DESIGN AND PLAN FOR AN AQUACULTURE RESEARCH CENTER IN COLOMBIA

by

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SUMMARY OF RECOMMENDATIONS

THE REPELON SITE

The site near Repelon appears to be suitable for development of an aquaculture research center based upon the following three basic requirements for a good fish culture station.

1. Soil has adequate clay content to allow construction of earthen ponds with a minimal amount of water seepage providing good pond construction methods are followed.

2. Water is available in quantity and at low cost from the COMPRESA Irrigation Project. A lateral irrigation canal immediately adjacent to the proposed site can supply a total of 2,500 m^3/hour (11,000 gal/min) to the aquaculture station. This is certainly adequate to fill any number of ponds that could be constructed on this site and maintain proper water levels even during the dry season when water loss through evaporation and seepage is high.

3. Size of area, approximately 19 hectares, is adequate for an initial development of an experimental pond complex of approximately 10 hectares, which normally is the minimal size suitable

for an effective aquaculture research program. The remaining land area is sufficient in size to accommodate the various buildings needed to support the experimental pond complex and still provide area for future pond expansion when this is needed.

Although the Repelon site appears to satisfy the majority of requirements for a good aquaculture research center, a very important obstacle remains to be solved:

The Repelon site, located some 75 km from Cartagena, is relatively isolated. Both Repelon and Soplaviento are quite small villages with very limited availability of conveniences such as good medical, educational, transportation, and shopping facilities. Under these conditions, staffing of the Aquaculture Center with personnel of high caliber for extended periods of time will be difficult. On the other hand, unless adequately trained aquaculturists with a real desire to work in this specific area of fisheries can be recruited to work at the Center, meaningful contributions by the Aquaculture Center to fish culture development in Colombia very likely will be minimal.

The following recommendations are given since it is felt that implementation of these will provide acceptable solutions to potential staffing problems:

Residences should be constructed at the Aquaculture Center as an incentive in recruiting quality staff with families. The Aquaculture Center, with about 10 hectares of experimental ponds, initially will require the full-time services of three aquaculturists (specific areas are given below under Training), a general foreman or pond superintendent and probably two guards or watchmen plus a labor crew. In addition to providing appropriate housing for the key Station personnel, a dormitory facility of limited size should be constructed to accommodate visiting biologists assisting in fish breeding and other fish culture activities which often require round-the-clock effort extending over a period of several days.

Transportation to Cartagena should be provided at low cost to Center personnel on a scheduled basis, perhaps once or twice per week via Center vehicle.

TRAINING PROGRAMS

An adequate training program will be required to establish an aquaculture research and extension base where Colombian biologists, in a relatively short period of time, can be trained and gain experience in carrying out aquaculture programs. The following training plan is judged necessary if an effective aquaculture program is to be achieved in Colombia.

Graduate Training Program

Three professional aquaculturists will be required initially for the work program at the Aquaculture Center: 1) a general aquaculturist with training in experimental design and statistics, 2) a fish disease and parasite specialist, and 3) a fish feed and nutrition specialist. These should be trained at a Master of Science level. A graduate program in these areas normally can be completed within two years, providing the recipient is dedicated, has a good undergraduate background either in biology or agronomy and possesses good understanding of the English language upon arrival to campus. It is recommended that the USAID Mission make available at least three participant training positions to selected, qualified personnel of INDERENA. The graduate training program should be initiated as rapidly as possible to permit completion of the program and subsequent early participation by the recipients in the research program at the Aquaculture Center.

Short-term Training Programs

Two types of short-term training are proposed for INDERENA fisheries personnel who have major responsibilities in the aquaculture program:

1) Special Study Tours. The USAID Mission should support the travel of key staff of INDERENA and a few universities in Colombia who are presently involved in aquaculture programs to the FAO sponsored Aquaculture Conference to be held in Uruguay late this year. This same group also should schedule a stop-over visit in Fortaleza, Brazil enroute to Uruguay to carefully review aquaculture research and fish culture extension program being carried out by DNOCS (Brazilian Fisheries Department). This important aquaculture program with strong support of the Government of Brazil and the USAID Mission, has been in operation for approximately five years, during which a considerable amount of good aquaculture research and extension information has been obtained. INDERENA and Colombian universities involved in aquaculture programs could benefit a great deal through exchanging ideas, sharing information and establishing relationship on a personal basis with counterparts at the Pentecoste Aquaculture

Research Center - the latter is the largest and best designed aquaculture facility in Latin America.

A second study tour for the same or similar group from Colombia is recommended for the purpose of visiting various food-fish farming operations in southeastern United States and also to tour aquaculture research facilities of a few educational institutions. The former is suggested to give the visiting group some real appreciation of the basic economic facts of life as they relate to commercial aquaculture operations while the latter is recommended to provide the visitors with better appreciation of the various elements needed to achieve and maintain an effective aquaculture research and extension program. The International Center for Aquaculture, Auburn University, would cooperate by arranging a one-month travel program. November to mid-December would be best to observe large scale harvesting, processing, and marketing operations.

2. <u>In-Country Training</u>. To up-grade training of INDERENA fisheries personnel who previously had a very limited opportunity to receive academic training in aquaculture and related fisheries fields, it is proposed that a short-course training program be implemented on an annual basis. Duration of this program would be 2 weeks with a team of three professors in various aquacultural fields from Auburn's International Center for Aquaculture participating in the intensive short-course training program. Professors from Colombian universities with experience in aquaculture should also

participate in this program. The short-course training program should be maintained at least until the return of INDERENA staff following completion of participant training or until a sufficient number of field biologists and fish culture extension personnel had mastered the fundamentals of aquaculture.

TECHNICAL SERVICES

Additional technical services of specialists in fish hatchery design and pond construction should be provided to INDERENA on a short-term basis as needed. Substantial capital outlay will be required for the construction of the earthen pond complex with the related buildings needed to support a good aquaculture program. Moreover, a mistake made during the construction invariably proves to be quite expensive to correct. Careful planning and frequent checking will keep such errors to a minimum.

Although the potential for aquaculture development in Colombia appears good, there is little information available regarding the demand and market potentials for freshwater fish in Colombia. Before INDERENA embarks on a ambitious program of aquaculture development, it is important that some sound economic and fish marketing data be properly collected and analyzed. A determination then can be made regarding the possibilities for a successful aquaculture development program for Colombia.

Staff from the International Center for Aquaculture are qualified in areas indicated above and their services can be made available to INDERENA through the USAID providing adequate lead time is given so that teaching assignments and research responsibility on campus can be adjusted.

FIELD FACILITIES REQUIRED FOR THE AQUACULTURE CENTER

The basic field facilities required for a good and well balanced aquaculture program, in addition to housing for key Center personnel would include earthen ponds, concrete tanks, fish-holding house, warehouse-shop-office, field laboratory, fish feed and fertilization storage.

Earthen Pond Complex

An adequate number of well designed and properly constructed earthen ponds is requisite to implement a good aquaculture program. Normally around 100 ponds comprising a water surface area of about 10 ha will be required in the initial development with sufficient land area remaining for future expansion. Size of ponds should vary from 500 m^2, a good size for experimental ponds where substantial replication of treatments is needed, up to 5,000 m^2, a size that is adequate for producing fish fingerlings for use at the Center and for distribution to fish farmers. The larger size ponds also are best for production of food fish in commercial demonstration tests.

The earthen ponds should be constructed carefully utilizing good quality clay for the dams with adequate compaction to minimize loss of water by seepage. The pond complex should be designed so that each pond can be supplied with water and drained on an individual basis. Ponds should be constructed only slightly below the original land level, excavating from the pond bottom only the amount of soil required to build the dams. Pond bottom also should be sloped from the shallow (0.7 m in depth) to deep (1.5 m) end of pond to facilitate pond drainage during fish harvest operations. Cost of construction for the earthen pond complex will require a substantial capital outlay--roughly estimated at U.S. $5,000 to $10,000 per hectare of water, depending on size of pond.

Warehouse-Shop-Garage Building

There is need in aquaculture to fabricate or repair fish nets, seines, and a wide variety of other field equipment requiring frequent use of basic tools utilized in a machine and carpentry shop. Station vehicles including a farm tractor must be serviced and maintained in good operating condition as live fish all too rapidly become dead ones when transportation breaks down. A limited quantity of replacement parts and stock materials must be available (and secure from pilferage) at the Center as it would be completely unrealistic to have to send to Cartagena for a new tire, battery or fan belt for a disabled fish transport vehicle loaded with several thousand fingerling fish. A building incorporating workshop, garage and storage facilities, and probably an office for one of the three Station aquaculturists could be constructed for approximately $20,000.

Field Laboratory

A field laboratory consisting of sub-labs for the fish feed nutritionist and fish parasite and disease aquaculturists separated if possible by offices of these two specialists to provide isolation of work areas will be required. Thus risk of transmitting diseases from affected fish being treated in the fish parasite and disease laboratory to healthy fish receiving a test ration in the fish feed laboratory is substantially reduced. The laboratory will be supplied with adequate water for holding fish in small tanks, troughs or aquariums for extended periods. At least a portion of the building should be air conditioned to protect delicate laboratory equipment as balances, microscopes, analytical meters, and chemical supplies from excessively high humidity and temperature. This building will cost about $25,000.

Fish Holding House

A facility for holding large numbers and/or weights of fish for short periods of time is essential. Crops of fish as ponds at the Center are drained will be transported as expediently as possible to the Fish Holding House where they are placed in tanks supplied with flowing water. The fish subsequently are separated by species and appropriate data recorded on number, size and weight. Fingerling fish also are held in the fish holding tanks prior to stocking in the experimental ponds or distribution to fish farms located in the region. As it is imperative that the fish stocks be maintained in good physical condition, the fish holding house must be designed with care. It should be constructed at a site central to the earthen pond complex, and it must be readily accessible by vehicular traffic even in peak rainy season. Approximately 20 concrete tanks (3 m X 0.9 m X 0.9 m) supplied continously with flowing water will be required. If possible water for the fish holding tanks should be supplied by gravity flow from the lateral irrigation canal located in the vicinity. It is probably that the fish holding facility will require a capital outlay of $25,000.

Dormitory Facility

A facility is needed to accommodate visiting biologists and fish culturists during the fish breeding season when work around the clock for extended periods is required to successfully induce fish to spawn. Sleeping accommodations for six visiting biologists should be adequate with the appropriate bathroom and kitchen facilities. An additional room for use for lectures or for receiving visitors would not cost much, and likely would be extremely useful as the aquaculture program at Repelon develops. The dormitory facility probably could be constructed at a cost of $10,000. Thought should be given to including this facility as the second floor of the Field Laboratory Building as this would appreciably reduce total cost.

THE DESIGN AND PLAN FOR AN AQUACULTURE RESEARCH CENTER IN COLOMBIA

SUITABILITY OF THE REPELON SITE

The site near Repelon available to INDERENA for development of an aquaculture research center is suitable based upon three principal requirements for a good fish culture facility: 1) soil with adequate clay; 2) a sufficient supply of good quality water; 3) and a total land area sufficient in size to allow construction of an adequate number of ponds.

Soil

Soil at the Repelon site is brownish clay, consisting in part of alluvial sediments transported by rain from higher elevations. In June, prior to start of the 1974 rainy season, numerous cracks in the soil surface extending to depths of 5 to 10 cm were observed throughout the site area. This indicates presence of substantial amount of clay in the surface soil. This was subsequently verified through analysis of a series of soil samples taken by soil auger at depths of 1,2,3 and 4 meters at selected locations. Results of analysis carried out at Auburn are presented in Table 1.

The components of the soil which are most critical in pond construction are the relative amounts of sand and clay. All soil samples except one (KO + 200 at 1 meter) contained at least 30% clay. Soils with less than 30% clay generally are not suitable for pond construction in that excessive seepage of water will occur through the pond bottom and dam. Although quality of clay at the

Table 1

Analysis of soil samples taken by soil auger at various locations at the Repelon site.

