GEO-HEAT CENTER

FEASIBILITY STUDY FOR AQUACULTURE
AND SPACE HEATING

FT. BIDWELL, CALIFORNIA

October 1985

OREGON INSTITUTE OF TECHNOLOGY
A Geothermally Heated Campus
KLAMATH FALLS, OREGON 97601

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By: Gene Culver
Associate Director
Geo-Heat Center

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FEASIBILITY STUDY FOR AQUACULTURE
AND SPACE HEATING
FT. BIDWELL, CALIFORNIA

SUMMARY

Expansion of the aquaculture facilities and geothermal space heating at Ft. Bidwell, California were investigated. The lack of cold water is the limiting factor for aquaculture expansion and is also a problem for the town domestic water supply. A new cold water well approximately 1200 feet deep would provide for the aquaculture expansion and additional domestic water. A 2900 foot test well can be completed to provide additional hot water at approximately 200°F and an estimated artesian flow of 500 gpm. If these wells are completed, the aquaculture facility could be expanded to produce 6000 two pound catfish per month on a continuous basis and provide space heating of at least 20 homes. The design provided allows for heating 11 homes initially with possible future expansion.

BACKGROUND

The Indians at the Ft. Bidwell Reservation have been developing their geothermal resource for some time. Current development includes space heating for several tribal buildings, housing and a small aquaculture experimental project. The aquaculture

experiment (raising catfish) has been successful and they are interested in expanding that facility, which is currently restricted by a limited supply of both hot and cold water.

Recently, a test well was drilled on a bench overlooking the aquaculture facility and approximately 250 feet higher in elevation. The test well is 2917 feet deep with a bottom hole temperature of 211°F. The well is cased to 300 feet with 16 inch diameter casing, open hole 6 3/4 inch diameter to 2400 feet and 6 1/4 inch diameter to 2917 feet. In its current condition the well has a shut in pressure of 42 psi and flows 387 gpm at 205°F when the control valve is fully open. It is estimated by the tribe's hydrogeological consultant, David Lawrence, that when properly completed the well will produce 500 gpm of artesian flow at at least 205°F. TDS is 1010 (see Appendix A for water analysis).

The experimental catfish facility consists of two fiberglass raceways each 25 feet long, eight feet wide and four feet deep. The raceways are recessed in the ground to a depth of approximately 3 feet. The FB#2 well, about 60 feet away, can supply up to 800 gpm at 97°F. This is mixed with cold water from Venning Creek to provide the correct temperature. During last winter's operation the two raceways required 350 gpm at 97°F to maintain the preferred raceway temperature of 80°F. Most of the heat is lost in an open ditch supplying water from the well and the splash arrangement at the heads of the raceways

which are required to de-gas and oxygenate the water. At the 350 gpm flow, 3.6 water changes per hour are obtained for flushing.

Last fall (1984) the raceways were stocked with 3,000 fingerlings each. Approximately half of these had grown to two pounds by early summer and were sold. The rest were equally divided between the two tanks to continue grow out. Mortality rate has been exceedingly low with only five fish known to have been lost.

During the early summer the flow of geothermal water was restricted to about 150 gpm since only 40 to 60 gpm of cold water was available from Venning Creek. The creek water at times reaches 67°F and in August the flow had stopped completely. In order to continue the catfish operation a ditch was dug to divert part of the flow of Soldier Creek to the catfish operation. This was supplemented by additional amounts of water from the town domestic water storage tank when available. The approximately 200 gpm available this summer provided only two changes per hour for flushing, but since stocking rates were low this apparently has not had a detrimental effect on the catfish. The recommended flushing rate is four changes per hour at maximum stocking rates of 3000 fish per raceway.

The Indians have requested technical assistance from both the California Energy Commission and the Geo-Heat Center's USDOE program for the utilization of the hot water. They are interested in expanding the aquaculture facility in order to provide jobs, possibly generating power using a binary system, and heating of homes near the aquaculture facility. The CEC has approved spending approximately \$1400 for this study with the remainder to come from the Center's USDOE contract.

WELLS

In order to expand the use of their hot water resource, the Indians must complete their test well as a production well and, for power generation and/or aquaculture use, obtain an increased supply of cold water.

