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77 Grove Street
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MASTER

WASTE HEAT UTILIZATION

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NUCLEAR POWER PLANT WASTE HEAT UTILIZATION

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*Including its successor, the U.S. Department of Energy (DOE). During this study the U.S. ERDA was incorporated into the U.S. DOE. Because the study was begun under ERDA sponsorship however, and to avoid confusion that otherwise may occur, the DOE-ERDA transition is avoided and reference is made to only ERDA sponsorship throughout.

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PREFACE

This report is a summary of results of work sponsored by the U.S. ERDA under Contract No. EY-76-C-02-2869.M001 having the principal objective of investigating the practical possibilities of using Vermont Yankee power plant waste heat for aquaculture enhancement. The report necessarily includes the results of a corollary effort sponsored by the U.S. EPA under Grant No. R804715-01-1. This grant had similar objectives with regard to the enhancement of commercial horticulture using Vermont Yankee waste heat. Since the two projects are interdependent by virtue of mutual support facilities (piping, pumps, service buildings, etc.), the two projects were combined into an integrated system concept which is described herein.

The Vermont Yankee Nuclear Power Corporation believes the recommendations of this report, representing completion of the conceptual design phase, can be satisfactorily implemented without infringing upon plant electrical generating capabilities. The Corporation therefore plans to make available company-owned sites suitable for the construction of the three complexes described. Further, the Corporation plans to make available main condenser discharge water in amounts up to plant capacity at no cost to waste heat endeavors, provided such endeavors in no way inhibit electrical generating capabilities. Finally, the Corporation plans to make available suitable personnel to serve as project coordinators between plant operations and waste heat utilization programs and experiments. The Corporation looks forward to making significant contributions to energy conservation efforts, the Atlantic salmon restoration program, and development of improved means for concentrated, closed-cycle fish farming.

ABSTRACT

The possibility of using Vermont Yankee condenser effluent for commercial food growth enhancement was examined. It was concluded that for the Vermont Yankee Nuclear Station, commercial success, both for horticulture and aquaculture endeavors, could not be assured without additional research in both areas. This is due primarily to two problems. First, the particularly low heat quality of our condenser discharge, being nominally $72 \pm 2^{\circ}\text{F}$; and second, to the capital intensive support systems. The capital needed for the support systems include costs of pumps, piping and controls to move the heated water to growing facilities and the costs of large, efficient heat exchangers that may be necessary to avoid regulatory difficulties due to the 1958 Delaney Amendment to the U.S. Food, Drug and Cosmetics Act.

Recommendations for further work include construction of a permanent aquaculture research laboratory and a test greenhouse complex based on a unique greenhouse, designed by Cornell University staff, wherein a variety of heating configurations would be installed and tested. One greenhouse would be heated with biogas from an adjacent anaerobic digester thermally boosted during winter months by Vermont Yankee condenser effluent.

The aquaculture laboratory would initially be dedicated to the Atlantic salmon restoration program. It appears possible to raise fingerling salmon to smolt size within 7 months using water warmed to about 60°F . The growth rate by this technique is increased by a factor of 2 to 3.

A system concept has been developed which includes an aqua-laboratory, producing 25,000 salmon smolt annually, a 4-unit greenhouse test horticulture complex and an 18,000 square foot commercial fish-rearing facility producing 100,000 pounds of wet fish (brook trout) per year. The aqualab and horticulture test complex would form the initial phase of construction. The trout-rearing facility would be delayed pending results of laboratory studies confirming its commercial viability.

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CHAPTER 1

SUMMARY

1. INTRODUCTION

Early in the evolution of our current concerns over the diminishing availability of primary energy sources, the role of conservation was recognized as a major component in any practical long-term energy program. Besides population control, discovery and recovery of additional sources of fossil fuels, and the development of new "alternative" energy conversion schemes, there is the potential of improving efficiencies of the overall thermal balance of heat machines in use today so that more work is obtained from the energy consumed.

In the case of large electrical generating stations, whether nuclear or fossil, more than 50 percent of the total energy input is lost in the conversion of heat to electricity. Ideas of how to recover this energy have ranged from the design of ancillary heat engines operating in temperature regimes between exhaust gases or condenser effluent and adjacent cooling ponds and rivers to using the reject heat for melting snow and ice in nearby communities. Most of these ideas, for the present at least, can be discarded for fairly obvious practical reasons. Carnot cycle heat engines might be possible but, except for so called combined cycle systems operated in conjunction with machines having relatively high exhaust gas temperatures, their massive dimensions require such large capital investments as to make the energy they recover uneconomical.