Sample location	Depth m	Composition (%) Sand	Silt	Clay
near lateral canal	1	23	6	71
	2	30	10	60
	3	53	3	44
KO + 00	1	33	37	30
	2	20	47	33
	3	51	7	42
	4	47	20	33
KO + 200	1	53	27	20
	2	20	47	33
	3	40	27	33
	4	20	47	33
KO + 400	1	33	27	40
	2	27	20	53
	3	40	20	40
	4	47	7	47
KO + 600	1	20	33	47
	2	13	20	67
	3	13	4	83
	4	13	4	83
Ko + 800	1	20	13	67
	2	53	13	34
	3	20	3	77
	4	4	3	93

Repelon site appears adequate, proper construction procedures must be followed. For example, in constructing ponds at the Repelon site, it is important that the base of all dams be excavated through the surface soil strata which may contain tree roots and isolated pockets of sand. Also, only the best quality clay should be used in building up the cores of the dams. The earth fill for the dams should be applied in relatively thin layers, not exceeding 15 cm, with adequate compaction by sheeps foot rollers or other soil compaction methods.

Water

The Aquaculture Station will be supplied with water from Lake Guajuaro, which is approximately 16,000 ha in surface area, through a government sponsored Irrigation Project (COMPRESA). The COMPRESA Irrigation Project, a water supply canal and three large pumps with a capacity for delivering water at the rate of 7,500 m^3 per hour, is located immediately adjacent to the 19-ha site made available to INDERENA (Figure 1). Fisheries officials of INDERENA indicated that the Irrigation Project will supply, at nominal charge, an amount of water equivalent to the delivery capacity of one of the large irrigation pumps--2,500 m^3/hr or 11,000 gal/min. This amount certainly will be more than adequate to fill and replenish water that is lost through evaporation and seepage of any number of experimental ponds that can be constructed on the 19-ha site.

Apparently the Irrigation Project is shut down for a period of 20 days each year for servicing and providing other maintenance to the pumping

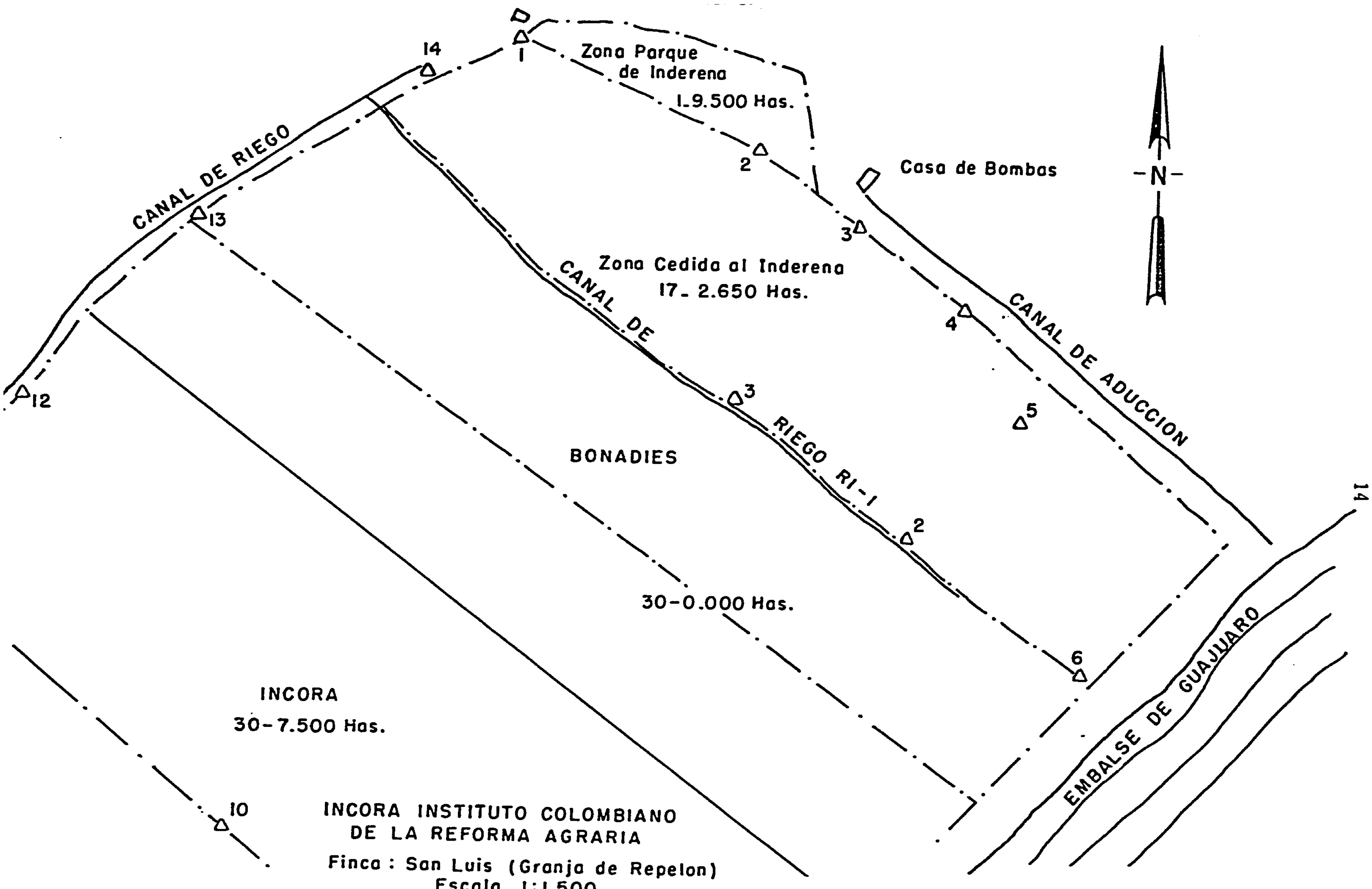


Figure 1. General of site available to INDERENA for development of an aquaculture research center.

equipment. If at all possible the maintenance program should be modified so that water will be provided to the aquaculture complex without interruption. Otherwise, the experimental aquaculture would be seriously handicapped.

Chemical analysis were not made on the lake water, but it is considered suitable for experimental fish culture since the lake contains a diversified fish population. A sample of bottom mud from the lake, taken near the aquaculture site, was anlyzed for presence of heavy metals. Concentrations of these elements were much below levels that would prove detrimental to fish or other aquatic organisms.

Land Area

The area available to INDERENA for development of an Aquaculture Center is 19.2 ha with 1.95 ha of this designated as a site for residences, laboratory and other service buildings--indicated as Zona Parque de INDERENA in Figure 1. The minimal land area suitable for development into an experimental pond complex is about 10 ha if improved aquacultural methods are to be developed in a reasonable period of time. This particular site is of sufficient size to permit initial development of the minimal size earthen pond complex (8.5 ha) and also provide an additional area of approximately 9 ha for future expansion.

EARTHEN POND COMPLEX

The initial development of earthen ponds should consist of a sufficient number of ponds to allow adequate replication of field trials so that statistically reliable data can be obtained in a relatively short period of time.

Size and Number of Earthen Ponds

The pond complex designed for INDERENA for the Repelon site includes forty 500 m^2 ponds, twenty 1,000 m^2, twelve 3,000 m^2 ponds, and two 4,500 m^2 ponds. Total water surface of the 74 ponds is 8.5 ha as illustrated in Figure 2.

A rather large number of small-size ponds are especially needed in aquaculture experimentation since a single field trial requires the use of one pond for the control and a minimum of three ponds for each treatment. Thus, the 500 and 1,000 m^2 ponds combined will provide 60 experimental pond units.

The Aquaculture Center must also function as a fish hatchery to produce fish fry and fingerlings for use in fish culture experiments and to supply fish to farmers in the region. Although the smaller ponds are suitable for fish breeding, growth of the tiny fry to fingerlings generally can be accomplished more efficiently and at less cost per 1,000 fingerlings in ponds of larger size. Hence, twelve 3,000 m^2 ponds are included in the pond design in Figure 2.

There will be need for the Aquaculture Center not only to breed various fish species and grow the recently hatched fry to fingerling size suitable for stocking ponds, but the Center must also be active in demonstrating commercial methods of food fish production. For this purpose, ponds of one-half to one hectare in surface area are best. In the earthen pond complex illustrated in Figure 2, two 4,500 m^2 ponds are included. There will be a definite need for

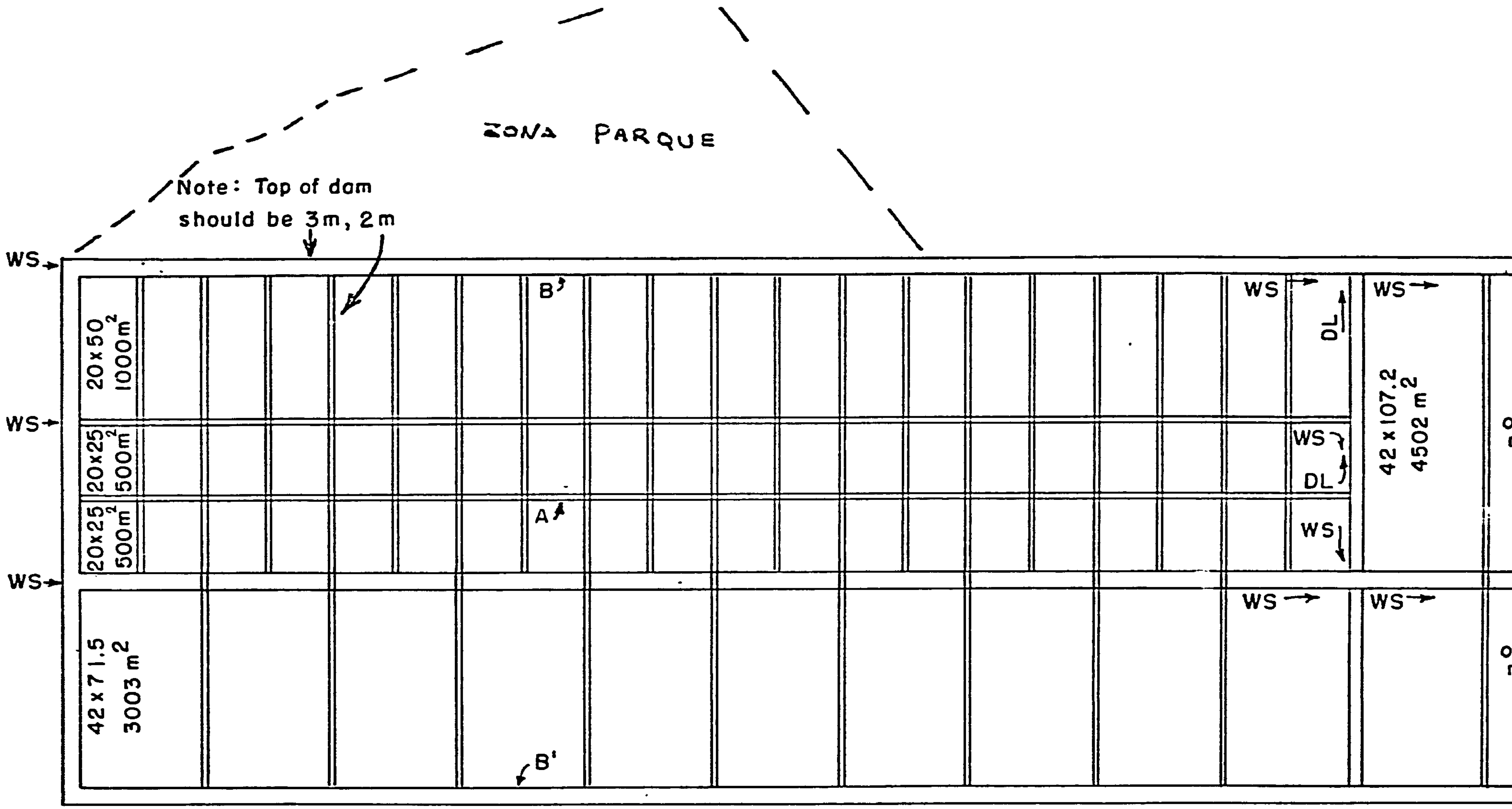


Figure 2. Sketch of earthen pond complex: Forty 500 m^2 ponds (2 ha); twenty 1000 m^2 (2 ha); twelve 3000 m^2 (3.6 ha); two 4500 m^2 (0.9 ha) with total of 74 ponds with water surface of 8.5 ha.
Scale: 1mm = 2 meters

an additional number of commercial-demonstration size ponds, but construction of these can be delayed until the second phase of the construction program.

