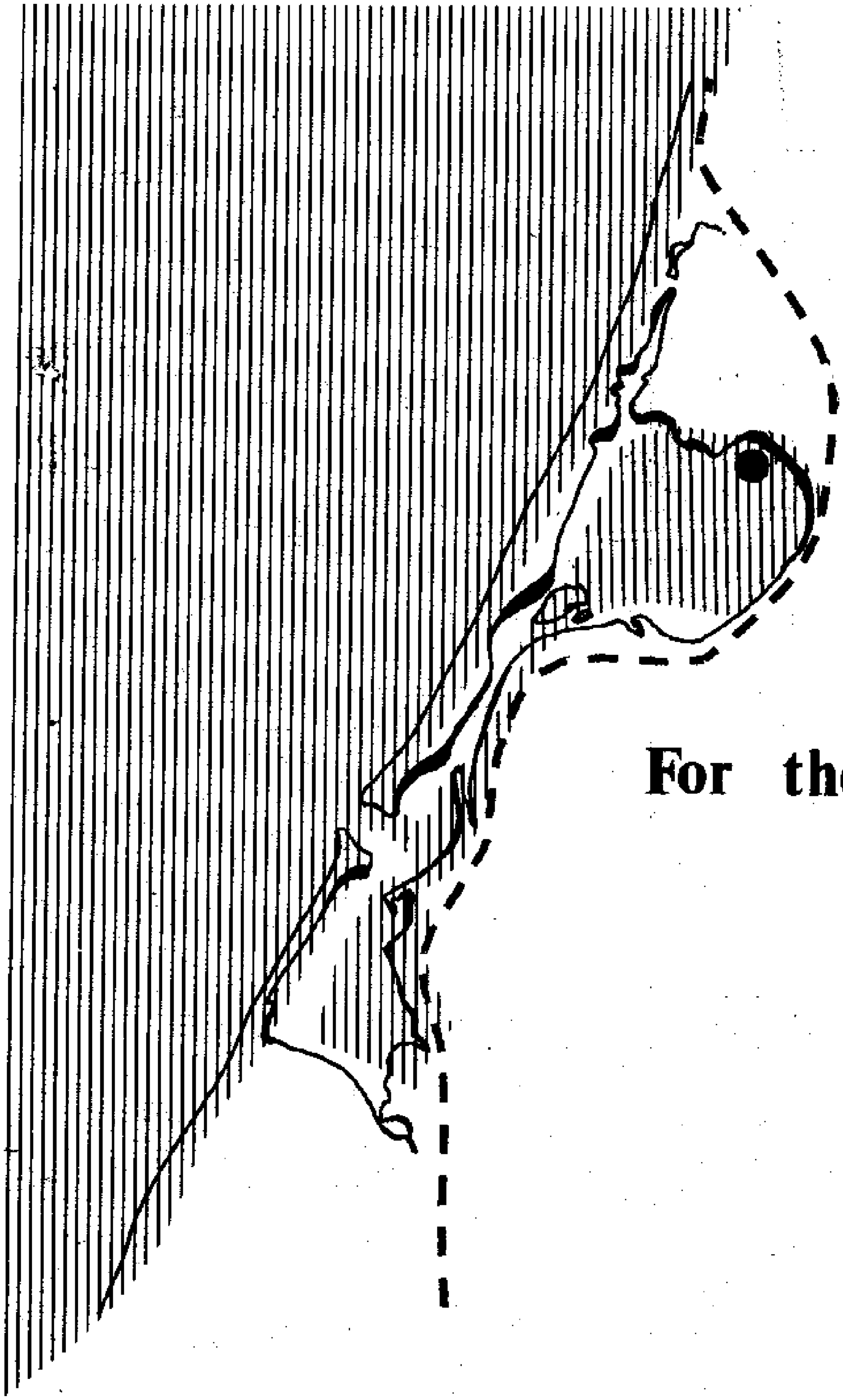

A Pilot Fish Pond System For the Utilization of Sewage Effluents, Humboldt Bay, Northern California

CSUH-SG-3

MARINE ADVISORY EXTENSION SERVICE
SEA GRANT PROGRAM
CALIFORNIA STATE UNIVERSITY,
HUMBOLDT

A PILOT FISH-POND SYSTEM FOR UTILIZATION OF SEWAGE EFFLUENTS, HUMBOLDT BAY, NORTHERN CALIFORNIA

by

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A Pilot Fish-Pond System for Utilization of Sewage Effluents, Humboldt Bay, Northern California

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I. BACKGROUND TO PROJECT

The fertilization of ponds to enhance the growth of fish with waste materials, including human wastes, has an ancient and wide-spread history throughout the world (Allen, 1970). In the United States, the use of waste waters to improve growth of plants on land (pasture, forests, orchards, etc.) has been underway for many years, but only recently has the potential for improving growth of aquatic organisms grown in ponds come under systematic investigation (Ryther, et. al., 1972).