On the other hand, direct utilization of "waste heat" for enhanced food production or biological stimulation seems worthy of careful assessment. The work reported herein is a result of an initial examination into benefits derivable from large quantities of water heated to a nominal $72 \pm 2^{\circ}\text{F}$ by the Vermont Yankee Nuclear Power Station.

1.1 Station Description

The Vermont Yankee Nuclear Power Station is located on the west shore of the Connecticut River immediately upstream of the Vernon Hydroelectric Station, in the town Vernon, Vermont. The Vermont Yankee power facility occupies about one hundred and twenty-five acres bounded by privately owned land to the north, south, and west by the Connecticut River to the east.

●

●

1.2 Project Objectives

The objectives of the Vermont Yankee waste heat study included examination and identification of Vermont Yankee operating and environmental conditions that could affect the success of commercial aquaculture and horticulture thermally optimized during winter months using Vermont Yankee main condenser discharge water. In pursuit of these objectives, we undertook an investigation of the impact of 1958 Delaney Amendment* to the U.S. Food, Drug and Cosmetics Act (FDCA), selected plant and animal species having good potential for commercial aquaculture and horticulture, and developed and analyzed a system concept integrating both horticulture and aquaculture endeavors with the necessary support facilities.

2. SYSTEM CONCEPT

The Vermont Yankee waste heat concept includes three major components: the aquaculture facilities, the horticulture facilities, and the mutual system support facilities (pumps, heat exchangers, control systems, protective buildings, etc.). Figure 1.2 is a simplified sketch of these three components and Figure 1.3 is a fluid balance diagram for the integrated system.

Figure 1.2 Sketch of Vermont Yankee Waste Heat Utilization Concept

*This law prohibits any carcinogens in food additives.

Figure 1.3 Fluid Flow Balance Diagram

2.1 Aquaculture

The aquaculture component includes a commercial fish-rearing facility consisting of eight enclosed raceways each twelve feet wide by eighty feet long. The facility is designed for the annual production of about one-hundred-thousand pounds of live brook trout. The fish would be stocked in early October at four inches in length to be reared at a constant 55°F until June of the following year when they will be harvested at a length of about nine inches.

Besides the commercial trout aquaculture facility, the aquaculture system component includes construction and long-term operation of a research facility dedicated to resolution of fundamental problems of intensive, closed-cycle fish farming. A plan view of the aquaculture laboratory is shown in Figure 1.4. The design includes nine circular rearing tanks each with 250 square feet of surface area and eight smaller tanks providing a research area for one-thousand fish.

Figure 1.4 Plan View of Aqualab

Water supplied to these tanks will be in continuous circular motion and maintained at a temperature of about 60°F. The initial task of this facility is to produce approximately 25 thousand Atlantic salmon from fingerling size to smolt size between the months of September and April of the following year. This would be in support of efforts to restore Atlantic salmon to the Connecticut River. The long range purpose of the laboratory, however, would be to generally address problems associated with intensive closed-cycle aquaculture.

2.2 Horticulture

The horticulture component consists of four special greenhouses designed by Cornell University staff. A cross-section diagram of the greenhouse is shown in Figure 1.5. Each of the four greenhouses would be heated in a different way so that cost comparisons can be developed. Figure 1.6 illustrates the four heating methods envisioned.

A unique feature of the horticulture component is incorporation of an anaerobic digester, converting manure from an adjacent 220 animal dairy farm to biogas and concentrated fertilizer. Calculations indicate that sufficient manure is available from this source to adequately heat one of the experimental greenhouses solely by burning

Figure 1.5 Cornell Greenhouse

Figure 1.6 Greenhouse Heating Methods

biogas in conventional gas heaters. The digester itself would be enhanced by the use of Vermont Yankee condenser effluent to preheat the manure slurry. Theoretical results indicate that this method could increase gas production by 40 percent or more during winter months.