In the northwestern corner of the aquaculture site (near points 1 and 14 on Figure 1), there is adequate space to construct a small pond which could serve as a holding pond or a reservoir for supplying water to the pond system on an emergency basis when supply of water from the Irrigation Project is temporarily interrupted. It is strongly recommended that this particular site be reserved for development of a water supply reservoir.

Water Supply System

Water for the Aquaculture Center is pumped from the water supply canal (Canal de Aduccion) connecting to Lake Guajuaro to Darsena Canal Interior (near point A on Figure 1) from which the water flow is diverted into lateral canals (Canal de Riego) for use in irrigation. Difference in elevation from the lateral canal supplying water to the pond complex at point 1 in Figure 1 to point 6 near the shore of the lake, a distance of approximately 800 m, was reported to be around 14 m. Thus, water supply lines for the earthen pond complex should follow the topography so that water can be provided by gravity flow. Each pond should be supplied with water on an individual basis rather than allowing water from one pond to flow into one or more other ponds.

Three sets of water supply lines are recommended for the earthen pond complex. These are designated by the symbol WS in Figure 2. Plastic pipe (PVC) is ideal for water supply lines since the pipe can be readily installed without the use of specialized tools or highly skilled technicians and it generally can be easily repaired should the pipe become damaged. The primary water supply lines (WS) should be 6 inches (150 mm) in diameter if the entire 19-ha area eventually is to be developed into ponds. However, 4-inch (100 mm) diameter lines would be adequate if only 8.5-ha of ponds were constructed as shown in Figure 2.

Two-inch (50 mm) diameter lines should tee off from the primary water supply lines to supply each individual pond. However, the 1,000 and 4,500 m^2 ponds, as shown in the plan in Figure 2, will be supplied with water inlets at both shallow and deep ends of each pond. This will allow these two series of ponds to be filled more rapidly. It also will permit removal of fish crops with less stress to the fish since water of food quality can be introduced at the deep end of the ponds where fish congregate during the pond draining operations.

Appropriate size gate valves (2-inch or 50 mm) should be installed on water inlets supplying each pond. Larger gate valves should be installed at the upper end of three primary pipe lines in order that repair of one line can be carried out without interrupting water flow through the other two primary lines. All water supply lines should be installed in one-third-meter deep trenches excavated along the center line of the appropriate dams after the dams have been constructed to final elevations. Dams with water lines underground are much easier to maintain and this also facilitates the use of the dam as a roadway for transport of fish, feeds and fertilizers.

As water supplying the earthen pond complex is pumped from Lake Guajuaro, some small wild fish or fish eggs from the lake undoubtedly will survive the trip through the turbines and subsequently enter the various ponds through the water supply lines. To prevent or minimize contamination of experimental ponds with undesirable wild fish species, a fish screening device should be installed. A rectangular concrete structure with dimensions of about 1 m X 1 m X 3 m resulting in a volume of 3,000 liters (790 gallons) should be constructed above the ground surface so that water from the lateral irrigation canal would pass through the fish screening device and subsequently to the water supply lines by gravity flow. A series of five square wooden frames constructed from 1 X 3 inch (25 X 75 mm) lumber and covered with saran screen on both sides will fit snugly in recessed grooves spaced at one-half meter intervals along the interior length of the concrete box. Although mesh or saran screen is sufficiently small to prevent eggs and small fish from passing through the screen, the large cross-sectional area of the screens will permit a rapid water flow through the fish screening device. It will be necessary that the screens be cleaned daily and the saran fabric replaced with new material two to three times each year. A fish screening device as described above should be constructed for each of the three major water supply lines (WS) illustrated in Figure 2.

Water Drain System

As in the case of the water supply system, each pond should have its own drainage outlet that functions independently of any other pond in the complex. The 500 m^2 ponds will drain through monks to a central drain pipe running longitudinally along the base of the dam identified as A in Figure 2.

The drainage system of two adjacent 500 m^2 ponds sharing a common dam and a central drain pipe is illustrated in Figure 3. Inside diameter of the drain pipe extending from the monk to the central drain pipe should be 6 inches (150 mm) to facilitate rapid draining of the experimental pond. However, the central drain pipe must be of larger diameter (10 to 12 inches or 250 to 300 mm) in order to allow for the draining of several ponds simultaneously.

At the juncture of the 500 m^2 and 4,500 m^2 pond series, the central drainage line of the smaller ponds is turned 90 degrees, thereby flowing into an open drainage canal and subsequently back into the lake.

The larger ponds, 1,000, 3,000 and 4,500 m^2 in water surface, are also drained by the monk system as illustrated in Figure 4. Diameter of the drain pipe extending from the monk to the open drainage ditch on the opposite side of the dam need not exceed 6 inches (150 mm) since each pond empties individually to the open drainage canal.

The monk is simply a concrete tower reinforced with steel rods for added structural strength. All monks have an external dimension of 0.9 m X 0.75 m with inside measurement of 0.6 m X 0.6 m and with concrete reinforced walls of 150 mm. The monk extends from the deepest point in the pond to 0.5 m above the water surface. The side of the monk facing away from the dam is open with the two adjacent sides constructed with recessed grooves to accept a screen and dam boards. Dam boards are made from 2 X 6-inch (50 X 150 mm) lumber and are 0.7 m in length so that the boards will fit in the recessed grooves of the monk. Water level of a pond is adjusted by removing or adding

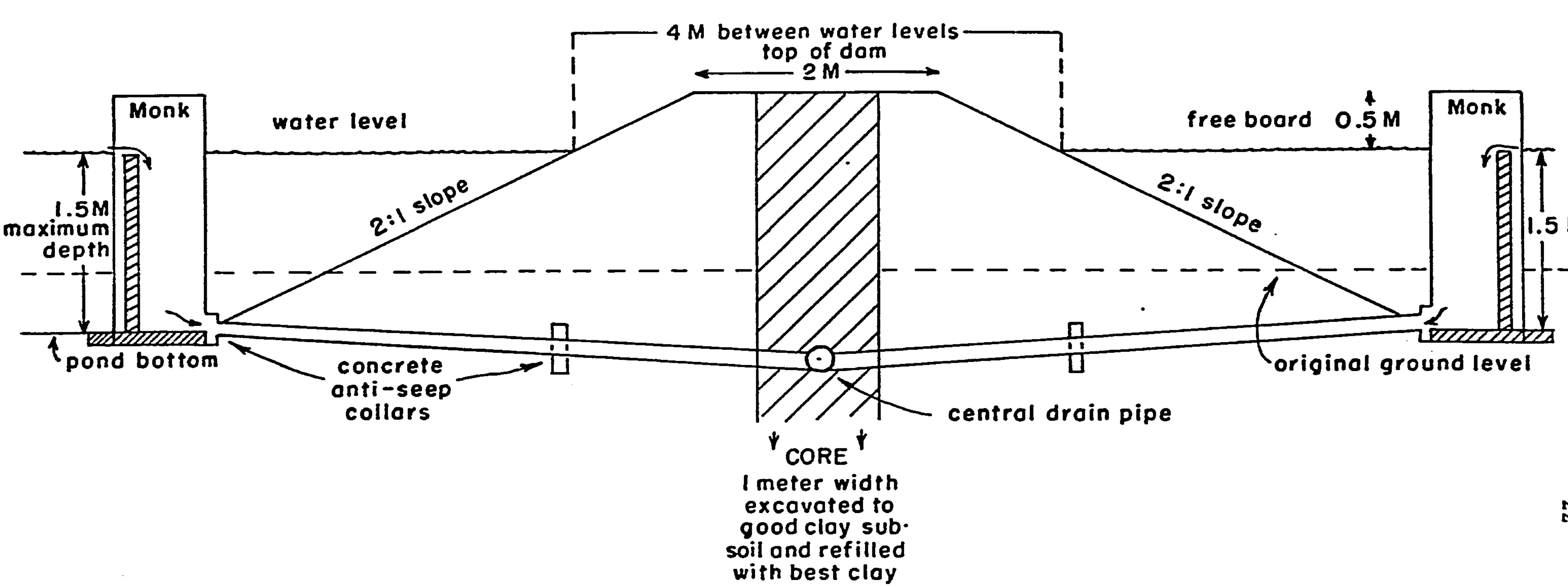


Figure 3. Cross-section of dam of 500 m^2 ponds (point A on Figure 2) showing deep end of two adjacent ponds sharing common dam and drainage system.
Approximate scale 20 mm = 1 meter

|← 1 m →|

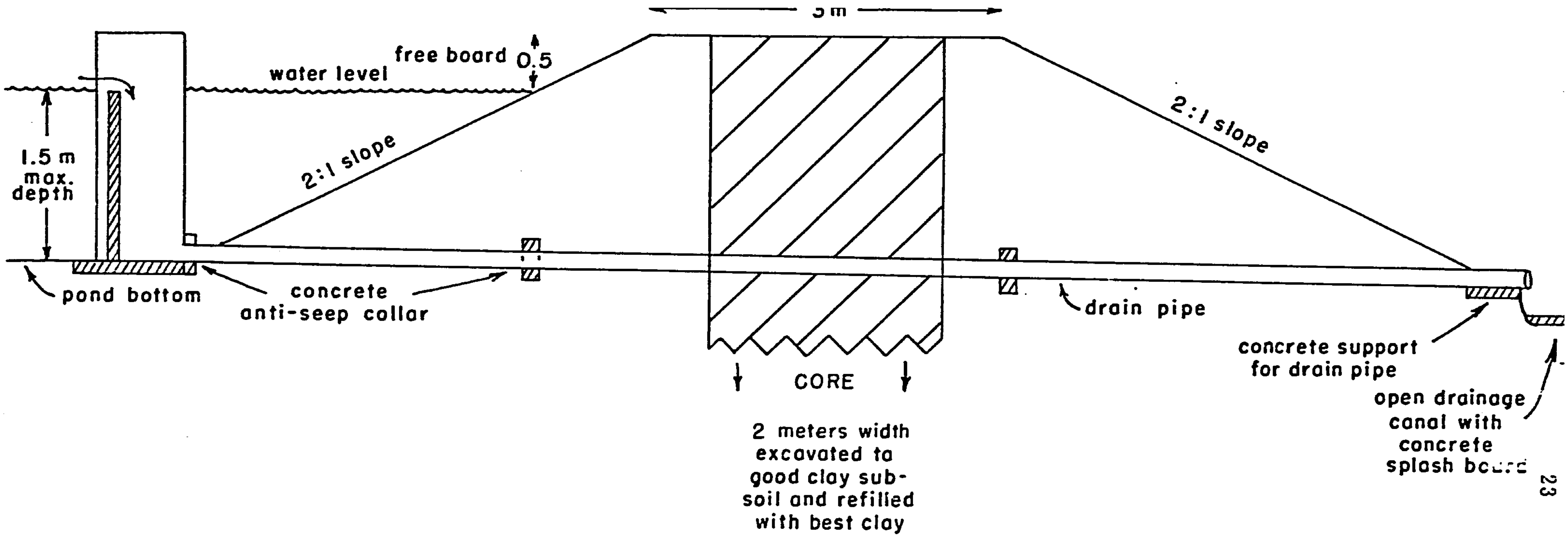


Figure 4. Cross-section of dam of 1000 m, 3000 m, and 4500 m ponds (points B and B' in Figure 2) at deep end of pond with drain system.
Approximate scale 20 mm = 1 meter

|← 1m →|

dam boards. For complete draining, dam boards are successively removed until the pond is dry.