In 1957, the City of Arcata constructed a 55-acre oxidation pond on City lands located on the intertidal mud flats of North Humboldt Bay (Figure 1). This oxidation pond has been of interest to fisheries personnel at the University of Humboldt, and several studies were directed in total or in part as to its potential for aquaculture (DeWitt, 1969; Hansen, 1967; Hazel, 1963). During winter months, when cool air temperatures and fairly high rainfall occur locally, the water in the Arcata oxidation pond has been found non-toxic to chinook salmon fingerlings (Allen and O'Brien, 1967), and the study indicated a pilot fish-culture project was feasible. In October of 1969, the California Wildlife Conservation Board

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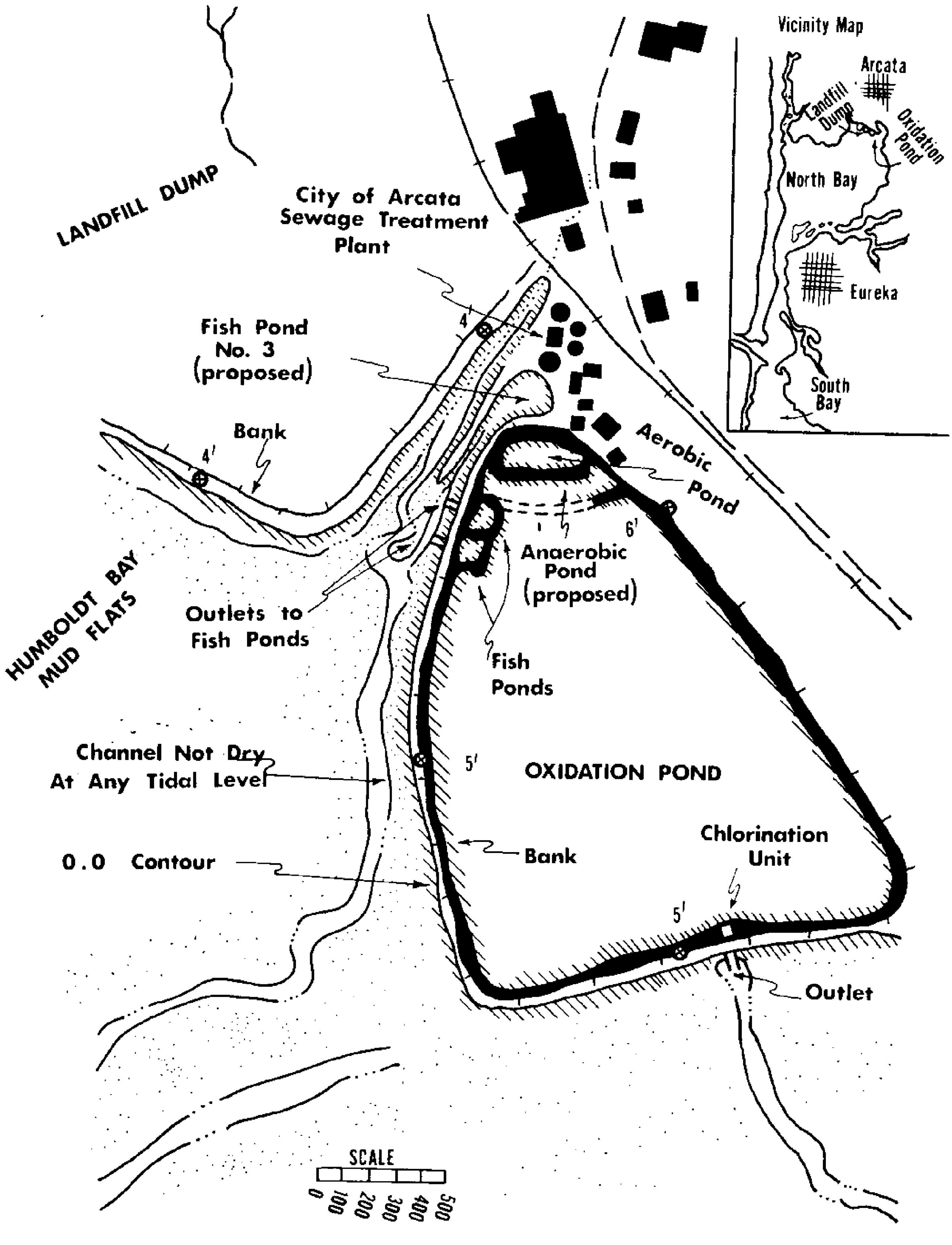
FIGURE 1

Location of Fish Pond System in Humboldt Bay

and

Location of Fish Ponds within City of Arcata Sewage Treatment Facilities


LANDFILL DUMP
City of Arcata
Sewage Treatment
Plant
Fish Pond
No. 3
(proposed)
Bank
Aerobic
Pond
Anaerobic
Pond
(proposed)
HUMBOLDT BAY
MUD FLATS
Outlets to
Fish Ponds
Fish
Ponds
Channel Not Dry
At Any Tidal Level
OXIDATION POND
0.0 Contour
Bank
Chlorination
Unit
Outlet
Vicinity Map
Arcata
Landfill
Dump
Oxidation
Pond
North Bay
Eureka
South
Bay
SCALE
0
100
200
300
400
500

authorized funds to construct two fish ponds to undertake such pilot studies. The City of Arcata granted to California State University, Humboldt, the use of the area for a minimum of ten years for aquaculture purposes. Studies within the system are being conducted with funds provided through the California State University, Humboldt, Coherent Area Sea Grant Program (National Oceanographic and Atmospheric Administration, U. S. Department of Commerce).

The purpose of this paper is to document all out-of-pocket and other real costs in the construction of these two ponds, and to discuss the engineering and construction problems encountered. In addition, ways are suggested to minimize such problems and to reduce the costs for any similar ponds which might be planned in the future either for experimental or production purposes.

The general plan for this pilot project was developed by the senior author. Detailed design and specifications were prepared by the engineering section of the Public Works Department of the City of Arcata.