During drilling of the test well a lost circulation zone was encountered at 1007 feet which was very difficult to shut off. The consultant estimates that a well drilled nearby to a depth of 1000 to 1100 feet would produce 2000 gpm at 55°F. Static water level is expected to be at or near ground surface and pumping level for 2000 gpm at about 100 feet. Estimated cost of completing a cold water well is about \$60,000.

Completion of the test well as a production well will require reaming to the maximum diameter possible through the existing 16 inch casing to a depth well below the cold water lost circulation zone - probably about 1200 feet - setting and

• cementing 12 inch casing to case off the cold water, then reaming nominal 12 inch to total depth and setting and gravel packing eight inch casing perforated at production zones. Although it appears that the lost circulation zone has been controlled, the driller should be prepared to handle a major lost circulation problem at about 1000 feet during the first reaming operation. Estimated cost for completion of the well to 2920 feet is \$180,000.

For applications requiring lesser flow rates, i.e. space heating a few homes, the well may be made serviceable by only reaming and installing the 12 inch casing to case off the cold water and leaving it open hole below. This is not quite as simple as it sounds since it entails a new mud pit, mobilization, performing the reaming, setting and cementing casing, and cleaning out of open hole portion to total depth.

Ft. Bidwell lies at the north end of the Surprise Valley geothermal system, and on the intersection of the Surprise Valley fault and several northwest trending faults (along Soldier, Ft. Bidwell and Venning Creeks). Water from previous warm wells at Ft. Bidwell indicated mixing of hot geothermal water with cooler surface bicarbonate type waters. The test well, Ft. Bidwell #3, has water very close in chemical nature to the hotter waters near Lake City and further south but indicates some mixing is still occurring.

Appendix A contains a trilinear plot and geothermometry for waters at Ft. Bidwell and the Magma well taken from Lawrence's drilling report for the test well FB#3.

Geothermometry applied to the FB#3 water analysis gives temperatures ranging from 266°F to 312°F. This is in good agreement with temperatures of 320°F obtained in a 4948 foot deep Magma well (Phipps #2) approximately 13 miles south near Lake City. The Magma well and Ft. Bidwell wells are located on the same fault system but this well is the strongest evidence thus far that similar temperatures possibly could be obtained at Ft. Bidwell. The test well, FB#3, has an almost isothermal gradient near the bottom but this is to be expected in a flowing aquifer. Maximum temperature in Phipps #2 was reported at 160°C (320°F) at 3800 feet, approximately 1000 feet deeper than FB#3.

Although it does not appear to be prudent to deepen the test well at this time, it should be completed so as to allow re-entry at some future time if economic conditions of power generation are improved.

BINARY POWER GENERATION

If the well were fully completed as above and produced 500 gpm at 205° to 208°F, a binary machine could produce 260 kW net power. However, since the machine would be operating at low efficiency it would have a high capital cost relative to its output. Total estimated capital costs for installing a binary system are:

Completion of well to existing depth	\$170,000
260 kW binary machine (Barber Nichols)	450,000
Well head and piping	10,000
Site improvements	10,000
Switch gear	100,000
Cold water well and pump	<u>75,000</u>
TOTAL	\$815,000

Ft. Bidwell is in the Surprise Valley Electric service area. Surprise Valley Electric purchases BPA power through Pacific Power and Light. Their current PURPA rate through 1988 is 3.13 c/kWh. Assuming 85% availability and operating and maintenance costs of 10% of the binary machine, the 260 kW machine would produce 1,935,960 kW/year for a net income of only \$15,402. Simple payback is 53 years.

However, if in the future, power could be sold at 6 cents and a temperature of 300°F with comparable flow could be obtained, 825 kW could be produced. This would generate a gross income of

over \$368,000 and the economic picture would be drastically changed.

Before the decision to drill significantly deeper is made, more information about the Magma and other wells should be obtained (if possible) and compared to the test well. This should include correlation of lithology, depth and temperature of aquifers, and water chemistry. Much of this information is proprietary but Magma may be willing to share it if properly approached.

COLD WATER SUPPLY

As noted earlier the existing aquaculture facility had a limited supply of cold water last summer. Also the town supply is somewhat limited at times.