The concrete reinforced monks will last for 30 to 50 years if constructed properly. However, monks are quite expensive to construct in terms of labor and materials. INDERENA may wish to consider an alternative drain structure that may be more economical. Heavy-gauge PVC pipe, 13 to 15 mm in thickness, provides a suitable drain structure when a 1.5 m section of the plastic pipe is affixed to the horizontal drain pipe by means of an unthreaded ell connector. The vertical PCV stand pipe is glued to one side of the 90^{o} ell while the other side of the ell slides over the drain pipe. Before filling the pond with water, it is necessary to coat the two touching surfaces of the ell and the drain pipe with water proof grease to prevent water seepage through this joint. Once the pond is filled, water pressure holds the vertical standpipe firmly against the drain pipe. To preclude accidental drainage of the pond, a metal or wood stake should be driven into the pond bottom very near the vertical standpipe and with the top of the standpipe tied by wire to the stake.

Either heavy gauge plastic pipe (PVC) or asbestos cement (transite) pipe is suitable for drain lines. Drain lines, which are installed after the base of the dam has been excavated and the core trench refilled with good clay, should have a slope of three per cent to effect rapid drainage of the pond.

Design and Construction of Dams

The earthen pond complex basically consists of dams that are slightly different in size but quite similar in design. All dams are designed with a 2:1 slope; that is, the toes of each dam extend a distance of 2 meters horizontally for each meter in height. The perimeter dams, which with a gravel surface will serve as roadways for light transport vehicles for hauling fish and supplies such as feeds and fertilizers, have a top width of 3 meters while the small dams have a top width of 2 meters. Cross-sections for these dams are shown in Figures 3 and 4. Volumes of earth required for each linear meter of the 2 and 3 meter wide dams are 32 m^3 and 48 m^3 respectively.

Base of all dams are excavated slightly below original ground level to remove brush and tree roots. A core trench is then excavated to good clay and subsequently refilled using only the best quality clay. The drain pipe should then be installed with adequate care taken to re-pack the earth very firmly along the trench made to accommodate the pipe line. Also, antiseep collars should be placed around the drain pipe at 5 meter intervals to prevent water seepage channels developing along the pipe. The balance of the earth fill in the dams should be applied in 6 inch (15 cm) layers and compacted with a sheeps foot roller. Fill for the dam is excavated mainly from the deep ends of the pond as shown in Figure 5. Water depth at the deep end of the pond is 1.5 m while at the shallow end it is 0.7 m. Pond bottoms should slope sufficiently to permit rapid and complete removal of water through the drainage system (Figure 5).

Construction along lines as described above is expensive. However, no short-cuts can be taken without running the risk of making construction errors that later will prove even more costly to correct.

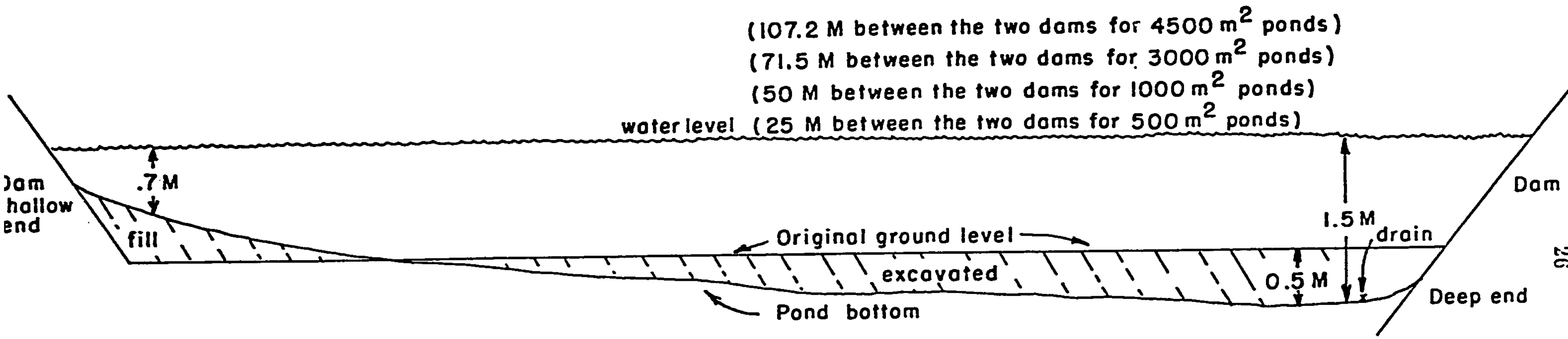


Figure 5. Sketch showing approximate slope of pond bottom to facilitate complete draining and excavated and fill areas.

OTHER REQUIRED FACILITIES

Concrete Pools

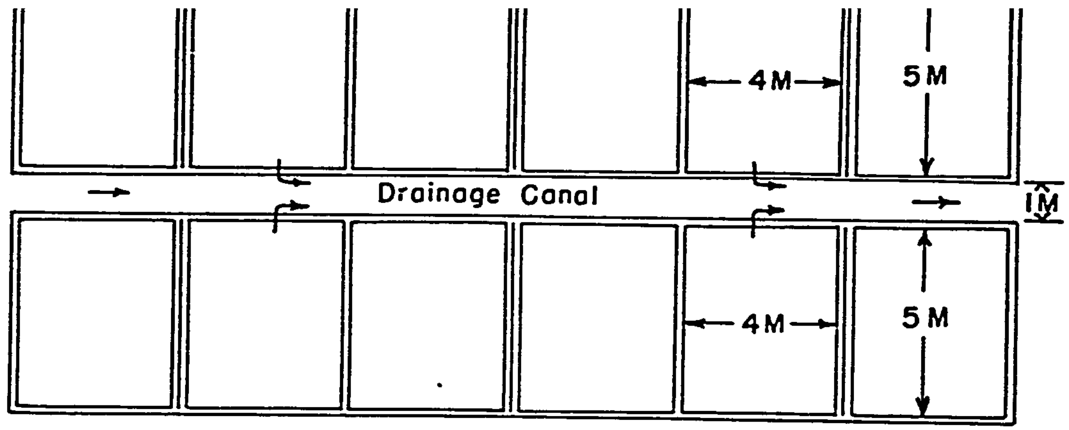
Concrete pools are useful in aquaculture research for: 1) holding brood fish for short periods; 2) selective breeding and hybridization experiments; 3) hatching of eggs and rearing of fry; 4) growth studies; 5) fish nutrition studies.

A minimum of 12 concrete pools with inside dimensions of 4 X 5 m and with a water depth of 1 m should be constructed initially. Thus, each pool has a volume of 20 m^3. Construction should be heavily reinforced concrete with double cross walls between every second tank as shown in Figure 6. A 2-inch (50 mm) diameter water supply pipe (PVC) will span the length of concrete pool series with a 1-inch (25 mm) line supplying each pool. Also, each pool should be constructed with a top overflow slot, a middle drain and a bottom drain as shown in Figure 6. The central or common drainage canal should slope sufficiently to drain water overflowing the pools away from the pool area to avoid settling of the earth and damage to the pools through cracking.

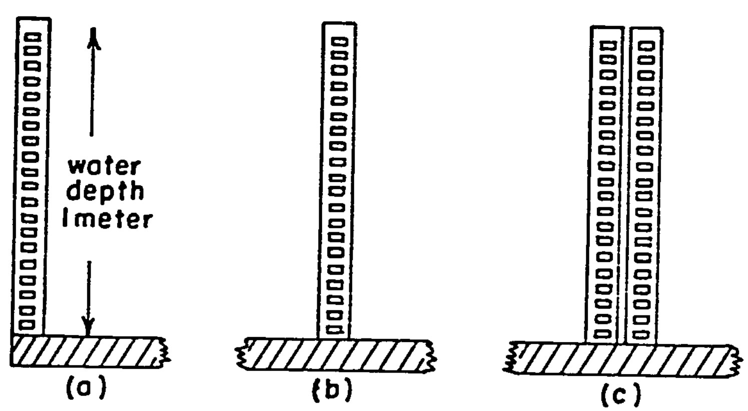
Additional concrete pools, if needed, can be constructed during a later phase of the construction program.

Fish Holding House

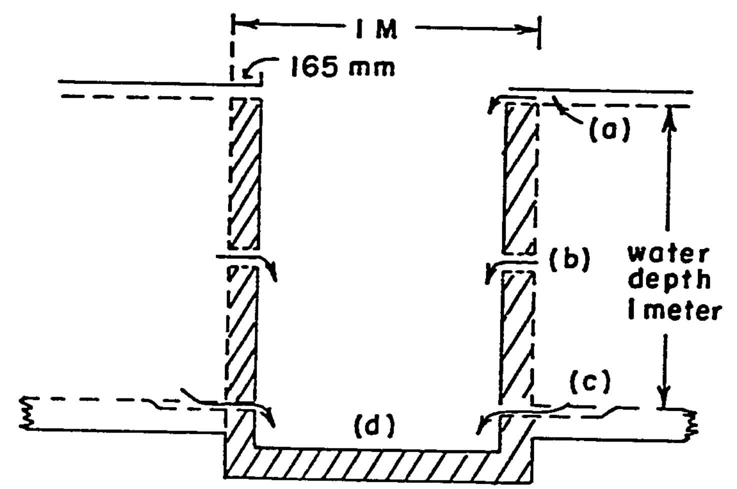
A facility for holding large numbers and/or weights of fish for short periods of time is necessary for the Aquaculture Center. As ponds are drained, crops of fish are transported as expediently as possible to the fish holding



Top view of concrete pools showing common drainage canal. Each pool has a surface area of 20 M^2 with water depth of 1 meter = 0.0020 ha; volume = 20 M^3. Scale: 5mm = 1 meter



Cross-section of concrete pools showing (a) end wall, (b) single wall between pools and (c) double between every second pool.
Scale: 40 mm = 1 meter



End view of drain between two series of concrete pools showing (a) overflow outlet, (b) middle drain, (c) bottom drain with sump and (d) drainage canal. Scale: 40 mm = 1 meter