II. DESCRIPTION OF PROJECT SITE

The Arcata oxidation pond is located on mud flats bayward from the edge of original salt-marshes now greatly reduced in Humboldt Bay by encroachments by man. The banks of this oxidation pond were constructed by a floating dredge that scooped mud from a line located inside the present perimeter of the pond. The dredge channel appears to be about 20 feet wide and from 3-7 feet deep. Dredged bay muds are basically of clay-silt or silt-clay material, and blue-gray in color. Once this mud becomes dehydrated and is compacted, it is extremely impervious to water. Operation of the oxidation pond since 1957 has resulted in the deposition of a layer of black organic material over the original intertidal sediments. Especially large concentrations of organic material accumulated in the dredge channel mentioned above.

On undisturbed intertidal areas adjacent to the oxidation pond, many natural drainage channels sculpture the surface of the mud flats. Such a drainage channel occurs immediately adjacent and parallel to the west bank of the oxidation pond. (Figure 1). The level of the bottom of this drainage channel controls the design and operation of the fish ponds.

The oxidation pond is currently the terminal unit of the waste water treatment system of the City of Arcata. Initially in 1957 the pond represented the major treatment facility. In 1966, the City of Arcata was required by the California North Coastal Regional Water Quality Control Board to increase the degree of treatment to waste waters being discharged into North Humboldt Bay. A major water quality objective of this increased treatment was to eliminate Arcata sewage effluents as a possible source of pathogenic bacterial contamination of commercially-grown oysters located on extensive beds in North Humboldt Bay. Increased treatment, as required in 1966, was met by increasing the amount of clarification, installation of an aeration pond, and by chlorination of final effluent leaving the oxidation pond. An anaerobic unit, (Figure 1) planned for the improved system was deleted when available funds for the system were not sufficient for the entire project. This anaerobic unit is under construction and will be added to the system in the near future.

III. CONSIDERATIONS IN CHOICE OF SITE

The decision to locate the fish ponds within the confines of the oxidation pond was based on both engineering and non-engineering considerations.

Four major engineering considerations supported the site chosen: (1) Part of the wall of the fish pond could be combined with the proposed anaerobic unit planned within the oxidation pond (Figure 1). Originally the fish pond project was to receive savings from use of a common bank. When the anaerobic unit was not built, these costs were assigned to the fish pond project. Eventually the anaerobic unit of the sewage treatment facility will receive the benefit from the use of a common bank. (2) Problems of erosion of pond banks to be expected from southerly wind-generated waves would be less for ponds inside the perimeter than for any ponds located outside the perimeter of the oxidation pond. Outside the perimeter, wave erosion can be severe when accompanied by high tidal levels. (3) Wastewater receiving different degrees of treatment would be available for use in fish pond fertilization experiments by locating near the aerobic-anaerobic units of the sewage treatment system. (4) Further additions to the system could be easily added both to the south of the ponds as sited and outside the oxidation pond, especially in the area identified as Fish Pond No. 3 (Figure 1).

The non-engineering considerations were as follows: (1) The intertidal area where the oxidation pond is located had been converted by the City of Arcata to an alternative public use. Thus a use permit or environmental impact statement was not necessary for the Army Corps of Engineers as would have been the case had we decided to locate the ponds on undisturbed intertidal area. This reduced by one the number of public agencies requiring involvement in the present project. (2) Security of the fish ponds and associated facilities is provided because easy access to the ponds is

mainly through the City of Arcata Corporation Yard which is enclosed by a fence and gate. The gate is locked when employees are not on duty. Both police patrols and maintenance patrols of the oxidation pond area pass directly through the fish culture facility. These were important considerations because fish culture facilities not under good security arrangements generally are subject to considerable vandalism.
(3) Converting part of the oxidation pond to mariculture is an enhancement activity by using land beyond its current primary function of waste water treatment.

An ancillary benefit has been the joining of students and faculty together with City officials and City employees to work on environmental problems of mutual concern and interest. Such development of cooperation and understanding can result in long-term benefits to society at large.

IV. DEVELOPMENT OF COST ESTIMATES

Preliminary cost estimates for material to build banks for the fish pond were developed by the City Engineer. Soundings were made from a skiff along the proposed fish pond bank sites to obtain a rough profile of the oxidation pond bottom. From this survey an estimated cross-sectional area for fish pond banks was developed. As the organic material accumulating on the oxidation pond bottom had approximately the same resistance to surface penetration as the underlying bay muds, it was difficult to ascertain that cross-sectional profiles reflected anything other than the true bottom conditions. Although location of the dredger excavation could be discerned, it was difficult to determine its exact profile. Because of these factors, the estimated volume of fill necessary for pond bank construction, including a 30 percent coverage, eventually proved inadequate, and increased considerably the major item of costs in the system.

Design of headgate and inlet-outlet facilities was developed by the senior author, and preliminary estimates of construction cost were developed by the engineering section of the City of Arcata.

Based on preliminary cost figures, an allotment of $30,000 was authorized by the California Wildlife Conservation Board. Detailed estimates of cost and final plans of the fish pond system were developed to conform to this allotment. Although a contract could have been placed out to bid, we chose instead to negotiate with a prime contractor who was currently engaged in the construction of a joint City-Federal sewage treatment renovation project for the City of Arcata. This project was required of the City by the Regional Water Quality Control Board in 1966 as discussed previously. The apparent advantages to the contract procedure used were as follows: (1) Elimination of administrative costs to the project inherent to formal bid letting. (2) Reduction of construction and administration costs by utilizing the services of the construction administration of the prime contractor. (3) Taking advantage of the on-site availability of the construction forces of the prime contractor thereby eliminating mobilization costs which in turn would provide a savings to the project.