In order to fully utilize for aquaculture the 500 gpm at 205°F expected from the test well when completed will require approximately 2000 gpm at 55°F. Happily, this is exactly the flow and temperature estimated by Dave Lawrence to be available from a new cold well near the test well site.

Most of the existing domestic water supply system for the town was installed in the mid 1800's by the US Army. Cold water is collected from several springs at the head of Soldier Creek approximately two miles up the mountain from town and one and a

half miles from the new water tank. The spring boxes, if any, have been covered and grown over with brush and trees. When looked at now it appears that steel pipes protrude from the undisturbed mountain side. Water originally collected in cisterns at the springs now feeds directly into the old four inch steel pipe running down the mountain to the tank. Recently, a new closed tank and chlorinator were installed and the old cisterns were abandoned.

Although it may be possible, using modern equipment, to develop the springs and increase the flow, it would certainly be less than the amount needed. Although there are still surface seeps, they amount to perhaps 50 gpm at the headwaters and the total flow of Soldier Creek near town was estimated at one fourth to one third cubic feet/second or 100 to 150 gpm in August.

Proposals for collecting spring water at the head of Venning Creek in the next canyon, diverting it to Soldier Creek via approximately one and a half miles of pipes and ditches, around and down the ridge to combine the two flows have been submitted to the Tribal Council. The springs at the head of Venning Creek feed several small ponds and appear to flow considerably more than those on Soldier Creek, but during summer the water percolates into the ground before it reaches the lowlands. Although full development of all the springs, capturing and combining the water before it percolates into the ground would greatly increase available water, it probably would still be less than the required 2000 gpm and entail considerable expense.

It appears that a new cold water well is the only way of obtaining the required cold water supply.

AQUACULTURE EXPANSION

As noted earlier, a source of approximately 2000 gpm of water at about 55°F will be required to fully utilize the existing FB#2 and FB#3 hot wells for aquaculture. It appears that drilling a new cold water well is the only way to obtain that amount of cold water. If 2000 gpm can be obtained from a new cold water well the community will have approximately 3180 gpm (allowing 120 gpm at 200°F for space heating) of 82.9°F water available for aquaculture. The flow rate and temperature can be adjusted to suit climactic factors by changing flows of one or more wells.

Since the raceway flow rate requirement changes not with the number of fish, but with the total pounds of fish stocked in each raceway, stocking at intervals can increase the number of raceways and the number of fish in growout. A two pond raceway stocked with 6000-7000 fingerlings can get by on 100 gpm, while the same 6000-7000 fish near two pounds each will require 450 gpm.

To maintain 90°F water flowing into the raceways will require 380 gpm at 200°F plus 800 gpm at 97°F plus 1400 gpm at 55°F, for a total of 2580 gpm. This flow will maintain nine raceways of two ponds each if fingerlings are stocked at 30 day intervals. Stocking could be as shown on Table 1:

Table 1

Days Since Stocking	Raceway #	Fish/ Raceway	Flowrate
0-fingerlings	1	6,000	120 gpm
30	2	6,000	140 gpm
60	3	6,000	170 gpm
90	4	6,000	220 gpm
120	5	6,000	280 gpm
150	6	6,000	340 gpm
180	7	6,000	400 gpm
210	8	6,000	450 gpm
240	9	<u>6,000</u>	<u>450 gpm</u>
		54,000	2,570 gpm

When one raceway is harvested, it would be cleaned and a new batch of fingerlings stocked. This provides for marketing 6000 fish every month on a continuing basis. Gross income, assuming two pound fish at marketing and \$1.15 per pound, equals \$13,800 per month.

Raceway construction would be ground excavation with concrete head, mid and tail dams. This construction, fully detailed in a short report (Appendix B) to the Tribal Community by Klamath Consulting Services Inc. is simple, inexpensive, follows good practices used in other locations and can be accomplished using community labor and equipment. The natural slope of the present site will provide for most of the required drop between ponds in

the raceways. Outflow water can be used for flood or sprinkler irrigation during summer. Adequate ditches must be available to handle the flow during winter to discharge into Upper Lake.