3. RESULTS

3.1 Legal Restrictions

A detailed examination of the implications of the 1958 Delaney Amendment to the Federal Food, Drug and Cosmetics Act has been performed (see Appendix A). This investigation concludes that "since the use of nuclear power plant waste heat for aquaculture and horticulture is very recent, there is little law which directly establishes standards applicable to the Vermont Yankee waste heat project. The requirements affecting the project are chiefly case-by-case permanent requirements of the Environmental Protection Agency and the Nuclear Regulatory Commission" . . . "The precise application of the Food, Drug and Cosmetics Act (FDCA) depends largely upon whether heat exchanger systems are used, and if they are not, upon the probability that the circulating water will contain potentially unhealthy substances. If heat exchangers are used, as is generally contemplated, the FDCA will not apply unless food accidentally becomes contaminated with poisonous or deleterious substances. If heat exchangers are not used, the Delaney Clause setting zero tolerance levels for carcinogens will still not be implicated to the extent that contamination is not to be expected, despite the fact that Vernon is a nuclear station; but a regulation may be required for certain chemicals or pipe residues contained in the cooling water. The FDCA also is implicated if particular food produced at the project becomes contaminated so as to present a health hazard."

3.2 Aquaculture Results

An economic model was developed for the operation of a commercial trout farm raising approximately 100-thousand pounds of live weight fish per year. Initial results (Appendix E) indicate that profit cannot be made on today's market from this facility due primarily to the high capital costs involved (principally the costs of heat exchangers and support facilities). In recognition that the heat exchangers as now contemplated may not be required, and to take advantage of scaling effects and other economies, the facility was enlarged by a factor of 3, considered to be operated without heat exchangers, and constructed as economically as possible (Appendix E'). An analysis of the economics of such a facility with construction costs (1977 dollars) as shown in Table 1.1 and estimated operation and maintenance costs as shown in Table 1.2 suggests a net

profit, on the 1977 market, at between 10 and 20 thousand dollars per year. Included in this profit is utilization of the facilities for the production of bait fish during the summer and fall months and the stocking of fingerling trout at five-and-one-half inches for growth to pan-size during winter months. These adjustments, however, may not be biologically justifiable. Therefore, generally speaking, we have concluded that the commercial success of a trout fish farm utilizing Vermont Yankee waste heat cannot be assured on today's market. In the years ahead the situation may become more favorable.

TABLE 1.1
NEW COSTS
(Single, 8-Raceway Unit)

Support Systems	\$431,650	
Commercial Trout-Rearing:		
Building Shell	98,750	vice 450,000
Mechanical	133,000	
Raceways	31,500	vice 138,000
Electrical	10,500	
Furnishings	30,000	
Vehicles	12,500	
HVAC		
Ventilation only	3,000	vice 12,000
	<u>\$319,250</u>	
Subtotal	750,900	
Mobilization-5%	37,550	
Contingency-10%	<u>75,900</u>	
Grand Total:	\$864,350	

TABLE 1.2
OPERATION AND MAINTENANCE COSTS

Water Pumping (0.015/kwh)	34,300 (optimistic)
Boiler Heating (emergencies)	-0-
Building Utilities	15,000
Supplies (including feed)	42,000
Insurance (auto, fire, etc.)	3,000
Maintenance (at 2%/year)	26,000
Labor (1 manager, 2 assistants)	<u>34,000</u>
Total	154,300

The construction and operation of an aquaculture research laboratory, on the other hand, appears appropriate for the Vermont Yankee facility (Appendices F & G). This facility will be designed to produce approximately twenty-five thousand Atlantic salmon from fingerling to smolt size between the months of September through April of the following year. Building and facilities will be constructed for a forty-year life expectancy. (Capital and operation and maintenance costs are shown in Tables 1.3 and 1.4).

TABLE 1.3
AQUALAB CAPITAL COST SUMMARY

Sitework, Paving, and Utilities	\$ 24,350
Site Mechanical	212,100
Mechanical Building (shell and electrical)	57,500
Mechanical Building (water heating system)	193,700
Rearing Building (shell)	243,000
Rearing Building (mechanical, electrical and tanks)	57,600
Furnishings, Special Equipment and Vehicles	<u>33,200</u>
Subtotal	803,950
Mobilization @ 7%	56,280
Contingency @ 15	129,030
Escalation (Fall 1978) 14%	138,500
Fees and Special Services	<u>112,240</u>
	\$1,240,000

TABLE 1.4
OPERATION AND MAINTENANCE COSTS
(Aqualab - 8 months of operation)