A change order with the prime contractor for construction of fish ponds was negotiated and signed on April 2, 1970.

V. CONSTRUCTION

Although a date of one year was agreed upon between the City of Arcata and the contractor for completion of the work, no provision was made for a mandatory early starting date in order to take advantage of routinely dry weather which occurs locally during the summer months. No difficulty was anticipated in executing the work during the summer dry season. At the time the fish pond work was authorized by contract change order as noted above, the contractor was on, or ahead of, schedule in all phases of the prime contract. Subsequently, however, the city sewage project began to encounter construction delays. This produced, in turn, substantial delay in initiating work on the fish ponds. As a consecuence, no authorization by the prime contractor for a sub-contractor to haul earth fill for fish pond banks was issued until mid-October, 1970.

Fill material utilized in the subcontract for pond banks was a yellow sandy-clay soil (Hookton series). This material, under the weight of loaded trucks, sloughed off into the oxidation pond, especially into the old dredge channel, where it slipped under and displaced the black organic deposit developed from operation of the oxidation pond. Money allocated for this fill dirt became exhausted with only about 80 percent of the pond bank work complete (Table I, material for levee). As the contractor's bid was based on estimated volumes required as provided by the City, the contractor could legally claim any costs for over-runs to complete the job.

Funds for extra fill dirt needed to provide minimal pond banks were generated by: (1) modifying the original plans to eliminate every feature not essential to minimal functioning of the ponds, and (2) making up the shortage of funds not covered above by a cash grant from the Humboldt State University Foundation ($1,000) and the remainder ($500) from operating expenses from the HSU Sea Grant Project. Re-negotiations caused about a three-week delay in obtaining all these necessary funds and approval of changed design certification from the Wildlife Conservation Board. An additional change order with the prime contractor was signed on October 10, 1970. Earth fill was finally completed in late October. In early November, 1970, extremely severe winter storms hit the north coast of California and continued for six weeks. Winds, accompanied by heavy rains, swept in from the south and east, causing serious erosional damage to the unprotected earth banks of the fish ponds. No provisions had been made in the contract for protection of exposed soil by rip-rap or other means as we had assumed that project personnel would have had time to undertake this work prior to the advent of winter weather.

During the stormy period a series of stop-gap measures were taken simply to avoid loss of the work completed. These emergency measures did succeed in saving the levee system although secondary leakage problems did occur as a result of the work done in these salvage efforts. These secondary problems are detailed below.

Personnel and equipment of the City of Arcata placed a concrete rip-rap and gravel cap along the south and north pond banks in early November when the need for such protection became clear. They were prevented from completing the capping along the east banks by the constant rains. Before the severe storms subsided and equipment could again move on to the earth banks, a major portion of the east bank of the south fish pond had been flattened. Again, the City provided men and equipment, with this portion of the pond wall eventually being built with broken concrete material mixed with river-run gravel. This concrete-gravel cap formed a solid layer on which 3/4-ton pickups or a backhoe could ride without any visible signs of additional consolidation. At the level of the water in the oxidation pond at this time, the pond bank showed no leakages of oxidation pond effluent into the fish ponds.

Once the pond banks had become reasonably stabilized, coffer dams were made in preparation for ditching and laying 3-foot diameter tar-lined steel

Table I. Final contract quantities for Humboldt Bay Fish Rearing Facilities constructed by City of Arcata with funds provided by California State Wildlife Conservation Board.

1. Material for levee: [1]		
7,992 cubic yard (CY) at $2.70/CY (pond banks)		$21,578.00
2. Structure, piping and appurtenances:		
36" CMP, 10 Gal., Coated (110 Linear Feet (LF) at $15/LF)	1,650.00	
36# Gate Valve Armco M1001C (2 at $750/gate)	1,500.00	
Str. Exc & B. F. (300 CY at $2.00/CY)	600.00	
Concrete (8 CY at $150/CY) Headgates	1,200.00	
12" AC (70 ft. at $5.92/LF)	414.40	
12" Snow valves (Water works) (2 at $200 each)	400.00	
Iron grills fitted to outlet pipe (2 at $180 each)	360.00	
12" Armco Mdl 150 Turnout Gate (4 at $15.00)	60.00	
Redwood boards (49 at $1.00 each)	49.00	
12" Flange Tee	36.00	
CMP Sections (12" x 8') (3 LF at $10/LF)	30.00	
SUB-TOTAL		6,299.40
3. Engineering, City of Arcata: [2]		1,438.72
4. Total:		29,316.12

[1] This represents a minimal cost as it will require about 250 additional cubic yards of fill to bring the pond banks up to design level. In addition, the cost of rip-rap to face the pond banks is not included. Both the City of Arcata and Humboldt State University are contributing fill dirt free to complete these banks, as well as contributing personnel and machinery for levelling and distributing fill.