At the projected flow rates there should be adequate dilution of hot water with cold water to preclude any problems with salt buildup in soil from irrigation or excessive mineral content for discharge to the lake. Permits must be obtained for discharge. Total discharge will amount to approximately 4000 acre feet per year with perhaps one third of this being utilized for irrigation.

The system proposed would consist of:

1. A new cold well sized to accept a 12 inch line shaft turbine pump set at approximately 130 feet.
2. A 60 hp pump capable of producing at least 1400 gpm at 120 feet total head. If the well has excess capacity, a larger pump could be installed to supplement the existing domestic water supply.
3. A buried steel pipeline consisting of a six inch line from FB#3 and a 10 inch line from the new cold well connecting at a Y between the wells. From the Y, 10 inch line running approximately 1800 feet down the hill to the aquaculture facility. Nominal flow would be 1780 gpm at 85°F, but would change depending on weather.

4. A pressure reducer valve to reduce the pressure due to elevation difference to approximately 20 psi.
5. A pressure relief valve.
6. Approximately 250 feet of 12 inch buried PVC line from the pressure reducer valve along the top end of the raceways. This line would have nine risers, one at each raceway. This line and risers will be standard buried irrigation main line construction.
7. Approximately 280 feet of buried six inch PVC line from FB#2 paralleling the 12 inch line. This line will also have nine risers and be standard irrigation construction.
8. Each riser will have an elbow, manual four inch gate valve, and short section of pipe extending over the splash board of the raceways (see Fig. 1).
9. Nine raceways with two ponds each as described in the report from Klamath Consulting Services Inc.

An option to the above would be to install an automatic mixing valve to maintain a selected temperature and a manual gate valve to control flow rate into each raceway. Each mixing valve will

Cross Section Through Raceway and Piping

FIGURE 1

cost approximately \$5000, adding a significant amount to the capital cost and present a potential source of maintenance problems. It is recommended that manual control valves be used - at least initially.

Estimated costs for the system are:

Completion of FB#3	\$170,000
Cold water well	60,000
12 inch pump and column	9,100
Pump electrical panel & starter	1,500
50 feet of 6 inch steel pipe	230
50 feet of 10 inch steel pipe	376
10 in x 6 in x 10 in steel Y	200
1800 feet 10 in steel pipe	13,536
Pressure reducer valve	1,800
Pressure relief safety valve	1,200
250 feet 12 in PVC pipe	1,750
280 feet 6 in PVC pipe	616
Nine 12 x 4 in risers	585
Nine 6 x 4 in risers	496
18 4 in gate valves	1,080
One 6 in gate valve	304
One 10 in gate valve	748
Two 6 in PVC ells	32
One 12 in PVC ell	128
Misc. flanges & fittings	<u>600</u>
Total Materials	\$264,281
Labor (inc. trench, backfill, pipe laying, etc)	<u>9,000</u>
TOTAL	\$273,281

Note that the above estimate does not include costs for constructing the raceways. As noted above, much of this can be done by Indian community labor using community equipment.

SPACE HEATING

In addition to possible expansion of the aquaculture facility, the community has requested assistance in assessing the feasibility of heating the eleven homes nearby. Seven of the homes are now heated with electric forced air furnaces and four with electric baseboard units.

The seven homes with forced air will be relatively easy to retrofit requiring a new fan coil installed in the main duct either ahead of or just behind the resistance heaters, and a relatively simple heat exchanger/circulating loop to isolate the heating system from the geothermal water (see Figure 2).

Because of the low total heat load and open system design, individual heat exchangers are utilized rather than a central heat exchanger serving all the homes.

The four baseboard heated homes are the older homes in the study area. Plans for these homes were not readily available and detailed inspections were not made, therefore retrofit costs were not estimated. These homes do have adequate crawl space and could be retrofitted by adding either forced air (preferred) or hydronic baseboard heat.

