	Trochilidae	
Mammals		*Sciurus aestuans*
		Dasypus novemcinctus
		Mustela frenata
		Sylvilagus brasiliensis
		Cavia porcellus
		Caenolestes fuliginosus
		Dusicyon culparus
		Didelphis albiventris
		Didelphis sp.
Reptiles and Amphibians		*Buffo sp.*
		Hyla labialis
		Phenacosaurus heterodermus
		Atractus crassicaudatus
Fish		*Eremphylus mutisii*
		Grundulus bogotensis
		Cyprinus carpio
		Carassius auratus
Crustacea	Decapoda	*Hipolo bocera macropa*
Arachinid		*Chactas Keyserlingi*

	Family	Scientific Name
Insect		
Odonata	Libelluidae	*Erythemis sp.*
	Coenagrionidae	*Acanthagrion sp.*
	Aeschnidae	*Anax amazili*
Coleoptera	Chrysomelidae	*Danacia sp.*
	Scarabaeidae	*Golofa eacus*
Ephemeroptera	Tricorythidae	*Tricorythodes sp.*
Hemiptera	Hydrometridae	*Hydrometra caraiba*
	Mesoveliidae	*Mesovelia mulsanti*
	Veliidaae	*Microvelia sp.*
		Microvelia sp2.
	Corixidae	Centrocoisa kolllasi
Diptera	Chironomidae	
	Tipulidae	(Cranefly)
	Gryllidae	*Loxablemmus sp.*