[2] Other *in lieu* costs furnished by City of Arcata divided into appropriate categories in Table II.

pipes at inlet sites. No detail of pond bottom profile was provided at the preliminary design stage. The designer therefore provided an outfall elevation based on hydraulic and maintenance considerations only. The exact level of placement of these pipes represented an extremely critical decision for the success of the system. An on-site inspection by the senior author during the installation of the 36-inch outfall pipes indicated that an adjustment in pipe elevations would have to be made to fit field conditions. A field check was made by the resident engineer to determine as nearly as possible the lowest elevation the outfall pipes could be set. The southerly most installation had to be removed and the pipe bed subexcavated to fit the field elevations. Excavation for the northerly outfall installation then proceeded at the revised elevation. It was subsequently determined that the outfall of the south pond could have been lowered an additional 10 inches. This would have eliminated a considerable amount of labor subsequently needed to insure complete drainage of this pond.

Although installation of valves to outlet pipes could have allowed early drainage of the ponds, such draining was impossible because of delay in completing outlet ditches to the tidal channel west of the ponds. Ditching was completed finally using dynamite charges. This was done about the same time the aerobic pond unit of the Arcata sewage treatment facility (which was one of the final phases in the prime contract of the City's sewage treatment improvement project) was placed into operation (Figure 1). At this time, the water level of the oxidation pond had to be placed about a foot higher than original planning had indicated. This raising of the water level in the oxidation pond, coupled with the subsequent draining of the water of the fish pond, created a head difference that immediately produced serious leaks within the east wall of the south pond, particularly in that area previously damaged by winter storms (Point A, Figures 2 and 3).

The series of dynamic interactions at this point are somewhat complicated. Presentation of this detail seems in order to avoid similar problems in any future construction where such a situation could seriously hamper completion of the job due to a ceiling on available funds.

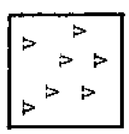
First, we had based our top elevation for the pond banks to be built with imported borrow material on water surface elevations originally provided in contract plans used in building the oxidation pond. This design elevation for water level in the oxidation pond was 3.2 feet, while the actual functional water surface elevation produced by the severe winter storm conditions varied around 4.5 feet elevation, with a peak elevation of 4.7 feet. The top elevation for the fish pond bank was set at 5.0 feet. We would have preferred a 6.0 - 6.5 foot elevation but this was impossible when over-runs in fill appeared inevitable during pond bank construction as previously noted. This 5.0 foot elevation appeared adequate during early construction when the oxidation pond was being operated at a 3.2 foot design level. When the oxidation pond was raised to an operating level of 4.5 feet, additional storms then raised the oxidation pond to its high water level of 4.7 feet. At this time the fish-pond bank elevation of 5.0 feet proved too low, so that over-topping and serious erosion resulted. The sandy clay of the Hookton Series proved relatively impermeable and would have been entirely adequate had we been able to construct all fish-pond banks at the elevation of the oxidation pond bank (6.7 feet), and had we incorporated funds for slope protection in our initial design and cost estimates.

The added load from rock, concrete and gravel placed during storm damage repair caused further settlement, lowering the top elevation of the fish-pond banks to 4.0 - 4.5 feet in some places. The total effect was to

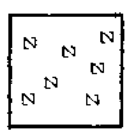
FIGURE 2

Plan view of completed fish ponds with details of pond substrates and associated structures