Water pumping costs based on 0.015 per kwh	\$18,500
Boiler heating costs based on \$0.50 per gallon	
Standby	11,000
20-day shutdown	37,500
Building Utilities	1,000
Supplies (including feed)	7,000
Insurance (auto, fire, etc.)	1,000
Maintenance (vehicular, building)	1,000
Labor	
1 Manager @ \$12,500/year	8,500
2 Assistants @ \$10,500/year	7,000
	\$92,500
Total	\$92,500

3.3 Horticulture Results

An experimental greenhouse complex has been conceived consisting of 4 Cornell designed greenhouses, each heated differently (Appendix C). A diagram of the experimental greenhouse complex is shown in Figure 1.7 and a description of the heating systems for each greenhouse follows:

Greenhouse No. 1: Solar Greenhouse - This structure is designed to store direct solar heat in gravel beds located in the greenhouse. Heat is recovered from the gravel storage system using a commercial water-to-air heat exchanger. A backup heat source is provided by a 9.5 kw electric resistance heater. No external solar collectors are utilized. The gravel heat storage units are also used as produce growing benches. Vermont Yankee condenser effluent is used as a "booster" heat source in the water-to-air heat exchanger.

Greenhouse No. 2: Heat Pump - This greenhouse utilizes a water-to-air heat pump with a constant source of 65 to 70°F water supplied by the power plant. The operating coefficient of performance (COP) for the water-to-air heat pump is approximately equal to 3 compared to 1.75-2.0 for air-to-air units now commonly used. In addition to the heat pump, one commercial water-to-air heat exchanger will be used, "boosted" by Vermont Yankee waste heat. The heat pump will be utilized as the backup heat source in the event of power plant down-time during the coldest operating periods. The COP in this mode, however, will be less than 2. English seedless cucumbers are planned for this house.

Figure 1.7 Plan View of the Greenhouse Complex

Greenhouse No. 3: Rutgers' Design - In this design the floor is constructed of porous concrete with a gravel bed beneath it. The heat exchangers consist of porous pipes draped with polyethylene sheets running the full length of the house in five separate rows. Water flows from the porous pipe down between the plastic sheets, through the porous concrete floor into the gravel bed.

The pipes draped with plastic may be raised at night for maximum heat exchange and lowered during the day when less heat is required and more light is needed for plant growth. A commercial water-to-air heat exchanger is also utilized to assist the plastic heat exchangers. The heat exchanger combination is designed to maintain a minimum of 50°F in the greenhouse on the coldest nights. It is planned to use this house for potted plants suitable for growth at cool temperatures (snapdragons and chrysanthemums).

Greenhouse No. 4: Methane House: This house is capable of being totally heated by methane gas produced in a nearby biogas generator (Appendix B). This generator (also known as a digester or fermenter) uses the manure from an adjacent 200-cow dairy farm. The manure is converted to a 60 percent methane gas mixture by an anaerobic process. The gas is piped to the greenhouse where it is burned in conventional heaters. Sufficient gas will be produced to maintain temperatures above 65°F continuously during the coldest periods. Because of the capability of maintaining high temperatures, crops such as roses can be grown in this greenhouse.

Warm water from the power plant can also be utilized as a supplemental heat source in the greenhouse and to boost the anaerobic process. The digester must be maintained at 90 to 95°F for maximum gas production. The 70°F water from the power plant assists in maintaining the higher temperature in the digester thus increasing gas production by as much as 40 percent. Without the assistance of the warm water from the power plant, nearly one-half of the methane gas produced would have to be used to keep the digester at the required 90-95°F. Using the warm water to preheat the manure slurry in the digester during winter months results in only 10 to 20 percent of the gas produced being required by the digester to maintain optimum operating temperatures.

Crops to be grown in the various greenhouses have been selected on the basis of the temperature fluctuations expected. The produce chosen for each greenhouse are given in Table 1.5. Since ornamentals, especially roses, in recent years have been giving New England horticulturists the highest net return on investment, we decided to design an economic model for Greenhouse 4 (Appendix D) and examine its operation more closely. The results are summarized in Table 1.6. In preparing this table we have included the effects of scaling from the original test complex of 4 greenhouses and one biogas generator to a total of 24 houses and 4 biogas generators. Scaling factors, supplied by consulting engineers, gave an overall costs savings of 15 percent for the greenhouses. Scaling factors of 0.80, 0.68, and 0.65, respectively, were used for each successive biogas generator. This gave additional cost savings of about 20 percent for the four units. The cost of the biogas generators also includes \$90,000 for gas storage facilities. The high cost of the first four greenhouses includes the cost of one biogas generator and all support systems (pumps, piping, controls, service buildings, etc.).