Estimated Costs for Forced Air Retrofit

1 ea. fan coil 2 row 10 fin/inch	\$ 240
1 ea. tube & shell heat exchanger	420
1 ea. circulator pump 7 gpm 12 psi	265
1 ea. expansion tank	38
1 ea. domestic hot water tank	560

Forced Air Retrofit Schematic

FIGURE 2

1 ea. system controller	230
3 ea. solenoid valves 3/4" @ 76.00	228
2 ea. PB to pipe adapter @ 18.00	36
1 ea. pressure relief valve	16
1 ea. air vent	14
1 ea. pressure reducer	43
1 ea. check valve	14
1 ea. main shut off valve	14
misc. pipe, fittings & electrical	<u>45</u>
Materials total	\$2,163
Labor	<u>500</u>
GRAND TOTAL	\$2,663

Geothermal water for space heating will be supplied from FB#3. The wellhead currently has two three inch kill valves installed and these should be retained or a similar arrangement installed during completion of the well. Figure 3 shows the proposed piping systems for both heating and aquaculture.

From the kill valves a buried three inch non-insulated fiberglass reinforced epoxy (FRP) pipe will run down the hill to a point near the four upper homes to a pressure reducing valve set at approximately 35 psi on the discharge side. From the valve, the three inch FRP line will continue to the intersection of the driveway to the homes and the main road along the hill. At the intersection, two inch polybutylene lines will tee off north and south. The south line will run along the road 1185 feet to the last home and the north line 415 feet to the last home in that direction. The four homes on the hill will be supplied by a two inch polybutylene line teed in just below the pressure reducing lines. From the two inch lines, one inch polybutylene will go to the homes and back to the ditch along the road for discharge.

Piping Layout

FIGURE 3

During peak heating load, flow requirement is 6.8 gpm for the newer four bedroom homes and 5.9 gpm for the three bedroom homes. Electrical cost savings will be approximately \$1000 per year for the four bedroom homes and \$950 for the three bedroom homes.

Both the FRP and polybutylene piping must be bedded and back filled with sand or soil to prevent rupture by rocks. Both piping systems can be assembled outside the trench eliminating the requirements for wide trenches. The FRP lines are joined by epoxy resins and polybutylene by heat fusion or compression fittings.

Estimated costs for the piping system are:

1300 ft. 3" FRP @ 6.60/ft.	\$ 8,580
2100 ft. 2" PB @ 2.64/ft.	5,544
Approx. 1700 ft. 1" PB @ .78/ft.	1,329
Pressure reducing valve 3" flanges	550
2 ea. FRP tees @ 34.00	68
3 ea. FRP flanges @ 30.00	90
11 PB 2x2x1 reducing tees @ 6.00	66
21 ea. 2" PB couplings @ 2.60	55
17 ea. 1" couplings @ 1.50	26
Materials total	<u>\$16,308</u>
1300 ft. trench in rock (FRP line)	\$ 2,500
1300 ft. backfill with soil and tamp FRP line	2,080
3000 ft. trench & backfill (PB lines)	2,650
Installation 2 men six days	<u>2,400</u>
Materials total	\$ 9,630
Subtotal	25,938
Engineering & contingencies	<u>4,000</u>
TOTAL	\$29,938