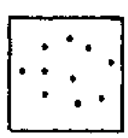
LEGEND FOR SUBSTRATE TYPES



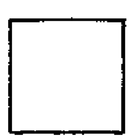
Oyster Shell



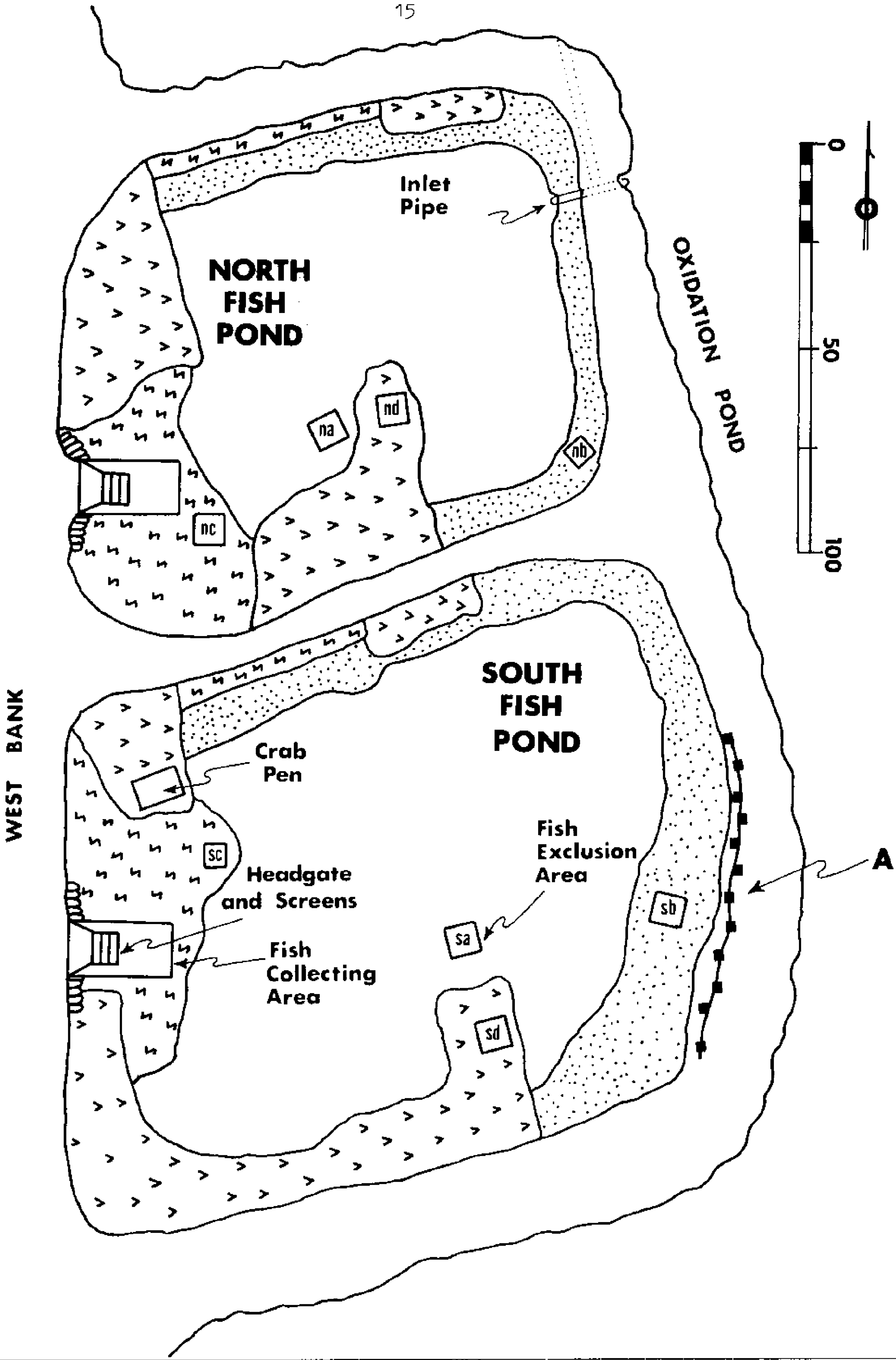
River-run gravel and sand



Hookton-series soil



Bay mud overlain with organic matter


Inlet
Pipe
NORTH
FISH
POND
na
nb
nc
nd
OXIDATION POND
0
50
100
WEST BANK
SOUTH
FISH
POND
Crab
Pen
sc
Headgate
and Screens
Fish
Collecting
Area
Fish
Exclusion
Area
sa
sb
sd
A

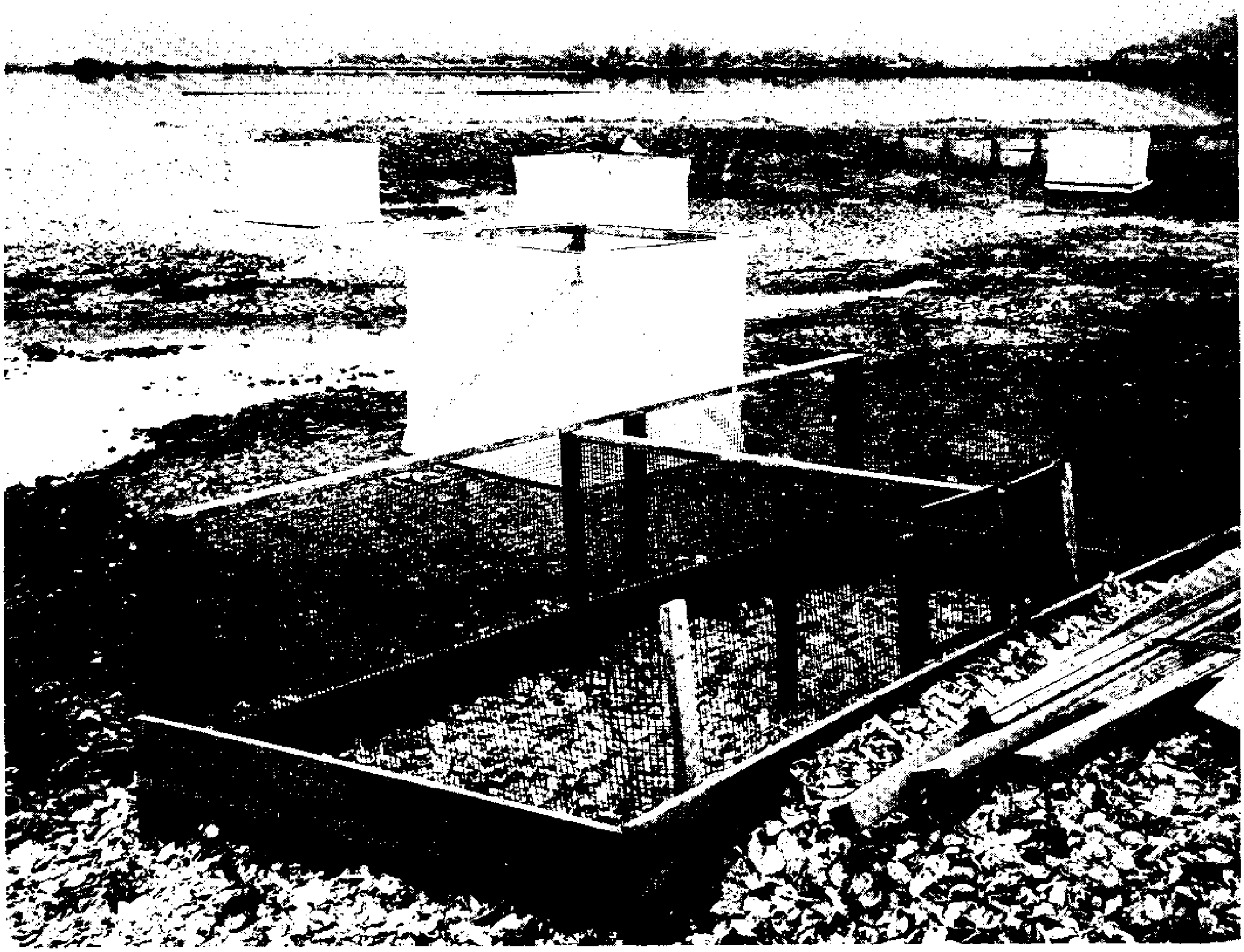


FIGURE 3. Photograph of South Pond showing pen for studying crabs in foreground, fish exclusion pens on four substrate types and plywood retaining wall in background corresponding to Point A, Figure 2.