Operation and maintenance (O & M) costs of Table 1.6 are based upon the data of Chapter 5. Ornamental sales gross income assumes a return of \$6.00 per square foot of greenhouse floor area. It is believed that a well run operation could achieve this return.

The biogas sales return assumes about 50×10^8 BTU of excess biogas per year available for sale at \$2.50 per 10^6 BTU. The fertilizer sales assumes the processing of residue from four, 200-animal dairy farms. The value of the fertilizer was based upon data cited in the ECOTOPE report referenced on Page D-1, Appendix D.

TABLE 1.5
ESTIMATED PRODUCTION INCOME
(Annual)

Greenhouse No. 1	
Tomatoes (fall crop)	
6 lb./plant, 390 plants/house @ \$.50/lb.	\$ 1,170.00
Lettuce (winter)	546.00
Tomatoes (spring crop)	
14 lb./plant, 390 plants/house @ \$.50/lb.	<u>3,276.00</u>
Total	\$ 4,992.00/year
Greenhouse No. 2	
Cucumbers (English Seedless)	
5 crops (3,438 cucumbers/crop)	
@ \$.40/cucumber	6,876.00
Greenhouse No. 3	
Snapdragons and 1 bench of Chrysanthemums	6,380.00
Greenhouse No. 4	
2/3 Red Roses (Forever Yours)	
1/3 Sweetheart Roses (Bridal Pink)	<u>7,962.00</u>
Total Gross Income	\$ 26,210.00

TABLE 1.6
SUMMARY OF COMMERCIAL HORTICULTURE
(24 greenhouses - ornamentals, biogas heated)

Capital Investment, First 4 greenhouses (1977 dollars)	\$ 538,100
Twenty Additional greenhouses	164,000
Additional Biogas Generators	180,000
Additional Support Facilities	<u>105,000</u>
Subtotal	987,100
Amortized @ 9-1/2%/30years	(99,600)
O & M, Greenhouses	(115,300)
O & M, Gas Generators	<u>(14,200)</u>
Subtotal	(229,100)
Gross Receipts, Ornamental Sales	224,100
Gross Receipts, Biogas and Fertilizer Sales	<u>26,500</u>
Subtotal	251,100
Approximate Net Profit	\$ 22,000
*Estimated Annual Overall Rate of Return:	12%

*Assuming successful demonstration of test unit.

4. CONCLUSIONS

The Vermont Yankee Nuclear Power Corporation has concluded that the construction of a permanent aquaculture research facility should be undertaken with the initial objective of contributing to the expeditious restoration of Atlantic salmon in the Connecticut River and with the long-term objective of contributing to fundamental understanding of problems associated with intensive closed-cycle fish farming. We have also concluded that waste heat stimulated horticulture can be made commercially attractive even in Vermont winter climates. However, the number and types of parameters affecting commercial success are many and varied and their interactions sufficiently complex to justify investment in a test of the greenhouse design and the various heating options before full scale construction is undertaken. Regarding impact of the Delaney Amendment, we have concluded that both horticulture and aquaculture may operate commercially at the Vermont Yankee station without intermediate heat exchangers since station design and operating procedures provide efficient barriers to radionuclides produced during normal operations. Moreover, these barriers appear to be sufficiently redundant to provide necessary consumer protection even during abnormal operating conditions. Experimental programs will establish the validity of these initial conclusions.

5. TEST PROGRAM IMPLEMENTATION

5.1 Fiscal Requirements

Capital investments of about \$1.9 million (1977 dollars) will be required for construction of the proposed aqualab (\$1.3 million) and the 4-house test horticulture complex (\$600,000). Construction of the commercial fish rearing facility is excluded for now, although land space allocation to accommodate such a facility will remain part of the Vermont Yankee long range waste heat utilization plans.

5.2 Schedule

Implementation of the test program is planned in four phases, extending somewhat beyond three years and commencing as soon as preliminary design funding is available. Figures 1.8 and 1.9 are time bargraphs, showing approximate intervals and key points for events to take place, leading to operation of each facility. While we generally expect both projects to be undertaken concurrently, they can be undertaken separately, provided the aqualab is constructed first. This is because the horticulture operation depends, in part, upon sharing certain support components that must be constructed for the aqualab.