Table G.1.3 Flora Survey Result

No.	Family	Scientific Name	No.	Family	Scientific Name
1	Pteridofito	*Pteridium aquilinum*	60	Melastomataceae	*Miconia sp.*
2	Gleicheniaceae	*Cherlanthes sp.*	61	Melastomataceae	*Tibouchina lepidota*
3	Azollaceae	*Azolla filiculoides*	62	Melastomataceae	*Tibouchina urvilleana*
4	Podocarpaceae	*Decussocarpus rospigliosii*	63	Melastomataceae	*Miconia squamulosa*
5	Pinaceae	*Pinus patula*	64	Umbelliferae	*Hydrocotile ranunculoides*
6	Cupressaceae	*Hipochaeris radiata*	65	Umbelliferae	*Conium maculatum*
7	Loranthaceae	*Gaiadendron tagua*	66	Haloragaceae	*Myriophyllum aquaticum*
8	Fagaceae	*Quercus humboldtii*	67	Onagraceae	*Fuchsia sp.*
9	Araliaceae	*Oreopanax floribundum*	68	Onagraceae	*Ludwigia peplides*
10	Elaeocaarpaceae	*Vallea stripolaris*	69	Oenotheraceae	*Fuchsia boliviana*
11	Ochidaceae	*Epidendrum elongatum*	70	Balsaminaceae	*Impatiens balsamina*
12	Orchidaceae	*Epidendrum sp. 1*	71	Euphorbiaceae	*Ricinus communis*
13	Orchidaceae	*Epidendrum sp. 2*	72	Euphorbiaceae	*Croton funcianus*
14	Amaryllidaceae	*Fourcaraea macrophylla*	73	Euphorbiaceae	*Ricinus communis*
15	Pontederiaceae	*Eichlornia crassipes*	74	Euphorbiaceae	*Croton bogotensis*
16	Lemnaceae	*Lemna minor*	75	Oxalidaceae	*Oxalis medicginea*
17	Cyperaceae	*Juncus bogotensis*	76	Fabaceae	*Lupinus bogotensis*
18	Cyperaceae	*Cyperus rufus*	77	Fabaceae	*Dalea coerulea*
19	Cyperaceae	*Scirpus californicus*	78	Fabaceae	*Desmodium sp.*
20	Gramineae	*Arundo donax*	79	Fabaceae	*Crotalaria agtiflora*
21	Gramineae	*Pseudoraphis sp.*	80	Fabaceae	*Cytisus monspessulanus*
22	Gramineae	*Paspalum plicatulum*	81	Fabaceae	*Trifolium repens*
23	Gramineae	*Chusquea scandens*	82	Fabaceae	*Trifolium pratense*
24	Hydeocharitaceae	*Egeria densa*	83	Cruciferae	*Lunaria annua*
25	Potamogetonaceae	*Potamogeton illinoensis*	84	Rosaceae	*Rubus floribundus*
26	Thyphaceae	*Typha latifolia*	85	Rosaceae	*Hesperomeles goudotiana*
27	Bromeliaceae		86	Rosaceae	*Prunus sp.*
28	Bromeliaceae	*Tillandsia usneoides*	87	Rosaceae	*Hesperomeles goudotiana*
29	Compositae	*Bidens laevis*	88	Escallonidae	*Escallonia paniculata*
30	Compositae	*Anaphalium sp.*	89	Crasulaceae	*Echeveria bicolor*
31	Compositae	*Ageratina sp.*	90	Crasulaceae	*Aeorium canariense*
32	Compositae	*Lourtergia stoechadifusa*	91	Mimosaceae	*Acacia melanxylon*
33	Compositae	*Acmella sp.*	92	Mimosaceae	*Acacia decurrens*
34	Compositae	*Hipochoeris radiata*	93	Pittosporaceae	*Pittosporum undulatum*
35	Compositae		94	Polygonaceae	*Polygonum hidropyroides*
36	Compositae	*Dalhia sp.*	95	Polygonaceae	*Rumex conglomeru*
37	Compositae	*Diphlostephium rosmarinifoliun*	96	Caesalpinaceae	*Adipera tomentosa*
38	Compositae	*Baccharis bogotensis*	97	Caesalpinaceae	*Senna viarum*
39	Compositae	*Baccharis latifolia*	98	Betulaceae	*Alnus acuminata*
40	Compositae	*Gnaphalium affine*	99	Magnoliaceae	*Magnolia grandiflora*
41	Compositae	*Polymnia pyramidalis*	100	Flacourtaceae	*Xylosma spiculiferum*
42	Compositae	*Taraxacum officinalis*	101	Caricaceae	*Carica pubescens*
43	Caprifoliaceae	*Sambucus peruvianus*	102	Myrtaceae	*Eucalyptus globulus*
44	Rubiaceae	*Spermacoce sp.*	103	Myrsinaceae	*Myrsine coriacea*
45	Solanaceae	*Streptosolen jamesonii*	104	Myrsinaceae	*Myrsine guianensis*
46	Solanaceae	*Solanum marginatum*	105	Bignoniaceae	*Tecoma stans*
47	Solanaceae	*Solanum lycioides*	106	Scrofulariaceae	*Digitalis purpurea*
48	Solanaceae	*Datura suaveolens*	107	Sapidaceae	*Dodonea viscosa*
49	Solanaceae	*Datura rosei*	108	Nyphaceae	*Nuphur sp.*
50	Solanaceae	*Cyphomendra betacea*	109	Agavaceae	*Fourcaraea macrophylla*
51	Verbenaceae	*Lantana camara*	110	Aizoaceae	*Melephora crocea*
52	Verbenaceae	*Lantana sp.*	111	Clusiaceae	*Clusia sp.*
53	Verbenaceae	*Duranta mutisii*	112	Escrofulariaceae	*Alonsoa meridonalis*
54	Ericaceae	*Befaria resinosa*	113	Sclepidaceae	
55	Ericaceae	*Cavendishia cordifolia*	114	Portulaceae	*Monina sp.*
56	Cactaceae	*Opuntia schumanii*	115	Malvaceae	*Abutilon insigne*
57	Salicaceae	*Salix humboldtiana*	116	Begonia	*Begonia cucullata*
58	Melastomataceae	*Bucquetia sp.*	117		*Usmea sp.*
59	Melastomataceae	*Chaetolepis microhylla*	118		*Sauralla sp.*

Table G.1.4 Previous Phytoplankton Survey in Fuquene Lake(1/2)