produce a contact between the river run gravel and the sandy clay Hookton soil at or below the storm water runoff high water pond surface elevation of about 4.5 feet. The major seepage problem of the east wall of the south fish pond occurred on this highly permeable contact as mentioned previously.

Plans provided for the installation of a 6-inch pipe with two valves and a T-joint for future connections to the anaerobic pond at the northeastern corner of the south fish pond (Figure 1). This should have been a relatively simple operation. A sufficiently large clay plug (6 feet) was to be left on the oxidation side of the installation to prevent leakage along the pipe. Although this was done, a wedge of river run gravel intersected the pipe and washed rock inside the clay plug. Water from the oxidation pond migrated along this wedge resulting in heavy leakage into the fish ponds along the inlet pipe. Three excavations, plus two cement collars, were required to reduce this major leakage to a seep.

When the ponds finally could be drained to the level of the outlet pipes, it was evident that dredging and filling of the pond bottom had to be undertaken to produce complete drainage. This work was not budgeted under Wildlife Board funds so that operating expenses associated with research under the Humboldt State University Coherent Area Sea Grant Project were used to complete this work. In addition, considerable donated hand labor was involved. The bulk of material was moved by hiring a large mobile drag-line which completed three jobs: (1) Removal of pond muds along west side of ponds to insure sloping to outlet site. (This material provided additional surface area to locate trailer for field laboratory, storage shed, and area for holding tanks to be used for marking of salmon and trout prior to release). (2) Removal of accumulation of mud in corners of ponds and placed into old dredge channel which was holding water at a level lower than that of the outlet pipe. (This problem was particularly evident in the south fish pond. Sufficient excess material was available to build up this bottom. Part of the need for this fill was a result of not placing the outlet pipe to its maximum possible depth as discussed previously). (3) Removal of mud to about one foot depth in a 20 x 20 foot area immediately in front of the headgates for a fish collecting area (Figure 2). (This area was filled with large river run gravel and framed with 2" x 4" timbers and plywood. This area is the lowest point in each pond. Most of the mud removed here was stock piled and eventually used to reinforce weak pond banks).

Considerable effort was expended in attempting to stop the heavy leaks and seepages along the west wall of the south fish pond. This involved student hand labor, erection of a retaining wall at the worst break, and much backhoe work in excavating several trenches which were filled with clay-silt materials. This work finally reduced leakage to a number of small seeps.

An important item in capital construction was an original project decision to cover portions of the pond bottom and sides of the pond with oyster shell and gravel substrates. Oyster shell had been moved to storage areas in Arcata during the summer of 1970. This material was donated by the local oyster industry, but had to be transported to Arcata from Eureka. This material was selected for its possible use in providing calcium to the pond water and to provide an increased surface area for organic production and benthic fish food organisms. The shell also helped fill low spots in the pond bottom as well as to provide good control of erosion on pond banks wherever placed. Gravel was placed on the pond bottom in late April. Shell was put in place in early May as a joint City, College, and student work party.

During June and July, 1971, final modifications were completed. These included installation of screens into headgates which was complicated by the insufficient size of slots in the headgate (1¼ inches from a design size of 2 inches). These slots should have been 3 inches wide. Cement-filled bags were used to provide protection against slumping of pond banks next to the headgates, to provide access to the water for water sampling and as a place to anchor floating pens (live cars) for bioassay of pond waters. Electric power outlets and recirculating water pumps were also installed during this period. Fish collecting areas in front of the headgates, started early in the year, were finally completed during the June-July period.

In late July, 1971, the ponds were flooded and the first experimental plants of fish made in the system.

VI. <u>COSTS</u>

Out-of-pocket and real costs of this pilot project could be assigned to three categories: (1) capital construction funds provided by the California Wildlife Conservation Board (Table I), plus a minor capitol supplement from other sources, (2) operations and equipment funds provided by the Coherent Area Sea Grant Project used to modify basic pond into adequate experimental fish rearing facility (Table II), and (3) donated labor, equipment and services computed at equivalent dollar value rates used in private enterprises (Table II). Cost of pond banks, headgate structure, and associated water inlet and outlet units was $31,500 with major cost being the hauling of fill dirt for the pond banks ($21,600) The completed headgate structures with concrete work, piping, valves and trash screen was the second largest item (about $5,000) (Table II). The

Table II. Final real and in lieu quantities for Humboldt Bay Fish Rearing Facilities constructed by Humboldt State University with funds provided by HSU Coherent Area Sea Grant Project and other sources.