The large triangles in the body of each bargraph represent specific dates when positive assurance exists that adequate funds are available to support the next phase. The numbers represent the approximate number of months' duration of each phase. Horizontal arrows indicate possible time period "stretch-outs" or indefinite termination dates. The dotted vertical lines, with arrows, indicate when an intervening, or follow-on, step should be introduced. For example, in the first year completion of the Detailed Project Definition must include an environmental impact assessment.

Figure 1.8 Aqualab Construction Schedule

Figure 1.9 Horticulture Test Complex Construction Schedule

CHAPTER 2

AQUACULTURE PROGRAM

1. COMMERCIAL TROUT-REARING FACILITY (See Appendices E and F)

1.1 General

An assessment of first species suitable for commercial aquaculture, using Vermont Yankee waste heat for growth rate enhancement, was undertaken by Dr. John H. Ryther (Appendix F). His conclusions, based upon the New England market, Vermont Yankee operative conditions and the thermal characteristics of the Connecticut River led him to conclude that brook trout was an attractive species for the Vermont Yankee aquaculture program. Accordingly, the consulting firm of Kramer, Chin and Mayo, Inc., was requested to design an optimum rearing facility for these fish. The results of their investigation are reported in this chapter.

1.2 Fish-Rearing Program

The commercial trout-rearing program is based on an annual production goal of 100,000 pounds of brook trout. These fish will be stocked into the facility on about October 1st at four inches in length, and will be reared at a constant 55°F until June, when they will be harvested at a length of about nine inches. This rearing program is shown in Table 2.1 where three conditions are examined: high, low, and average temperatures in the Connecticut River over a ten-year period.

Brook trout may not survive in this facility during the summer due to the high ambient water temperatures; therefore an alternate summer rearing program may be considered to keep the facility in production year-round. Rearing units will consist of only raceways, as no trout eggs or fry will be handled.

The biological criteria used in developing this facility are as follows:

Brook Trout

- 1) Temperature Range:
32°F to 70°F (0 to 21°C) maximum
45°F to 55°F (7 to 13°C) optimum
- 2) Growth:
28TU* per inch

One temperature unit (TU) = 1°F over 38.6°F for one month.

TABLE 2.1
FISH GROWTH PROGRAM BASED ON
TEN-YEAR WATER TEMP., CONN. RIVER

FISH GROWTH PROGRAM BASED ON
TEN-YEAR AVERAGE WATER TEMP., CONN. RIVER

COMPUTER PROGRAM FOR NEW FISH GROWTH SCHEDULE WITH TEMP. ADJUSTMENT
FOR THE VT. YARKEE RUN 3X
THE BEGINNING DATE IS 4/1/78 THE RELEASING DATE IS 6/1/79

TYPE OF FISH IN THE PROGRAM IS BROOK TROUT

DATE	WATER AVER.	TEMP MAX.	TEMP ADD.	STATUS OR EVENT	CUMULAT -DAYS FR FERT EGG	LENGTH INCHES	WEIGHT EACH LB.	NUMBER OF EGGS OR FISH	TOTAL WT. LB.	TOTAL REAR REQD CPH	REAR VOL. CF.	NH4 PPH	O2 #/DAY	BTU HR.	CUR COST \$
10/1/78	61.0	61.0		REAR FINCLNG	79	4.15	.0289	371400	10749	2273	5170	****	109.6		0.00
11/1/78	55.0	55.0	5.0	REAR FINCLNG	102	5.03	.0515	363800	18736	3659	7440	****	176.4		0.00
12/1/78	55.0	55.0	17.0	REAR FINCLNG	118	5.62	.0719	356600	25650	3432	9120	****	190.3		0.00
1/1/79	55.0	55.0	21.0	REAR FINCLNG	135	6.24	.0981	349400	34272	4354	10990	****	243.7		0.00
2/1/79	55.0	55.0	21.5	REAR FINCLNG	152	6.65	.1299	342200	44460	5484	12980	****	304.1		0.00
3/1/79	55.0	55.0	21.0	REAR FINCLNG	167	7.40	.1640	335900	55097	6581	14890	****	364.9		0.00
4/1/79	55.0	55.0	18.0	REAR FINCLNG	183	8.01	.2082	329100	68525	7919	17100	****	439.1		0.00
5/1/79	55.0	55.0	7.0	REAR FINCLNG	200	8.60	.2579	322600	83211	9337	19340	****	517.7		0.00
6/1/79				RELEASE DATE	216	9.22	.3170	310000	100184	10926	21740	****	605.8		0.00