Order	Suborder	Family	Scientific Name
Blue-green alge	Chrooccales	Chrooccaceae	*Aphanocapsa delicatissima*
(Cyanobacteria)			*Chroococcus turgidus*
			Gloeocapsa sp.
			Microcystis aeruginosa
	Nostocales	Oscillatoriaceae	*Oscillaatoria sp.*
			Porphyrosiphon sp.
		Nostocaceae	*Anabania (Anabaeena) cricinalis*
			Anabania sp.1
			Anabania sp.2
Green alge	Volvocales	Volvocaceae	*Eudorina elegans*
(Chlorophyceae)	Tetrasporaales	Plamellaceae	*Sphaerocystics sp.*
	Chlorococcales	Characiaceae	*Characium sp.*
		Oocystaceae	*Oocystis sp.*
		Dictyosphaeriaceae	*Dictysosphaerium pulchelhum*
		Hydrodictyaceae	*Pediastrum boryanum*
			Pediastrum duplex
		Scenedesmaceae	*Scenedesmus quadeicauda*
			Scenedesmus acuminatus
			Scenedesmus denticulatus
			Scenedesmus arcuatus
			Scenedesmus ecornis
			Scenedesmus abundas
		Botryococcaceae	*Botryococcus braunii*
	Oedogoniales	Oedogoniaceae	*Oedogonium sp.*
	Zygnematales	Zygnemaceae	*Zygnema sp.*
		(Zygnemataceae)	*Splrogyra sp.*
		Mougeotiaceae	*Mougeotia sp.*
		Desmidiaceae	*Closterium limneticum*
			Closterium acutum
			Staurodesmus lobatus var. ellipticus
			Staurodesmus dejectus
			Cosmarium punctulatum
			Staurastrum chaetoceras
			Staurastrum volan
Xanthophyceae	Heterochloridales	Heterochlodidaceae	*Pleurochloris sp.*
Diatom	Centrales	Coscinodiscacease	*Cyclotella badanica*
(Bacillaariophyceae)		Melosiraceae	*Melosira granulata*
			Melosira italica
	Pennales	Fragilariaceae	*Fragilariaceae construens*
			Tabellaria flocculosa
		Naviculaceae	*Navicula capitata*
			Navicula rhynchoncephala
			Navicula sp.
		Cybellaceae	*Cymbella ventricosa*
		Gomphinemaceae	*Gomphonema parvulum*
		Epithemiaceae	*Epithemia zebra*

Table G.1.4 Previous Phytoplankton Survey in Fuquene Lake(2/2)

Order	Suborder	Family	Scientific Name
Euglenods (Euglenophyta)	Euglenophyceae	Euglenaceae	*Euglena acus*
			Euglena oxyuris
			Euglena elastica
			Euglena graciltis
			Euglena sp.
			Trachelomonas hispida
			Trachelomonas armata
			Trachelomnas acanthophophora
			Leponcinclis sp.
			Phacus triqueter
			Phacus longicauda

Source : Fritsch, 1977; Fernandez, 1982; Lewin and Gibbs, 1981

Table G.2.1 Areas for Bed Elevation in 1984

Elevation (EL.m)	Area (ha.)	Persent
2532.0	0.89	0.03
2532.5	1.51	0.05
2533.0	2.62	0.09
2533.5	43.47	1.49
2534.0	11.26	0.39
2534.5	61.40	2.10
2535.0	37.87	1.30
2535.5	36.31	1.24
2536.0	51.23	1.76
2536.5	135.07	4.63
2537.0	536.95	18.40
2537.5	927.87	31.79
2538.0	441.7	15.13
2538.5	262.94	9.01
2539.0	367.65	12.60
Total	2918.74	100.00

Table G.2.2 Areas for Bed Elevation in 1997

Elevation (EL.m)	Area (ha.)	Persent
2533.0	2.33	0.14
2533.5	4.84	0.30
2534.0	42.19	2.62
2534.5	78.69	4.89
2535.0	0.66	0.04
2535.5	77.26	4.80
2536.0	8.31	0.52
2536.5	573.73	35.68
2537.0	99.59	6.19
2537.5	677.60	42.14
2538.0	42.91	2.67
Total	1608.11	100.00