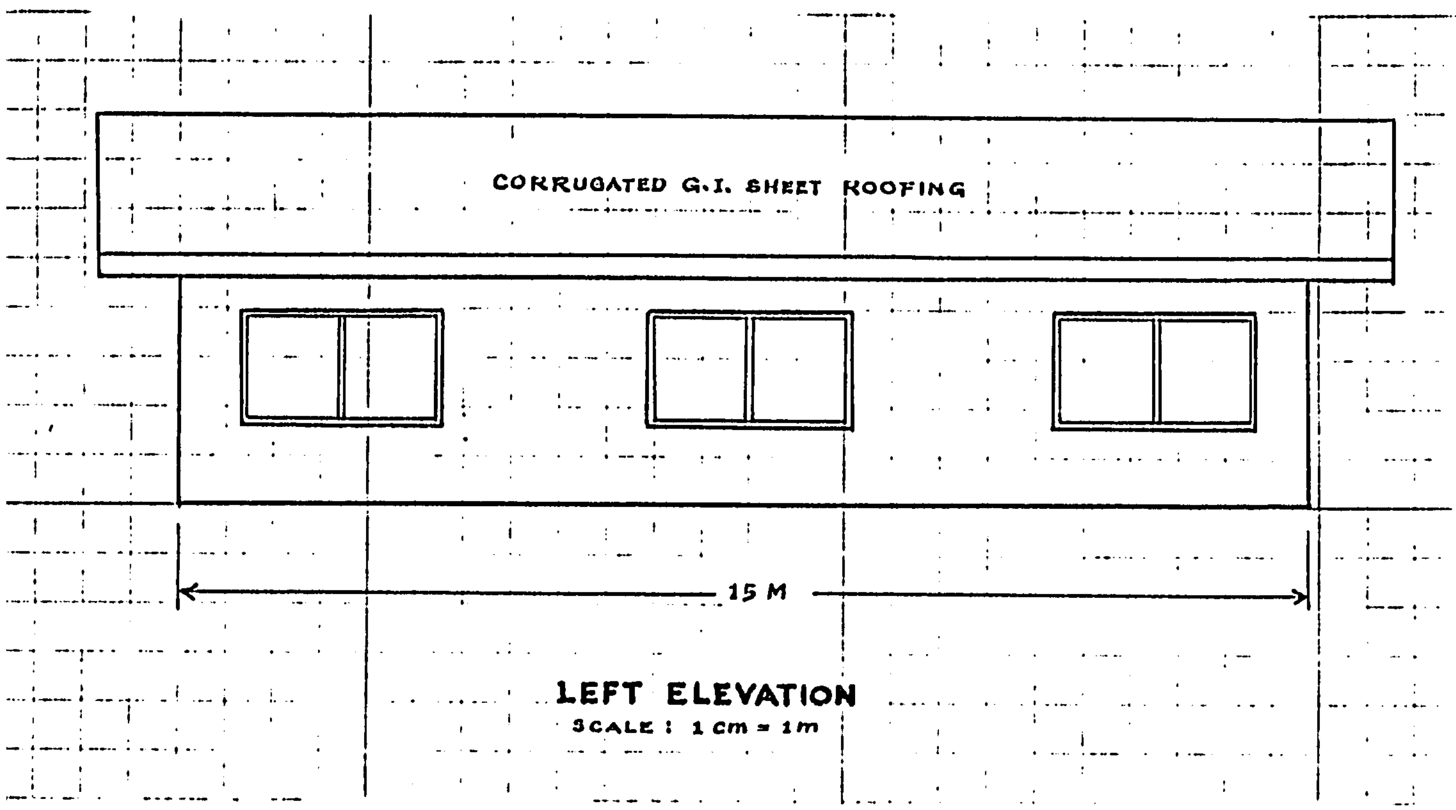
Figure 6. Sketches of concrete tank facility.

house where they are placed in tanks supplied with flowing water. Fish are then separated into different size groups by species and appropriate data recorded. Fingerling fish are also held in the fish holding facilities prior to stocking in the experimental ponds or distribution to fish production ponds located in the region.

As it is imperative that the fish stocks be maintained in good physical condition, the fish holding house must be designed with care. It should be constructed at a site central to the earthen pond complex, and it must be readily accessible by vehicular traffic even in the rainy season. Approximately 20 concrete tanks (3 m X 0.09 m X 0.9 m) supplied continuously with flowing water will be needed. If possible, water for the fish holding tanks should be supplied by gravity flow from the lateral irrigation canal located near the Zona Parque de INDERENA. Otherwise an elevated water storage tank with a reliable pumping system for periodically refilling the tank will be required. Engineering details and design for a fish holding house are provided in the five illustrations included in Figure 7.

Warehouse-Shop-Garage Building

There is almost a constant need in aquaculture to fabricate or repair fish nets, seines, and a wide variety of other field equipment. Thus machine and carpentry shops with basic tools and equipment will be essential to the effective operation of the Aquaculture Center. Also, station vehicles including pick-up trucks and a farm tractor must be serviced and maintained in good operating condition. A limited quantity of replacement parts and stock materials



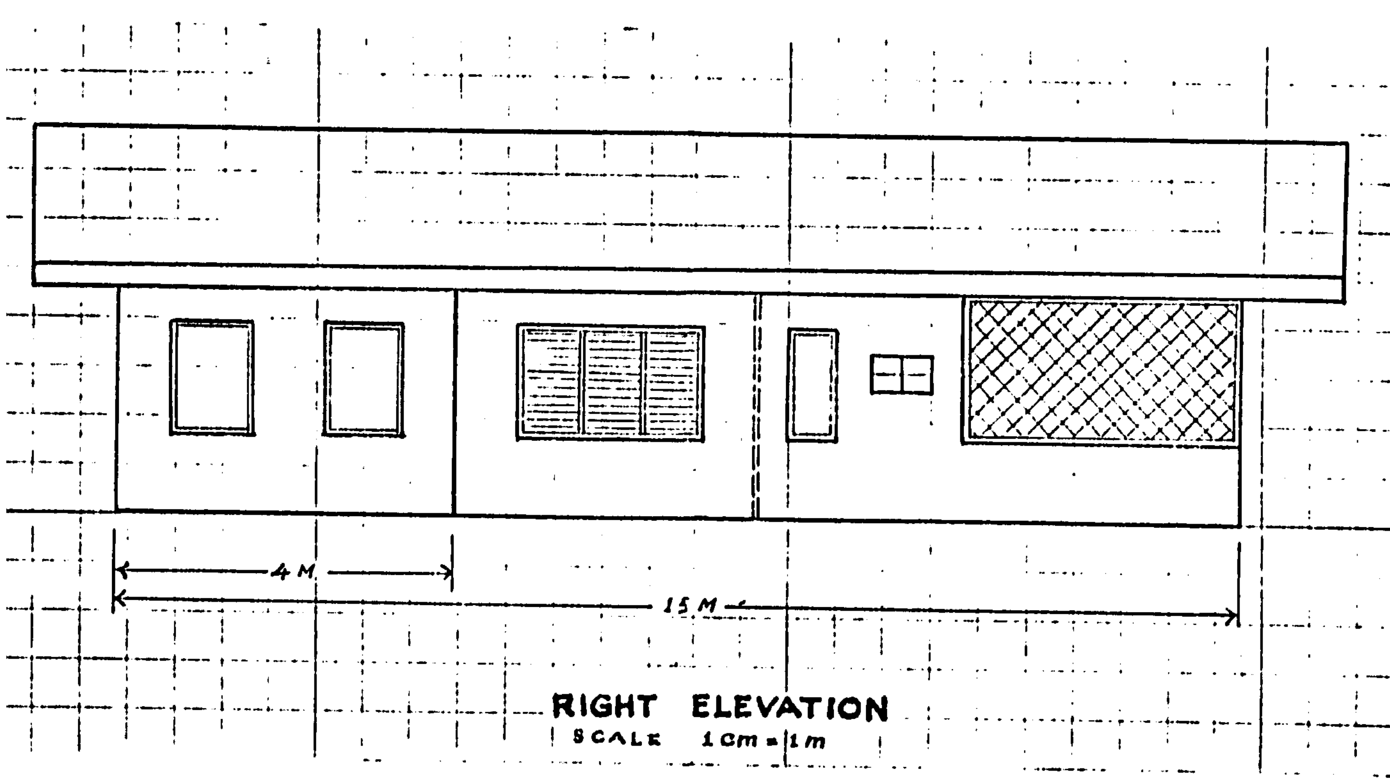


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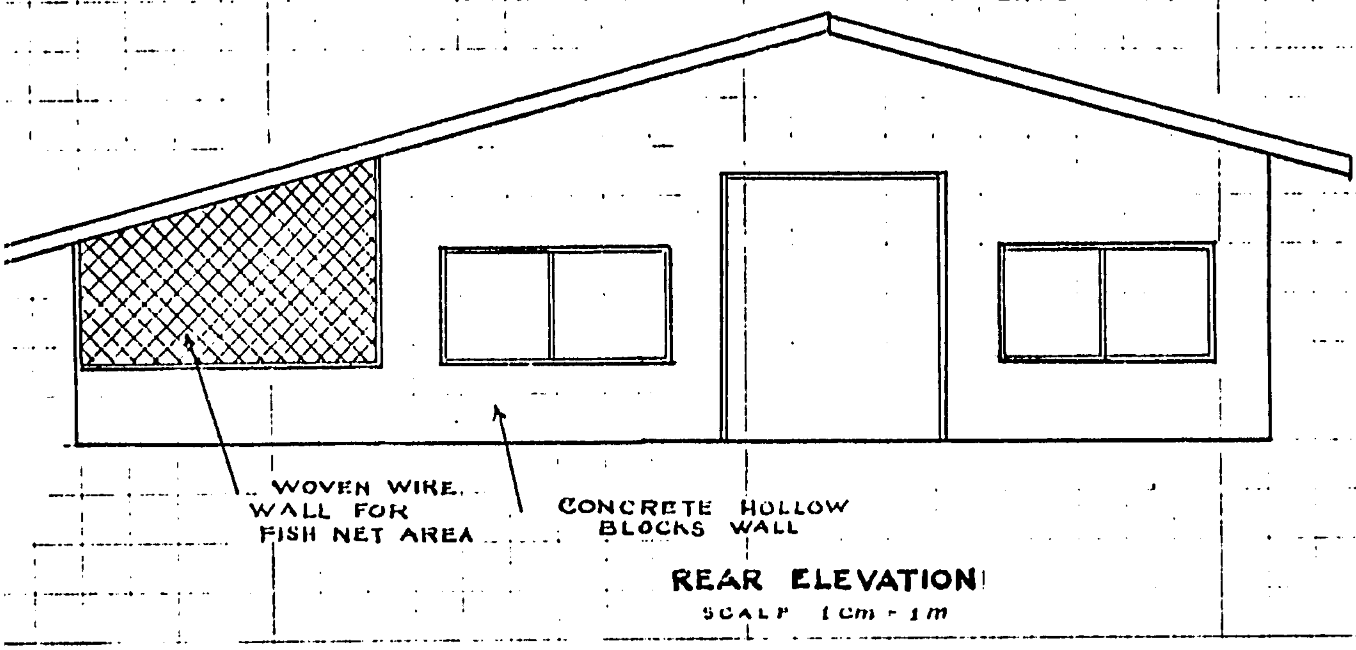
Figure 7a. FISH HATCHING AND HOLDING HOUSE



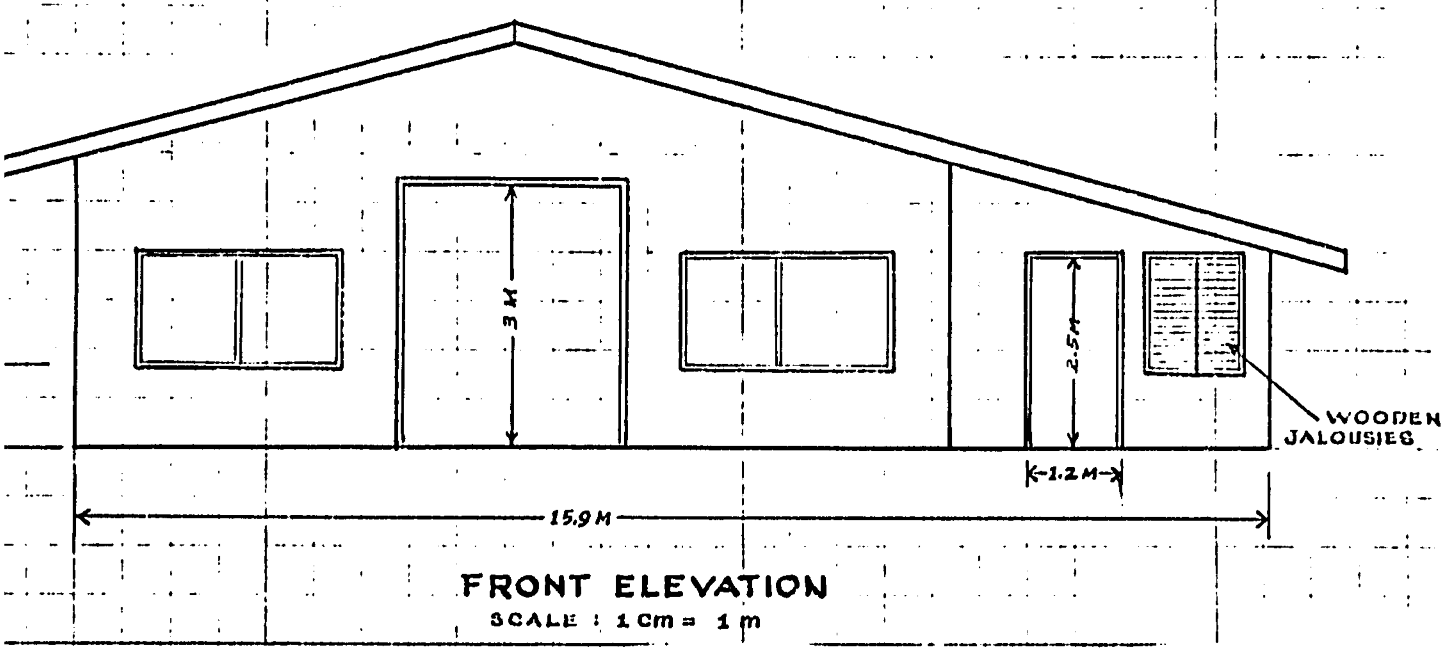


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Figure 7b. FISH HATCHING AND HOLDING HOUSE