Item	Source of Support		Cost due to
	Sea Grant	Other	Storm Damage
1. Fish Pond Bottom Shaping and Substrate Modification			
Oyster shell transport costs	750.00	0	0
Oyster shell placement			
May 8 HSU Bldg. and Grds. Students ($527)			
City of Arcata, equip. and labor ($418)	0	945.00	0
May 22 HSU faculty and students	0	245.00	0
Dredging, commercial unit	1,294.00	0	0
Backhoe rental (leakage repair)	713.00	0	713.00
River-run gravel substrate and site preparation	758.00	0	0
Lumber	75.00	0	0
Food for work parties	59.00	0	0
City of Arcata, equipment, labor and materials to restore east pond banks	0	3,375.00	3,375.00
TOTAL	3,649.00	4,565.00	4,088.00
2. Construction Labor			
Actual salaries and wages Sea Grant funds assignable to pond construction (all work averages about $2.00/hr.)	1,500.00	0	358.00
Added real value of student Sea Grant work if contracted privately ($7.50/hr. average cost for carpenters, electricians plumbers, etc.)[1]	0	3,000.00	0
Donated student labor (computed as above)	0	1,500.00	0
City of Arcata, equipment and labor	0	900.00	0
Project director	0	2,500.00	500.00
TOTAL	1,500.00	7,900.00	858.00

[1] Recent hourly wage rates have been at least double their figure, consequently value-added figures here are probably conservative.

Table II (Continued)

Item	Source of Support Sea Grant	Other	Cost due to Storm Damage
3. Utilities (electricity and water)			
Ditching for utilities	255.00	0	0
Electrical installation (220 and 110V)	1,190.00	0	0
PVC water line	150.00	0	0
Extra 220V line	140.00	0	0
TOTAL	1,735.00	0	0
4. Portable Pumping System			
Barnes 220V trash pump	413.00	0	0
Electric motor	250.00	0	0
Trailer for pump and motor	109.00	0	0
Hose (4" diameter)	510.00	0	0
TOTAL	1,282.00	0	0
5. Water Aerating and Circulating System			
Jet pumps (2); used cost $35.00 market value - new $350.00	35.00	315.00	0
Pipe fittings, adapters to modify for ponds	96.00	0	0
TOTAL	131.00	315.00	0
6. Screens and Headgate Modifications			
Stainless steel screen plates	680.00	0	0
Angle iron and contract labor	475.00	0	0
TOTAL	1,155.00	0	0
TOTALS Items 1 through 6	9,452.00	12,780.00	4,946.00
TOTAL Sea Grant Support and Other		22,232.00	

out-of-pocket cost to make the ponds a functional study unit for fish culture was $8,700. Among a number of items in this cost, dredging and electrical installations by private contractors were the major expenses (Table II). The amount of labor, equipment, and services donated to the project, equated to equivalent cost if completed by private enterprise, amounted to about $13,000 (Table II). The total real worth of the functional fish pond units was estimated to be at least $53,000 of which about 25 per cent was donated (in lieu) value (Table III). About $5,000 (ten percent) of the total costs of the project could be attributed to storm damage (Table II).

VII. RECOMMENDATIONS

In any future construction of such facilities within the Arcata oxidation pond or any similar intertidal habitat, we recommend the following:

1. Hookton series soil would be adequate for making banks, although a clay fill, preferably intertidal clays or silts would be preferable if costs comparable to land soil were available.
2. Require some type of protective layer (plastic, rubble, etc.) be placed on any bank immediately after placement, with any erosion from wave action resulting from delay in bank protection to be the responsibility of the contractor.
3. All elevations critical to the function of the installation should be reviewed with the project designer during the preliminary design stage. If it is not physically possible to determine at that time, a note should be provided: "Adjust in field to fit tidal channel elevations, or whatever other physical feature is controlling."
4. Due to size and complexity of the prime contract in this study, the

Table III. Summary of estimated total real costs to construct two experimental marine fish ponds of about hectare total surface area on intertidal mud flats of Humboldt Bay inside the perimeter of a sewage oxidation pond.

Source of Value	Kind of Value	
	Dollars	Dollar Equivalent
California Wildlife Board Grant	30,000.00	
Deficiency Grant	1,500.00	
HSU Coherent Area Project, Sea Grant Program	9,452.00	
City of Arcata, HSU student and faculty		12,780.00
Sub-total:	40,952.00	12,780.00
Total Real Cost of Project:	53,732.00	

tendency of the contractor was to relegate the fish pond project to a secondary function. Future projects of this magnitude should be constructed under formal contract procedures with the project director as the responsible authority for the contracting agency. This procedure will provide direct and absolute control of all phases of the project. If future projects can be designed so that construction can proceed in phases, each of which costs less than the minimum necessitating a formal contract, it would be advisable to consider an equipment rental or service agreement method of construction. This would allow greater flexibility in producing a desired result by having the project director in control.

5. The final positioning of inlet-outlet pipes should be determined empirically. This would mean that any outlet ditches should be the first item constructed so that actual field conditions will control the final level of the outlet pipe, not elevations on any construction plans.
6. Require a construction timetable which begins in the spring to avoid winter rains which make operations around clays and muds virtually impossible. Such a schedule would allow pond bottoms to dry out during summer so they could then be worked with small power machinery.
7. Considerable benefit could result from development of a master plan for the oxidation pond and adjoining area. With an approved plan, any future projects requiring banks or dikes could use donated or inexpensive waste materials in their construction, thus reducing costs tremendously.
8. A plan should be developed to stock pile waste materials (e.g., concrete and paving rubble from repair or removal of streets and buildings) so

that rip-rap is available for emergencies.

9. Investigate the possibility of using broken concrete, rock, or other small rubble inside automobile tires as a possible method of bank and jetty construction or as a method for bank protection.

VIII. LITERATURE CITED

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