Table G.2.3 Aquatic Plant Survey

Type	1979 Survey	1986 Survey	1997 Survey	This Survey	English Name
Submerged Plant					
		Ranunculus sp.			
			Egeria densa	*Egeria densa*	Brazilian elodea
Floating Leaf Plant					
	Potamogeton sp.	*Potamogeton illinoensis*	*Potamogeton illinoensis*	*Potamogeton illinoensis*	Pondweed
		Potamogeton berteroanus			Pondweed
Floating Plant					
	Eichhornia crassipes	*Eichhornia crassipes*	*Eichhornia crassipes*	*Eichhornia crassipes*	Water hyacinth
		Lemna minor	*Lemna minor*	*Lemna minor*	Duckweed
		Azolla filiculoides	*Azolla filiculoides*	*Azolla filiculoides*	Azolla
			Lemna polyrhiza		Lemna
		Utricularia gibba			
Emergent Plant					
	Hydrocotyle ranunculoides				
	Scirpus californicus	*Scirpus californicus*	*Scirpus californicus*	*Scirpus californicus*	Bulrush
	Typha angustifolia		*Typha angustifolia*	*Typha angustifolia*	Cattail
	Bidens laevis	*Bidens laevis*	*Bidens laevis*	*Bidens laevis*	
		Cotula coronopifolia			
	*Jussiaea repens**				
	Cyperus luzulae	*Cyperus rufus*	*Cyperus sp.*	*Cyperus rufus*	Bulrush
		Ludwigia peplides	*Ludwigia peplides*	*Ludwigia peplides*	
		Ludwigia cf. peruviana			
		Polygonum hydropiperoides	*Polygonum hydropiperoides*	*Polygonum hidropyperoides*	
		Polygonum acuminatum			
		Myriophyllum acuaticum	*Myriophyllum acuaticum*	*Myriophyllum acuaticum*	Parrot-feather
		Holcus lanatus			
				Juncus bogotensis	Bulrush
				Hydrocotyle ranunculoides	
				Pseudoraphis sp.	
				Scripus sp.	Bulrush
				Begonia cucullata	Begonia

Note : *Jussiaea is another classification name of Ludwigia

Source : ESTUDIO DE LAGUNA DE FUQUENE, 1979
ESTRUCTURA Y DINAMICA DEL FITOPLANCTON DE LA LAGUNA DE FUQUENE CUNDINAMARCA, COLOMBIA, 1986
PLAN DE MANEJO CONTROL Y DISPOSICION DE MALEZAS ACUATICAS EN LA LAGUNA DE FUQUENE, 1997

Table G.2.4 Water Hyacinth Biomass Survey Results

No.	Biomas Density in kg/sq.m			Water Depth
	Water hyacinth	Others	Total	in m
1	115.33	0.00	115.33	1.78
2	107.70	0.00	107.70	2.30
3	28.26	1.95	30.21	2.20
4	168.83	0.00	168.83	2.97
5	117.43	0.51	117.95	1.80
6	98.64	0.32	98.96	1.30
7	59.86	4.18	64.04	2.37
8	114.62	0.00	114.62	2.17
9	114.62	0.32	130.91	1.44
10	235.01	0.00	235.01	2.78
11	110.45	0.00	110.45	2.00
12	104.42	0.00	104.42	1.87
13	52.08	0.66	52.75	2.00
14	102.96	0.00	102.96	2.60
15	74.92	0.00	74.92	2.00
16	144.62	0.95	145.57	3.30
17	62.99	0.00	62.99	4.10
18	94.50	0.00	94.50	2.33
19	129.70	0.00	129.70	3.30
20	119.20	1.21	120.40	2.70
average	107.81	0.51	109.11	

Other Plant Biomass in kg/sq.m	Toal Biomass in kg/sq.m
0.00	119.09
0.01 - 0.50	114.94
0.51 - 1.50	109.17
more than 1.51	47.12

Table G.2.5 Emergent Plants Biomass Survey Results

Scripus Californicus

No.	Biomass Density in kg/sq.m				Water Depth
	Over Water	Under Water		Toatal	
	Leaf and Stems	Leaf and Stems	Roots		
1	26.07	-	97.11	123.17	0.90
2	5.77	-	74.50	80.27	0.71
3	2.47	5.60	1.31	9.38	0.80
4	4.81	18.40	5.55	28.76	1.10
5	5.15	14.71	5.52	25.38	0.91
6	3.44	4.41	3.34	11.19	0.75
7	5.03	10.76	6.73	22.53	0.68
8	5.26	15.85	2.21	23.31	0.71
9	5.23	4.51	2.67	12.40	0.53
10	8.36	16.13	7.50	31.99	0.56
11	33.18	11.03	4.95	49.16	0.68
12	1.61	10.12	2.36	14.09	1.00
13	5.77	6.60	1.73	14.10	0.82
14	11.27	18.98	3.27	33.53	0.90
15	5.56	9.63	4.07	19.26	0.60
16	6.05	8.01	4.15	18.21	1.00
17	6.02	19.36	4.43	29.81	1.18
18	5.44	10.99	3.49	19.92	0.68
19	7.30	14.55	5.91	27.76	0.85
20	3.25	4.88	2.03	10.16	0.65
Average	7.85	10.23	12.14	30.22	