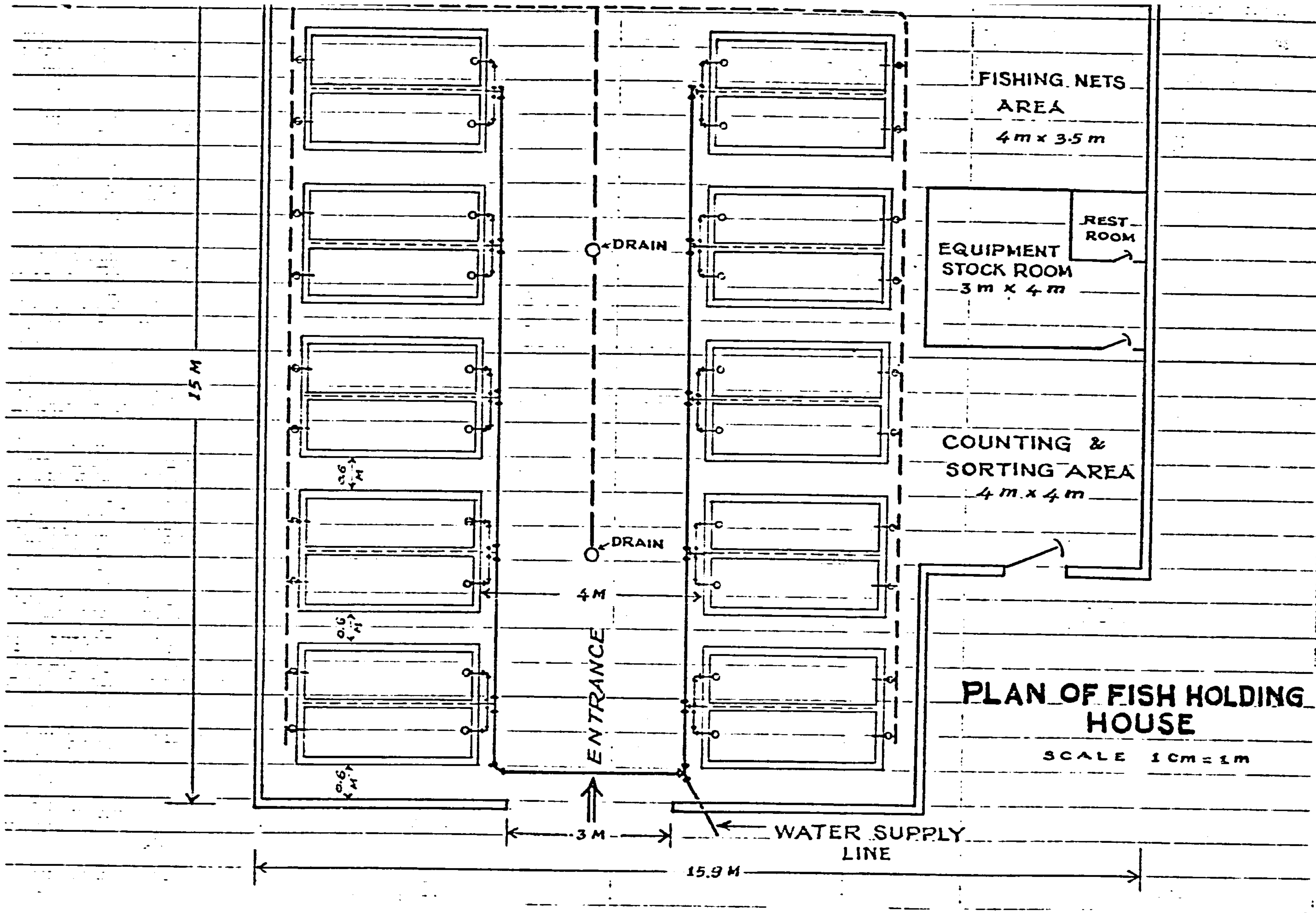

Figure 7c.

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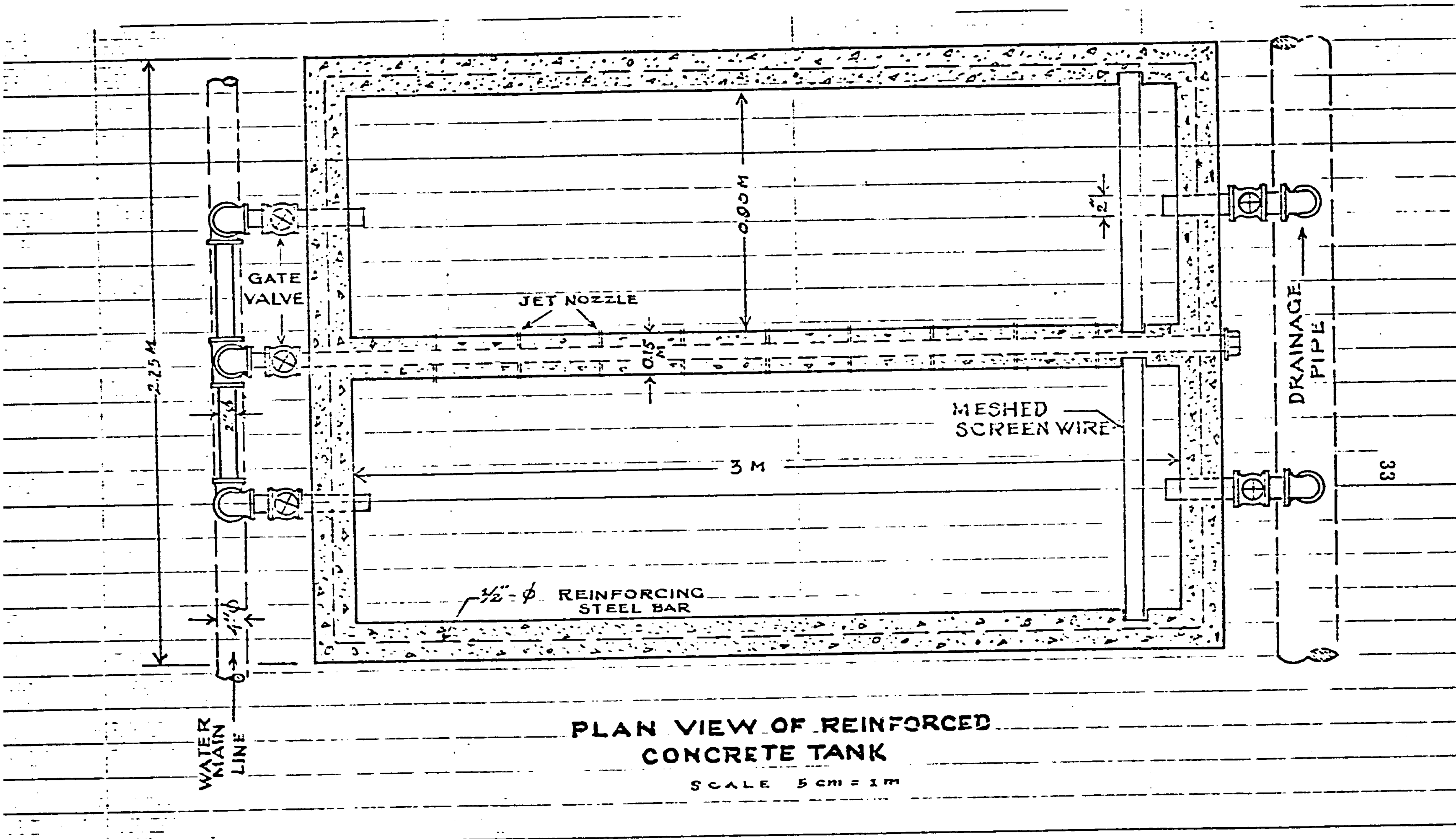

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PERFECT PROFILE
PLATE A
EUGENE DIETZGEN