/cc

10/85

APPENDIX A

ENVIRONMENTAL LABORATORY
2218 RAILROAD AVENUE, P.O. BOX 2088
REDDING, CA 96001—TELEPHONE (916) 243-5831

REF. NO. 12736

DATE 7/16/85

PAGE 1 OF 2

Physical
Chemical &
Bacteriological
Analysis

ANALYSIS

REPORT TO LAWRENCE & ASSOC.
1730 South St. Suite C
Redding, CA. 96001

ATTN: Dave Lawrence PHONE: _____

SAMPLE DESCRIPTION Fort Bidwell FB-3 Sample #1 SAMPLED BY: D. Lawrence

DATE OF SAMPLE 6/20/85 DATE RECEIVED 7/3/85

MAJOR CATIONS	milligrams per liter	milli-equivalents per liter	TRACE ELEMENTS	milligrams per liter	OTHER	milligrams per liter
Calcium (Ca)	14.0	0.70	Arsenic (As)		Phenolphthalein Alkalinity (CaCO ₃)	
Magnesium (Mg)	<0.05	<0.01	Barium (Ba)			
Potassium (K)	8.55	0.22	Cadmium (Cd)		Methyl Orange (total) Alkalinity (CaCO ₃)	
Sodium (Na)	326	14.18	Chromium (Cr) total			
			Copper (Cu)		Total Hardness (CaCO ₃)	
			Fluoride (F)	9.60	pH (units)	
total milli-equivalents per liter		15.1	Iron (Fe)		Electrical Conductivity (micromhos/cm @ 25°C)	1537
			Lead (Pb)			
MAJOR ANIONS			Manganese (Mn)		Turbidity (NTU)	
			Mercury (Hg)		Color (units)	
Bicarbonate (HCO ₃)	184	3.02	Selenium (Se)		Odor (units)	
Carbonate (CO ₃)			Silver (Ag)		Total Dissolved Solids	1010
Chloride (Cl)	203	5.72	Zinc (Zn)		MBAS	
Nitrate (NO ₃)			Silica	138	PESTICIDES	
Phosphate (PO ₄)			Boron	3.47	Endrin	
Sulfate (SO ₄)	370	7.70			Lindane	
					Methoxychlor	
			BACTERIA	MPN/100 ml	Toxaphene	
total milli-equivalents per liter		16.4	Total Coliform		2-4-D	
			Fecal Coliform		2-4-5-TP Silvex	

COMMENTS: _____

All analyses by EPA or State of California recommended methods, unless otherwise noted

State Approved Water Laboratory for Chemical, Bacteriological, and Bioassay Examinations

REPORTED BY:

The information shown on this sheet is test data only and no analysis or interpretation is intended or implied

Form 121

Legend

- 1 FB-3 (sampled 6-30-85)
- 2 FB-3 (Sampled 6-20-85)
- 3 FB-2
- 4 FB-1
- 5 Fort Bidwell Hot Spring
- 6 Well 46N/R16E-31R1
- 7 Magma Energy Well

Figure 9 - Trilinear Graph of Water Quality

APPENDIX B

KLAMATH CONSULTING SERVICE, Inc.

JOAN F. RIKER AA, BS; President
JOSEPH T. RIKER III, PhD
WILLIAM C. JOHNSON, BS
& ASSOCIATES

5127 Highway 39
Klamath Falls, Oregon 97601
Telephone (503) 884-3884

Environmental
Aquacultural
Agricultural
Nutritional
Biological

FORT BIDWELL INDIAN RESERVATION FISH CULTURE FACILITY NEEDS

AQUACULTURE RACEWAY PONDS

It is recommended for this pilot project that raceway ponds be simply constructed by ground excavation to the required conformation and controlled by concrete dam formations. The attached drawings show two parallel raceways composed of two 24 foot ponds each. If finances are not adequate for construction of the dual system, one two-pond set up could be used.

Pond Design

Recommended water volume per pond for catfish cultivation is 960 ~~674~~ feet (approximately 7,182 gallons)(U.S.D.A.-S.C.S "Catfish farming in Idaho"). This is based on a cement pond 4' x 10' x 24'. Converting this to an excavated facility with sloped sides and only a 3' water depth (for ease in harvesting and maintenance) the demensions become 24' long by 11.8' wide at the bottom, 14.8' wide at a 3 foot water level, and 15.8' wide one foot above the water level. This provides the stipulated 960 cubic feet of water: $((14.8 + 11.8)/2) \times 3 \times 24$. Actual width measurements can vary somewhat in the earthen construction, but side slope should be 1:2. It is recommended that the 24-foot length be met, as it would facilitate later conversion to cement structures.

For each raceway there would be three cement dams to contain the water and to control flow. The head construction would be a solid dam, approximately 8 inches thick, extending 18-24 inches beyond the sides of the pond to prevent washout, and 2 feet below the bottom of the pond. Any extension above the top of the pond sidewall is optional, but some type of back board should extend upward to help contain the inflow.

Two items would need to be included at this head dam: 1) A corrugated piece of material on which the incoming water can splash to allow oxygen saturation and to dissipate any unwanted dissolved gasses such as hydrogen sulfide or ammonia. This should be set to allow the water to fall about 2 feet before striking it and another 1-2 feet before entering the raceway. 2) Because aeration is so vitally important in providing adequate dissolved oxygen levels, it is recommended that a permantly placed aeration pipe be included at construction. This is simply a piece of standard plastic pipe with slits cut in it, capped and attached to the dam parallel to the bottom of the pond and approximately 6-8 inches above the bottom. The pipe should then be elbowed and extended to an accessable distance above the water level. If aeration is needed compressed air can be delivered to the bottom of the pond through this configuration.