Typha angustifolia

No.	Biomass Density in kg/sq.m				Water Depth
	Over Water	Under Water		Toatal	
	Leaf and Stems	Leaf and Stems	Roots		
1	9.66	-	114.46	124.13	2.57
2	8.72	5.24	88.68	102.63	2.20
3	13.19	13.19	52.02	78.40	2.11
4	6.76	9.03	87.20	102.99	1.93
5	12.09	5.35	96.18	113.62	2.34
6	7.41	2.14	71.85	81.40	2.40
7	7.97	6.14	72.33	86.43	2.21
8	5.97	11.79	152.66	170.42	1.88
9	9.14	8.67	80.35	98.16	1.80
10	3.68	24.43	90.74	118.86	2.18
Average	8.46	8.60	90.65	107.70	

Table G.4.1 Projection of Aquatic Plant Area

(unit: ha)

Year	Without Project				With Project I				With Project II				With Project III				With Project IV			
	Burlush	Water hyacinth	Elodea	Total	Burlush	Water hyacinth	Elodea	Total	Burlush	Water hyacinth	Elodea	Total	Burlush	Water hyacinth	Elodea	Total	Burlush	Water hyacinth	Elodea	Total
1999	899	697	1,204	2,800	899	697	1,204	2,800	899	697	1,204	2,800	899	697	1,204	2,800	899	697	1,204	2,800
2000	935	711	1,154	2,800	935	711	1,154	2,800	935	711	1,154	2,800	935	711	1,154	2,800	935	711	1,154	2,800
2001	972	725	1,103	2,800	972	725	1,103	2,800	972	720	1,108	2,800	972	720	1,078	2,770	972	720	1,103	2,795
2002	1,008	740	1,053	2,800	1,008	740	1,052	2,800	1,008	730	1,062	2,800	1,008	730	1,032	2,770	1,008	730	1,032	2,770
2003	1,043	754	1,002	2,800	1,043	754	1,003	2,800	1,043	739	1,018	2,800	1,043	739	988	2,770	1,043	739	988	2,770
2004	1,078	770	952	2,800	1,078	770	952	2,800	1,078	754	968	2,800	1,078	754	968	2,800	1,078	754	938	2,770
2005	1,113	785	902	2,800	1,113	785	902	2,800	1,113	694	993	2,800	1,113	694	753	2,560	1,113	694	602	2,409
2006	1,148	801	851	2,800	1,148	801	851	2,800	1,148	633	1,019	2,800	1,148	633	779	2,560	1,148	633	478	2,259
2007	1,183	817	801	2,800	1,183	817	800	2,800	1,183	571	1,046	2,800	1,183	571	806	2,560	1,183	571	354	2,108
2008	1,217	833	750	2,800	1,217	833	750	2,800	1,217	507	1,076	2,800	1,217	507	836	2,560	1,217	507	234	1,958
2009	1,250	850	700	2,800	1,250	850	700	2,800	1,250	442	1,108	2,800	1,250	442	868	2,560	1,250	442	115	1,807
2010	1,284	867	649	2,800	1,284	867	649	2,800	1,284	376	1,140	2,800	1,284	376	900	2,560	1,284	376	0	1,660
2011	1,317	884	599	2,800	1,284	906	610	2,800	1,284	318	1,198	2,800	1,284	318	958	2,560	1,284	318	0	1,602
2012	1,350	902	549	2,800	1,284	946	570	2,800	1,284	257	1,259	2,800	1,284	257	1,019	2,560	1,284	257	15	1,556
2013	1,382	920	498	2,800	1,284	989	527	2,800	1,284	194	1,322	2,800	1,284	194	1,082	2,560	1,284	194	78	1,556
2014	1,414	938	448	2,800	1,284	1,033	483	2,800	1,284	127	1,389	2,800	1,284	127	1,149	2,560	1,284	127	145	1,556
2015	1,446	957	398	2,800	1,284	1,080	436	2,800	1,284	58	1,458	2,800	1,284	58	1,218	2,560	1,284	58	214	1,556
2016	1,477	976	347	2,800	1,284	1,129	387	2,800	1,284	0	1,516	2,800	1,284	0	1,276	2,560	1,284	0	272	1,556
2017	1,508	995	297	2,800	1,284	1,179	337	2,800	1,284		1,516	2,800	1,284		1,276	2,560	1,284		272	1,556
2018	1,538	1,015	246	2,800	1,284	1,232	284	2,800	1,284		1,516	2,800	1,284		1,276	2,560	1,284		272	1,556
2019	1,568	1,036	196	2,800	1,284	1,288	228	2,800	1,284		1,516	2,800	1,284		1,276	2,560	1,284		272	1,556
2020	1,596	1,058	146	2,800	1,284	1,346	170	2,800	1,284		1,516	2,800	1,284		1,276	2,560	1,284		272	1,556