Figure 7d. FISH HATCHING AND HOLDING HOUSE

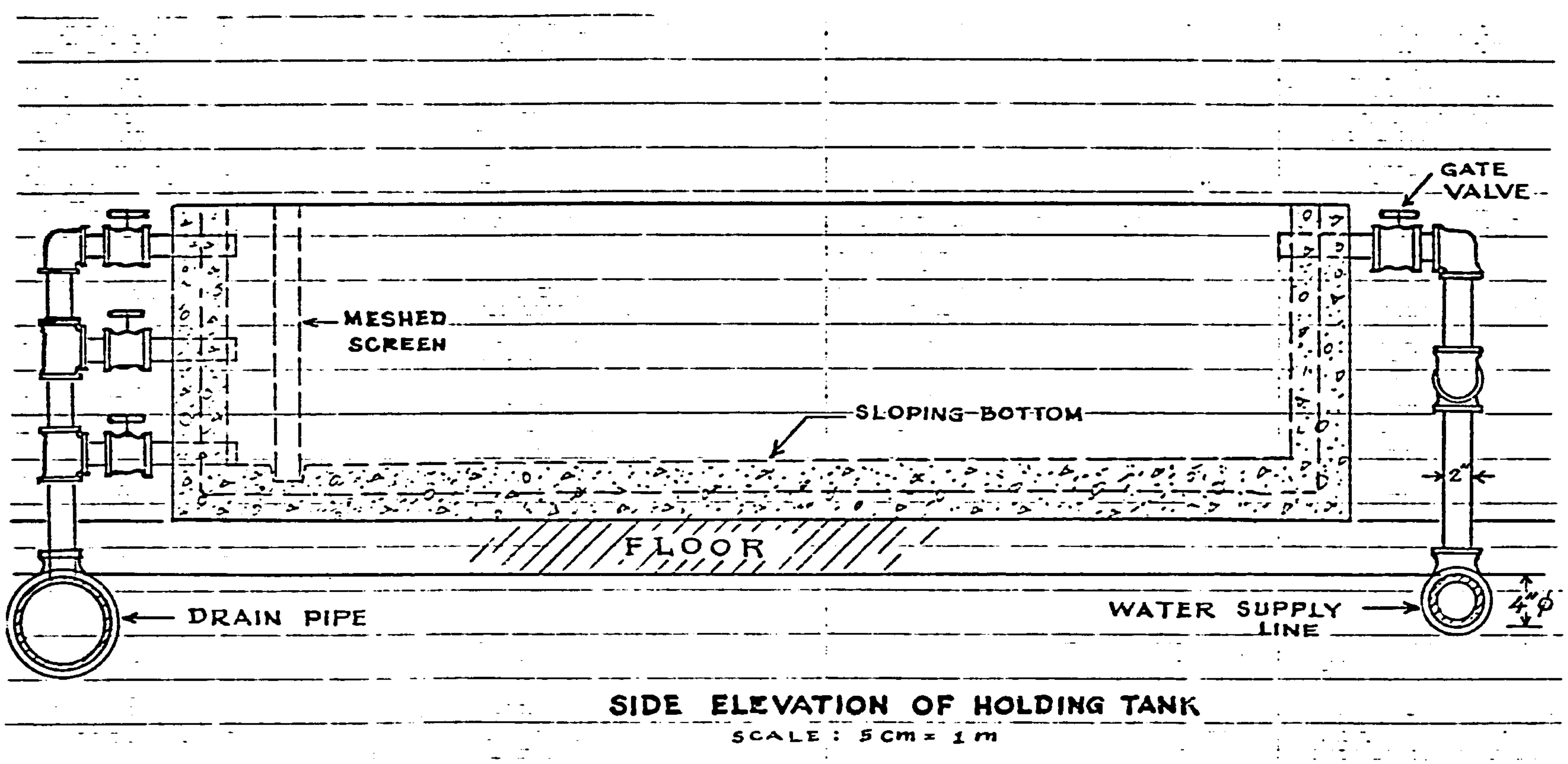

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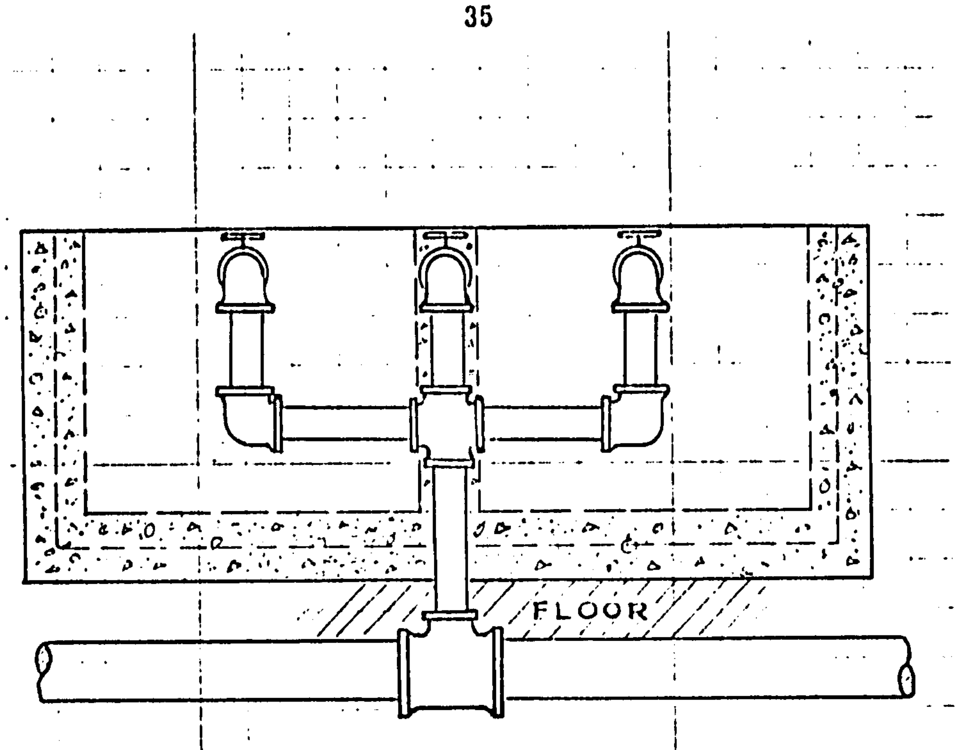
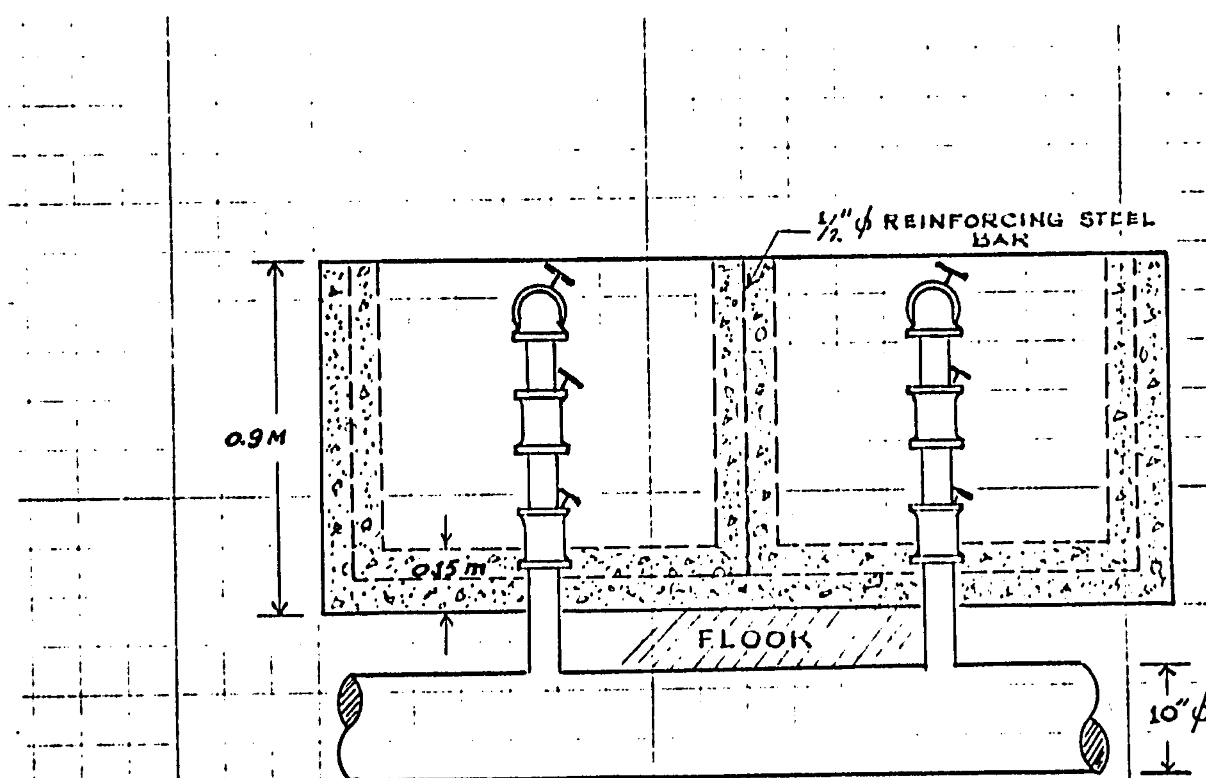
Figure 7e. FISH HATCHING AND HOLDING HOUSE



WATER SUPPLY END ELEVATION
SCALE 5 Cm = 1 m



DRAIN END ELEVATION
SCALE 5 Cm = 1 m

plans prepared by C. Dela Cr

Figure 7f. FISH HATCHING AND HOLDING HOUSE must be available (and secure from pilferage) at the Center. It would be completely unrealistic to have to send to Cartagena for a new tire, battery, fan belt, or spark plugs for a disabled fish transport vehicle loaded with several thousand fingerling fish.

A building incorporating a workshop, garage, storage facilities and an office is provided in four illustrations included as Figure 8.

Field Laboratory

A field laboratory consisting of sub-labs for the fish feed nutritionist and fish parasite and diseases aquaculturists separated if possible by offices of these two specialists to provide isolation of work areas will be required. Thus risk of transmitting diseases from affected fish being treated in the fish parasite and disease laboratory to healthy fish receiving a test ration in the fish feed laboratory is substantially reduced. These laboratories are supplied with adequate water for holding fish in small tanks, troughs or aquariums for extended periods. At least a portion of the building should be air conditioned to protect delicate laboratory equipment as balances, microscopes, analytical meters, and chemical supplies from excessively high humidity and temperature. No plans were developed for this facility as it was apparent from observing existing laboratories located in other areas of Colombia that INDERENA has expertise available for designing laboratory type buildings.

Dormitory Facility

A dormitory facility is required to accommodate visiting biologists and fish culturists during the fish breeding season when work around the clock