FISH GROWTH PROGRAM BASED ON
TEN-YEAR HIGH-WATER TEMP., CONN. RIVER

10/1/78	70.0	70.0		REAR FINCLNG	79	4.15	.0289	344700	9976	2109	4800	****	101.7		0.00
11/1/78	59.0	59.0		REAR FINCLNG	111	4.83	.0456	337700	13406	4846	6370	****	190.4		0.00
12/1/78	55.0	55.0	13.0	REAR FINCLNG	131	5.59	.0708	331000	23431	3931	8370	****	198.5		0.00
1/1/79	55.0	55.0	20.0	REAR FINCLNG	148	6.21	.0967	324300	31354	4028	10100	****	255.7		0.00
2/1/79	55.0	55.0	21.0	REAR FINCLNG	165	6.82	.1282	317700	40738	5034	11950	****	323.4		0.00
3/1/79	55.0	55.0	21.0	REAR FINCLNG	180	7.37	.1620	311800	50526	6045	13710	****	403.1		0.00
4/1/79	58.0	58.0	23.0	REAR FINCLNG	197	7.98	.2059	305500	62901	7281	15760	****	493.7		0.00
5/1/79	58.0	58.0		REAR FINCLNG	216	8.70	.2667	299400	79841	10559	18350	****	545.6		0.00
6/1/79				RELEASE DATE	235	9.44	.3410	293300	100003	12784	21180	****	660.6		0.00

FISH GROWTH PROGRAM BASED ON
TEN-YEAR LOW-WATER TEMP., CONN. RIVER

10/1/78	55.0	55.0	2.0	REAR FINCLNG	79	4.15	.0289	404900	11719	2478	5640	****	119.5		0.00
11/1/78	55.0	55.0	14.0	REAR FINCLNG	96	4.76	.0437	396700	17348	2486	7280	****	137.9		0.00
12/1/78	55.0	55.0	21.0	REAR FINCLNG	112	5.36	.0622	388800	24170	3300	9020	****	183.0		0.00
1/1/79	55.0	55.0	22.0	REAR FINCLNG	129	5.97	.0860	380900	32765	4278	10970	****	237.2		0.00
2/1/79	55.0	55.0	22.0	REAR FINCLNG	145	6.58	.1153	373200	43034	5396	13070	****	299.2		0.00
3/1/79	55.0	55.0	22.0	REAR FINCLNG	161	7.13	.1469	366300	53812	6526	15080	****	361.8		0.00
4/1/79	55.0	55.0	22.0	REAR FINCLNG	177	7.75	.1881	358800	67487	7910	17420	****	438.6		0.00
5/1/79	55.0	55.0	17.0	REAR FINCLNG	193	8.34	.2347	351700	82532	9382	19790	****	520.2		0.00
6/1/79				RELEASE DATE	210	8.95	.2903	344600	100029	11042	22350	****	612.3		0.00

CONTROLS USED
MIN. D.O. 5 PPM D.O. SAT. 90.0 % ELEV. 225 FT. GROWTH RATE 28.0 TU/INCH COST OF FUEL: \$ ***** FOR OIL/GAL
O2 DEMAND= .00000190*TEMP**3.13/WT**1.138 LBS/100 LBS/DAY LENGTH=13.51*WEIGHT**3.33
MORTALITY RATE IS 20% FROM EGG TAKE TO ALL FEED AND 2% PER MONTH FOR REAR FINCLNG

PROCESSING 10 UNITS

- 3) Dissolved oxygen requirements:
5 ppm minimum
- 4) Mortality:
2% per month
- 5) Length/weight relationship:
 $L = 13.51W^{0.333}$

Feeding will be done with a commercial dry trout food at the rate of about 3 percent of body weight per day. A monthly sample of fish will be weighed from each raceway to determine growth and feeding levels.