Note:

1) Project I: dredging only
2) Project II: dredging + Water hyacinth removal (pilot: 5 ha/year, full scale: 75 ha/year)
3) Project III: dredging + Water hyacinth removal (pilot: 5 ha/year, full scale: 75 ha/year) + Elodea havesting (pilot: 30 ha/year, full scale: 240 ha/year)
4) Project IV: dredging + Water hyacinth removal (pilot: 5 ha/year, full scale: 75 ha/year) + Elodea havesting (pilot: 30 ha/year, full scale: 240 ha/year) + grass carp (44,000 fishes)

Table G.4.2 Yearly Consumption of Grass Carp

Year	Released Grass Carp (44,000 fishes)		
	Unit Consumption (kg/fish/day)	Yearly Cosumption (ton/year)	Equivalent Consump. Area (ha)
1999			
2000			
2001			
2002			
2003	-	0	0
2004	0.3	4,818	30
2005	1.5	24,090	151
2006	3.0	48,180	301
2007	4.5	72,270	452
2008	6.0	96,360	602
2009	7.5	120,450	753
2010	9.0	144,540	903
2011	10.0	160,600	1,004
2012	10.0	160,600	1,004
2013	10.0	160,600	1,004
2014	10.0	160,600	1,004
2015	10.0	160,600	1,004
2016	10.0	160,600	1,004
2017	10.0	160,600	1,004
2018	10.0	160,600	1,004
2019	10.0	160,600	1,004
2020	10.0	160,600	1,004

*: Density of Elodea: 16 kg/m^2

Table G.4.3 Investment Cost of Aquatic Plant Harvesting and Composting (Pilot Project)

1. Procurement of Equipment

Item	Unit	Quantity	Unit Cost (million Col$)	Amount (million Col$)	Remarks
(1) Elodea/Water hyacinth Harvesting					
Harvesting Boat	no.	-	-	-	One existing equipment is used.
Barge	no.	2	76.0	152.0	150 m^3 loading/set
Tugboat	no.	1	152.0	152.0	
Belt Conveyor	no.	2	4.8	9.6	
Total				313.6	
(2) Compost Production					
Hopper	no.	1	95.0	95.0	
Dump Truck	no.	1	70.1	70.1	
Tractor Shovel	no.	1	124.3	124.3	
Total				289.4	
(3) Grand Total				603.0	

2. Construction of Compost Yard

Item	Unit	Quantity	Unit Cost (Col$)	Amount (million Col$)	Remarks
(1) Civil Works					
Yard Embankment	m^3	4,000	10,000	40.0	
Stok Bin Foundation	m^3	1,200	22,000	26.4	Gravel
Stock Bin Floor Works	m^3	400	250,000	100.0	Plain concrete
Stock Bin Particion Wall	m^3	200	450,000	90.0	Reinforced concrete
Stock Bin Roof	m^2	4,000	23,000	92.0	Incl. roof support structure
Others	l.s.	1		150.6	Access road, etc.
Total				499.0	
(2) Land Acquisition	m^2	8,000	3,000	24.0	
(3) Grand Total				523.0	

Table G.4.4 Annual O&M Cost of Aquatic Plant Harvesting and Composting (Pilot Project)