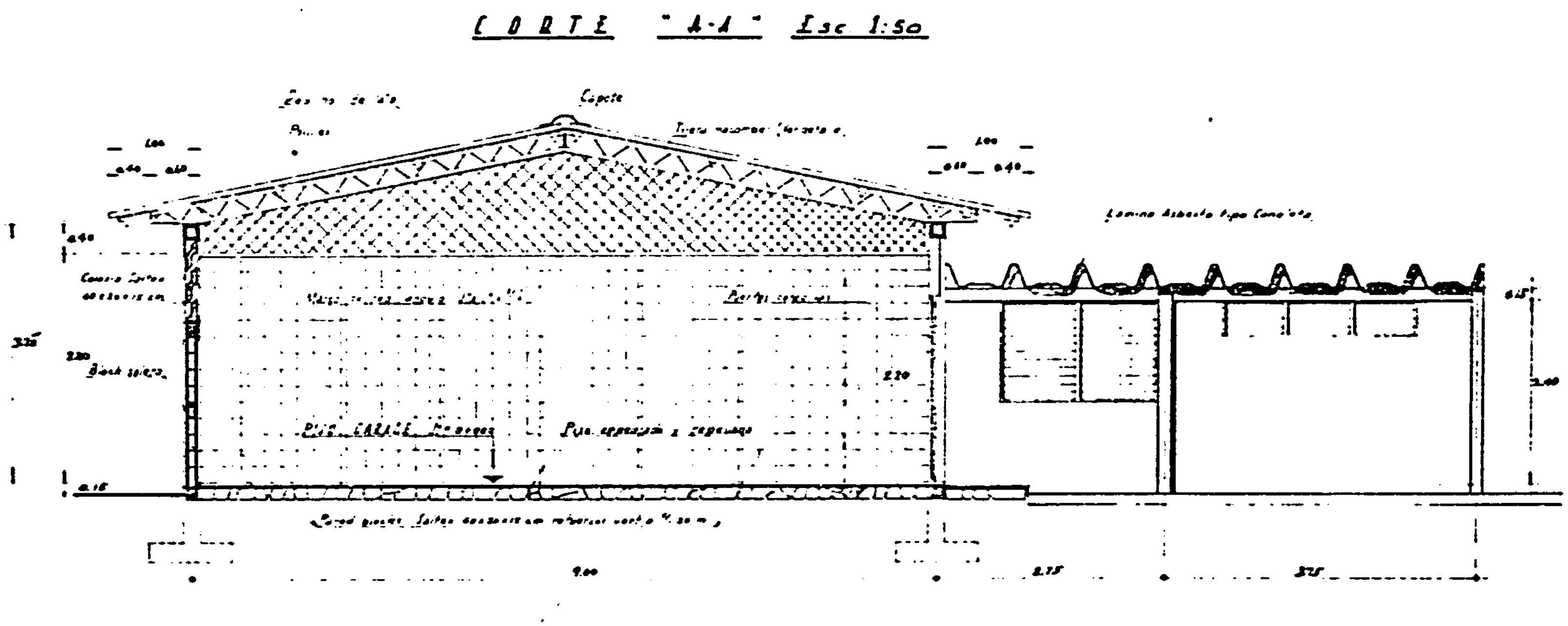


Figure 8a. RIGHT ELEVATION (A) WAREHOUSE, GARAGE AND SHOP BUILDING

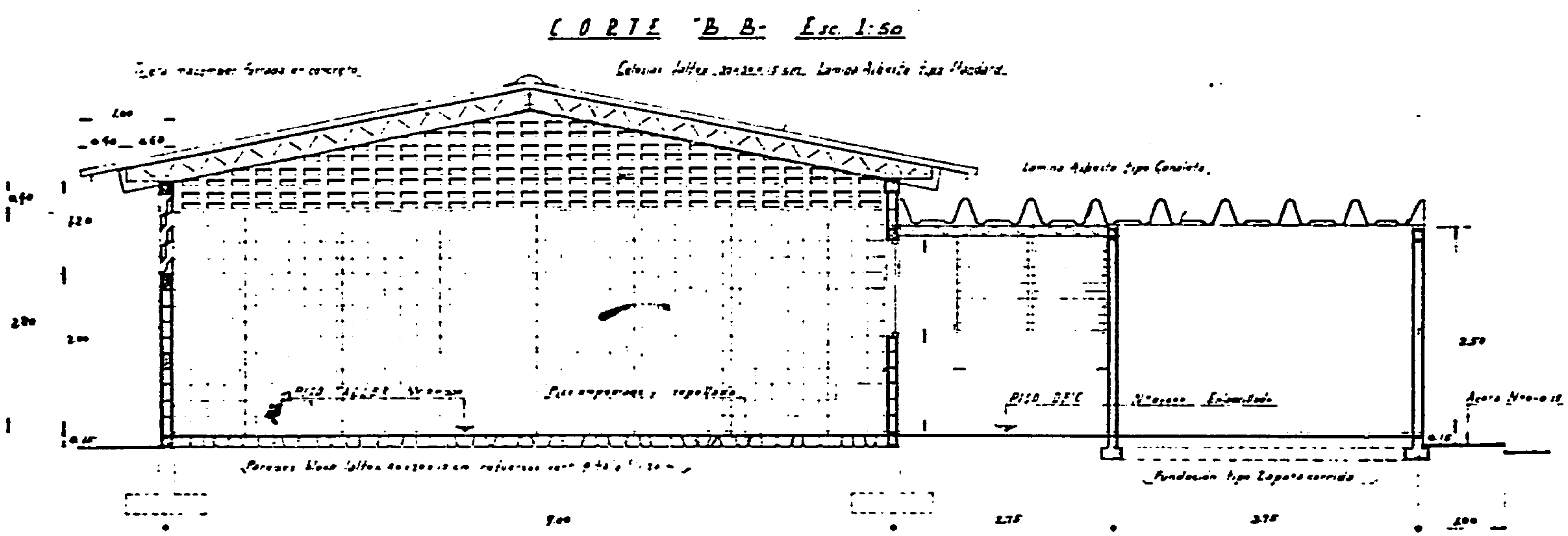


Figure 8b. LEFT ELEVATION (B) OF WAREHOUSE, GARAGE AND SHOP BUILDING

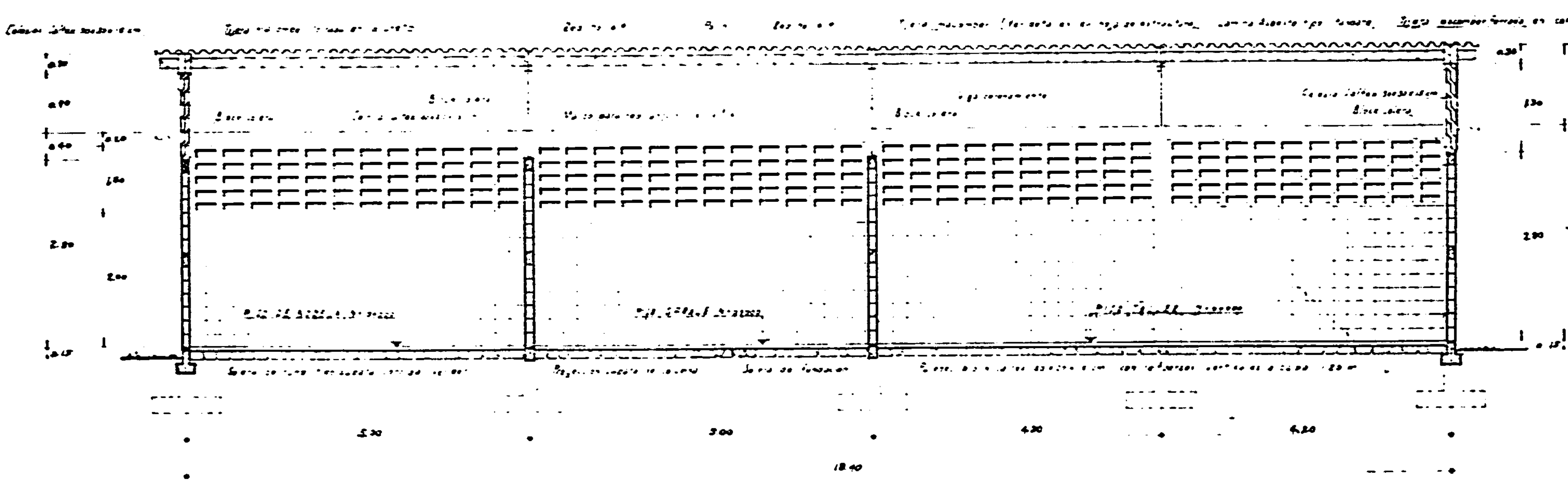


Figure 8c. REAR ELEVATION OF WAREHOUSE, GARAGE AND SHOP BUILDING

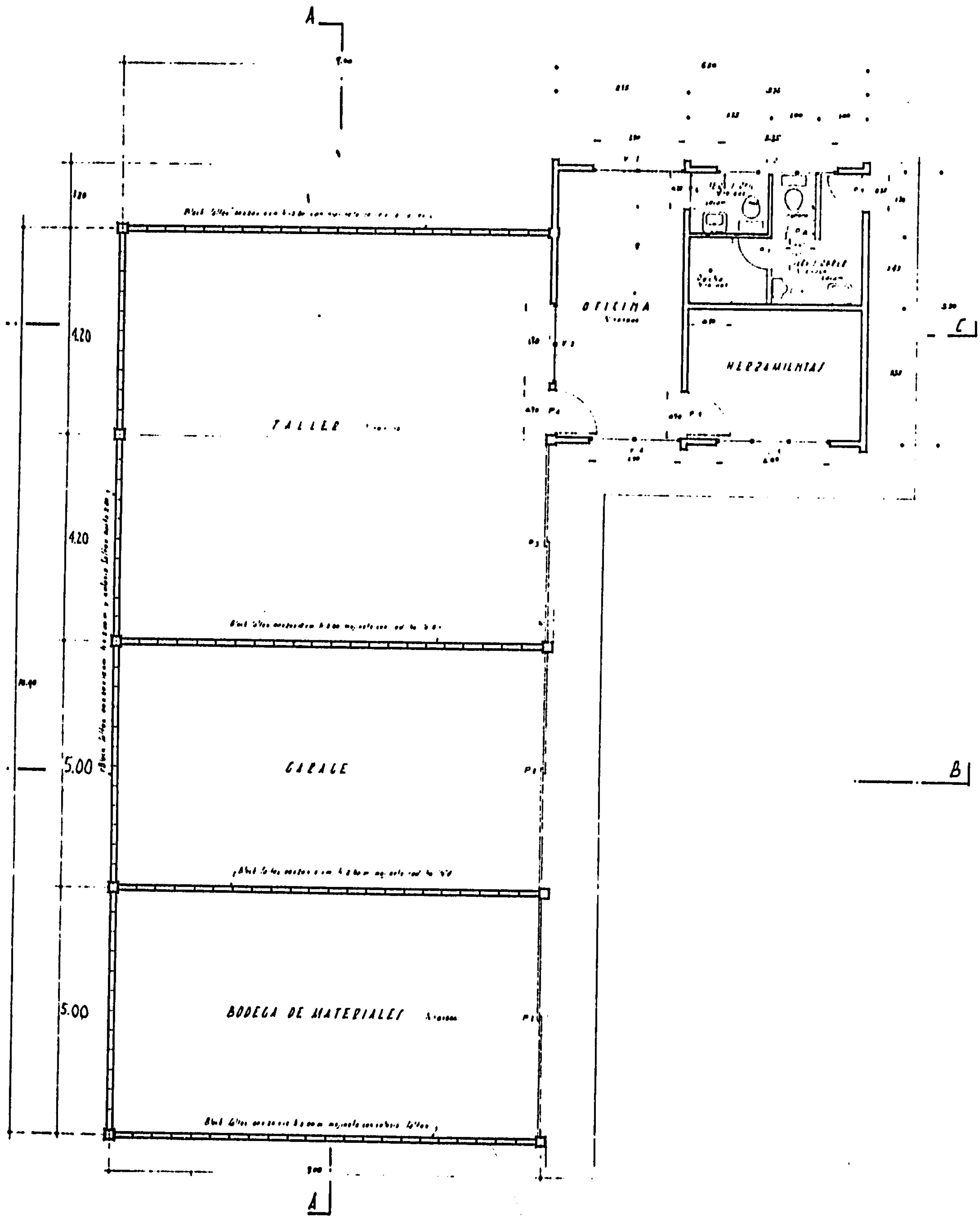


Figure 8d. FLOOR PLAN OF WAREHOUSE, GARAGE AND SHOP BUILDING

for extended periods is required to successfully induce fish to spawn. Sleeping accommodations for six visiting fisheries personnel should be adequate with the appropriate bathroom and kitchen facilities. An additional room for use for lectures and extension programs would not cost much and likely would be extremely useful as the aquaculture program at Repelon develops. Thought should be given for including this facility as the second floor of the field laboratory building as this likely would reduce total cost.

CAPITAL CONSTRUCTION COSTS

Costs for construction of the various components required for the Aquaculture Center can best be estimated by engineers in Colombia who are familiar with costs and availability of construction materials, labor and earth moving equipment.

The greatest single cost item will be for construction of the earthen pond complex. Estimates obtained on earth moving costs while the writer was in Colombia ranged from 9 pesos per cubic meter with a bulldozer and blade to 50 pesos/m^3 for earth moved by bulldozer and pan (25 pesos = U.S. $1.00). Thus, cost of dam construction for one of the 500 m^2 ponds can be calculated as follows:

Linear meters of dam = 20 + 20 + 25 + 25 = 90 meters
Volume of earth contained in one linear meter of dam with a cross-section of 32 m^2 = 32 m^3
Earth required for 90 linear meters of dam = 90 X 32 = 2,880 $m^3 \div \frac{1}{2}$ (dam is shared with adjacent ponds) = 1,440 m^3
1,440 m^3 earth X 50 pesos/m^3 = 72,000 pesos $\div$ 25 = U.S. $2,888.00

Thus, construction of a 500 m^2 pond will require a capital expenditure equivalent to U.S. $ 2,888, and this does not include costs for water supply and drain lines. In comparison to prevailing costs in Alabama, which range from $5,000 to $10,000/ha depending on size of pond, the above cost estimates for Colombia appear inordinately high. This example emphasizes the need for knowledgeable Colombian personnel to prepare accurate cost estimates and phase the construction program of the Aquaculture Center in such a way that INDERENA not only can proceed to develop the Aquaculture Center, but also can properly maintain and effectively operate the facility after it is completed.

The following cost estimates for various components of the Aquaculture Center are based upon prevailing prices in Alabama and should be modified as approprate for Colombia:

Component	U.S. $
Earthen Pond Complex	100,000
Garage-Workshop-Warehouse	20,000
Field Laboratory	25,000
Fish Holding House	25,000
Dormitory	10,000
Concrete Ponds	10,000
Fertilizer and Feed Storage	15,000
Residences, well, gravel for roads, fence	40,000
Total	245,000

It should be emphasized that the design and plans of the various components as given in this report should serve principally as a guide to INDERENA in developing the Aquaculture Center at Repelon. It should not hesitate to modify the design of the various components if this change will enable INDERENA to achieve its goals for a successful program of aquaculture development in Colombia.