The mid and lower dams would be of similar construction (8" thick, extending beyond the sides and bottoms of the adjacent pond(s)). However, both the mid dam and the lower dam would have a 4 foot wide opening reaching to the bottom of the pond it is containing. On either side of these openings should be attached (bolted to the concrete) 2-inch channel iron. Into these slots can be fitted 2" x 6" x 4' redwood flash boards. These will control the depth of the water in the ponds and at what level the outflow will be drawn from. They also allow ease in draining and cleaning of the ponds. Immediately in front of these there should be installed a fine mesh screen to prevent fish passage from one pond to another.

Down-flow from the last dam should be some type of catch basin channeling the water into the pipe leading to diffusion in the pasture (again, PVC pipe slotted to distribute the water over an extended area).

If possible it is recommended that there be a 3' drop between the upper pond and the lower pond to allow for additional aeration of the water. This also provides sufficient drop to allow water to be drawn from below the surface of the upper pond to increase water circulation. No aeration is required at the bottom dam, so the catch basin need only be at a level to allow complete drainage of the channel (for cleaning and maintenance).

Water Supply

For maximum production of catfish it is recommended that there be a minimum flow of 1 cubic foot per second (450 gpm) of 85-90 degree water for each raceway (S.C.S.). This volume would provide complete flushing 4 times per hour at maximum fish capacity. However, in this pilot project it is felt that this maximum level need not be met. A reasonable production can be obtained with a minimum flow of 100 gallons per minute (.22 cfs) per raceway.

The geothermal water will need to be mixed with cold water to obtain a temperature of about 90 degrees at the initial inflow into the ponds. Both flow and temperature will need to be adjustable throughout the season to provide the best growing habitat for the fish. This is influenced by the weather, by the BOD level of the ponds, by the amount and size of the stock present, and etc.

Each raceway would require its own temperature-flow control, and it is suggested that an extra valve be kept available for immediate replacement of a problem valve. Several types of these valves are available, including a gas operated model run by ammonia.

If either the hot or the cold water has to be pumped to be supplied for the raceways, some type of back-up system should also be available.

Inflow piping should be threaded, not glued together, as they sometimes have to be dismantled. They can be black iron or threaded PVC; "Schedule 80 PVC" is recommended.

The drain piping/difuser system should have a diameter of at least 8".

BUILDING FACILITY

There needs to be available at the raceway site a building to provide storage for food and equipment, and in which to keep continuing records of the system. At a minimum it would need to be 10'x12' with one window and be supplied with: a restaurant sink at least 12" deep, hot and cold running water, and a 1-1/2 " drainage; space heat (geothermal with thermostat?); electric overlights and 3 120-volt wall-plugs; and a concrete floor with a drain. It should also have available some type of desk and chair.

It is possible that California law requires some type of laboratory facility, if so, this may also have to be given consideration.

RACEWAY PONDS TOP VIEW

RACEWAY PONDS SIDE VIEW

Approximate
SCALE 1" = 2'

RACEWAY PONDS FRONT VIEW

WIDTHS CAN BE VARIED somewhat

Approximate
SCALE

1" = 2'

RACEWAY PONDS TOP DAM FRONT VIEW

WATER SOURCE

Backboard of some type

Corrigated splash board to
Aerate water

at least 3
foot, preferably 4
foot drop to
allow good
aeration

POND

CONCRETE

1" pvc pipe scored to form aeration pipe to be anchored against
dam $\pm 8"$ above bottom of pond and capped above edge
of dam so that compressed air may be pumped into
raceway to add O_2 at times of Low DO.

RACEWAY PONDS FLASH BOARD DAM FRONT VIEW

MID & BOTTOM DAM

2" channel now bolted to concrete

8" thick concrete
Extending
2' below
pond and
1 1/2' to
either side

DAM at MIDPOINT would have
to be deeper (23') to accommodate
drop, but dam design is same for mid + bottom dams.