Item	Quantity	O&M Cost Amount (1,000 Col$/year)	Equipment Depreciation (1,000 Col$/year)	Remarks
1. Elodea/Water hyacinth Harvesting		110,199	64,757	
(1) Harvesting by Boat	1 boat		50,667	
Fuel Cost	1 boat	4,308		
Personnel Expense	24 m/m	27,600		
Repairing Cost	1 boat	24,430		
Management Cost (10%)		5,634		
Total		61,972		
(2) Transportation by Barge	2 boats		6,080	
Total	2 boats	0		
(3) Transportation by Tugboat	1 boat		6,080	
Fuel Cost	1 boat	4,023		Working efficiency: 50%
Personnel Expense	12 m/m	11,040		
Repairing Cost	2 boats	3,040		Repairing need: 50%
Management Cost (10%)		1,810		
Total		19,913		
(4) Unloading by Belt Conveyor	2 equipment		1,930	
Fuel Cost	2 equipment	2,406		
Personnel Expense	48 m/m	22,080		
Repairing Cost	2 equipment	1,254		
Management Cost (10%)		2,574		
Total		28,314		
2. Composting of Elodea/Water hyacinth		99,803	24,640	
(1) Cutting/Squeezing by Hopper	1 equipment		6,333	
Fuel Cost	1 equipment	3,551		Working efficiency: 50%
Personnel Expense	12 m/m	11,040		
Repairing Cost	1 equipment	2,534		Repairing need: 50%
Management Cost (10%)		1,713		
Total		18,838		
(2) Transportation by Dump Truck	1 vehicle		7,011	
Fuel Cost	1 vehicle	4,773		
Personnel Expense	12 m/m	11,040		
Repairing Cost	1 vehicle	3,506		
Management Cost (10%)		1,932		
Total		21,251		
(3) Piling by Tractor Shovel	1 vehicle		11,296	
Fuel Cost	1 vehicle	6,038		
Personnel Expense	12 m/m	16,560		
Repairing Cost	1 vehicle	5,648		
Management Cost (10%)		2,825		
Total		31,071		
(4) Additive Collection and Mixing*			0	
Collection Cost		15,000		Sugar remnants
Personnel Expense	12 m/m	11,040		Mixing works
Management Cost (10%)		2,604		
Total		28,644		
3. Grand Total		210,002	89,397	

1) *: Additive to facilitate fermentation of compost is collected from sugar factories and mixed into aquatic plants.
2) m/m: man-month

Table G.4.5 Investment Cost of Aquatic Plant Harvesting and Composting (Full Scale Project)

1. Procurement of Equipment

Item	Unit	Quantity	Unit Cost (million Col$)	Amount (million Col$)	Remarks
(1) Elodea Harvesting					
Harvesting Boat	no.	2	760.0	1,520.0	6.5 ton/h/set, 2 existing, 2 additional
Barge	no.	6	76.0	456.0	150 m3 loading/set, 6 additional to pilot
Tugboat	no.	1	152.0	152.0	1 additional to pilot
Belt Conveyor	no.	2	9.7	19.4	Equipment of pilot project is not used
Total				2,147.4	
(2) Water hyacinth Removal					
Trawl Boat	no.	2	304.0	608.0	365 ton/day/set
Crawler Crane	no.	1	406.6	406.6	
Total				1,014.6	
(3) Compost Production					
Hopper	no.	3	95.0	285.0	3 additional to pilot
Dump Truck	no.	7	179.4	1,255.8	1small truck of pilot is used for miscellaneous works
Tractor Shovel	no.	3	256.5	769.5	1small shovel of pilot is used for miscellaneous works
Total				2,310.3	
(4) Grand Total				5,472.3	

2. Construction of Compost Yard

Item	Unit	Quantity	Unit Cost (Col$)	Amount (million Col$)	Remarks
(1) Civil Works					
Yard Embankment	m^3	18,500	10,000	185.0	Extension of pilot
Stok Bin Foundation	m^3	8,400	22,000	184.8	Gravel, extension of pilot
Stock Bin Floor Works	m^3	2,800	250,000	700.0	Plain concrete, extension of pilot
Stock Bin Particion Wall	m^3	1,300	450,000	585.0	Reinforced concrete, extension of pilot
Stock Bin Roof	m^2	28,000	23,000	644.0	Incl. roof support structure, extension of pilot
Others	l.s.	1		450.2	Access road, port improvement, etc. extension of pilot
Total				2,749.0	
(2) Land Acquisition	m^2	37,000	3,000	111.0	Extension of pilot
(3) Grand Total				2,860.0	

Table G.4.6 Annual O&M Cost of Aquatic Plant Harvesting and Composting (Full Scale Project)

Item	Quantity	O&M Cost Amount (1,000 Col$/year)	Equipment Depreciation (1,000 Col$/year)	Remarks
1. Elodea Harvesting		338,242	243,008	
(1) Harvesting by Boat	4 boats		202,667	
Fuel Cost	4 boats	17,233		
Personnel Expense	96 m/m	110,400		
Repairing Cost	4 boats	97,720		
Management Cost (10%)		22,535		
Total		247,888		
(2) Transportation by Barge	8 boats		24,320	
Total	8 boats	0		
(3) Transportation by Tugboat	2 boats		12,160	
Fuel Cost	2 boats	16,092		
Personnel Expense	24 m/m	22,080		
Repairing Cost	2 boats	12,160		
Management Cost (10%)		5,033		
Total		55,365		
(4) Unloading by Belt Conveyor	2 equipment		3,861	
Fuel Cost	2 equipment	7,217		
Personnel Expense	48 m/m	22,080		
Repairing Cost	2 equipment	2,510		
Management Cost (10%)		3,181		
Total		34,988		
2. Water hyacinth Removal		188,322	61,677	
(1) Trawling by Boat			30,400	
Fuel Cost	2 boats	32,183		
Personnel Expense	24 m/m	22,080		
Repairing Cost	2 boats	24,320		
Management Cost (10%)		7,858		
Total		86,441		
(2) Unloading by Crawler Crane	1 equipment		31,277	
Fuel Cost	1 equipment	5,221		
Personnel Expense	72 m/m	71,760		
Repairing Cost	1 equipment	15,638		
Management Cost (10%)		9,262		
Total		101,881		
3. Composting of Elodea/Water hyacinth		483,055	239,147	
(1) Cutting/Squeezing by Hopper	4 equipment		25,333	
Fuel Cost	4 equipment	28,405		
Personnel Expense	12 m/m	11,040		
Repairing Cost	4 equipment	20,267		
Management Cost (10%)		5,971		
Total		65,683		
(2) Transportation by Dump Truck	5 vehicles		89,680	
Fuel Cost	5 vehicles	43,452		
Personnel Expense	60 m/m	55,200		
Repairing Cost	5 vehicles	44,840		
Management Cost (10%)		14,349		
Total		157,841		
(3) Piling by Tractor Shovel	3 vehicles		69,955	
Fuel Cost	3 vehicles	29,759		
Personnel Expense	36 m/m	49,680		
Repairing Cost	3 vehicles	34,977		
Management Cost (10%)		11,442		
Total		125,858		
(4) Additive Collection by Dump Truck *	2 vehicles		35,872	
Fuel Cost	2 vehicles	17,380		
Personnel Expense	48 m/m	44,160		Incl. mixing works
Repairing Cost	2 vehicles	17,936		
Management Cost (10%)		7,948		
Total		87,424		
(5) Miscellaneous Works			18,307	
Fuel Cost	2 equipment	10,811		
Personnel Expense	24 m/m	22,080		
Repairing Cost	2 equipment	9,154		
Management Cost (10%)		4,205		
Total		46,250		
4. Grand Total		1,009,619	543,832	

1) *: Additive to facilitate fermentation of compost is collected/transported by dump truck from sugar factories and mixed into aquatic plants. 2) m/m: man-month

Table G.4.7 Implementation Program of Aquatic Plants Control

Item	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011-	Total
1. Dredging													
Pilot Project													
Full Scale Project													
D/D													
Construction													
Investment Cost Disbursement (million Col$)			419.1				1,290.0	3,872.0	3,872.0	3,872.0	3,871.0		17,196.1
2. Harvesting/Composting													
Pilot Project													
Procurement/Construction													
Operation													
Full Scale Project													
Procurement/Construction													
Operation													
Investment Cost Disbursement (million Col$)		1,403.5			10,284.7								11,688.2
O&M Cost Disbursement (1,000 Col$)		105,001	210,002	210,002	105,001	1,009,619	1,009,619	1,009,619	2,529,619	1,009,619	1,029,019	1,009,619	
3. Grass Carp													
Procurement/Construction													
Operation													
Investment Cost Disbursement (million Col$)				2,054.0									2,054.0
O&M Cost Disbursement (1,000 Col$)				25,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	
4. Total													
Investment Cost Disbursement (million Col$)		1,403.5	419.1	2,054.0	10,284.7		1,290.0	3,872.0	3,872.0	3,872.0	3,871.0		30,938.3
O&M Cost Disbursement (1,000 Col$)		105,001	210,002	235,002	155,001	1,059,619	1,059,619	1,059,619	2,579,619	1,059,619	1,079,019	1,059,619	

Note: O&M cost includes replacement cost of equipment