1.3 Facility Description

1.4 Trout-Rearing Facility

The proposed rearing building is viewed as a simple, utilitarian facility, closely approximating a structural shell that a commercial producer would select in order to reduce capital expenditures. The building will be insulated and cover the rearing and the support facilities under one roof. This configuration will permit rearing activities to take place throughout the severe Vermont winter season. The building is 125 feet by 144 feet in size and may be expanded in the future. A clerestory is provided to aid in lighting the rearing area and service drive.

1.5 Rearing Area

The rearing space covers 13,600 square feet and houses eight raceways 12 feet wide by 80 feet long. Alternating raceways have walkways along their length for cleaning, maintenance and observation purposes. Automatic fish feeders are provided. An interior service driveway permits vehicular traffic within the building. This feature permits vehicle access to raceways and the food storage area to simplify fish transfer and loading of food.

1.6 Garage and Shop

The garage/shop space (875 square feet) permits shop work and routine maintenance within the rearing environment. It will also permit out-of-the-weather storage for a vehicle and various rearing equipment.

1.7 Storage

The storage facility (490 square feet) provides stacked storage for miscellaneous maintenance and fish culture equipment.

1.8 Food Storage

The dry food storage space (770 square feet) provides pallet storage for sacked and dry food. This should be adequate space to store a three-month supply of fish food.

1.9 Mechanical Equipment Room

The mechanical room contains water conditioning and treatment equipment, including mixing valves, aerators, and a headbox to assure a constant flow of water to the rearing units. Rooms are provided for further conditioning (such as pressure filtration) should it be needed in the future.

1.10 Administrative facilities

Lunchroom, office, water quality lab, and sanitary facilities comprise the 1,400 square feet of administrative space. The space will accommodate one full-time manager, two assistants, and part-time crew personnel as required during unusually active periods.

2. AQUACULTURE RESEARCH FACILITY (See Appendix G)

2.1 General

Careful review of the current state-of-art of intensive fish farming reveals a very real need for additional research in areas such as growing methodology, biological cause-and-effect sequences, fish crop genetics, protein bio-conversion economics, and market potential. The value of having fish-farming research facilities located near a cheap source of large amounts of temperature-adjustable water suggested construction of a permanent aquaculture research laboratory at the Vermont Yankee generating station. One of the immediate tasks for such a laboratory located on the Connecticut River would be to assist in the on-going Atlantic salmon restoration program.

Populations of the Atlantic salmon in the United States have been in a serious decline for many years, to the point where fish runs in rivers of the Northeastern states have virtually ceased to exist. No single reason exists for this; rather, it is a combination of over-fishing, pollution, dams, destruction of spawning sites, and many other things.

A major factor in present-day restoration efforts is the production and release of Atlantic salmon smolts into river systems which once supported spawning runs. A potentially important part of this production is a warm-water rearing facility such as that being considered for the Vermont Yankee Nuclear Site.

The Atlantic salmon is a relatively difficult fish to culture. It is unique from other salmonids in its space, food and temperature requirements, and requires a unique facility design for optimum growth rates. The rearing basin will be designed to accommodate the special turbulence and water motion needs of Atlantic salmon. However, the design will not preclude culture of warm-water species during summer months and other cold-water species in the winter, since this will require only water velocity and temperature adjustments.

There are many unknowns and problems associated with present-day aquaculture technology. Hopefully, a test facility such as the one envisioned here will aid in answering many of these questions.

2.2 Fish-Rearing Program

The primary objective of the fish-rearing program is to stock out 25,000 Atlantic salmon smolts in the spring. In order to accomplish this, approximately 31,000 under-yearling fingerlings will have to be stocked into the facility each fall, assuming an overall 20 percent mortality.

Since many elements of fish-rearing in nuclear power plant effluents are still experimental, the fish-rearing program will contain several experiments to gain more information that may be used in later, scaled-up rearing programs.

Fish-rearing and experimental programs will be carried out over a two- or three-year period in order to determine the feasibility of an expanded scale, permanent, Atlantic salmon rearing station at the Vermont Yankee Nuclear Plant site. In addition, the rearing facility may be used to carry out other experiments during the summer, when water temperature is too high to hold salmon.

2.3 Facility Design

o Site

The site is in proximity to the Vernon Dam and future fish ladder, and is located so as not to interfere with any of the power-plant systems or operations. The area may be access-controlled for visitors without involving the entire plant security system.

o Water Supply

Three separate sources of water are needed for the fish-rearing programs: river-ambient, river-heated, and discharge-ambient. In addition, backup heating is needed for the rearing program in case of a sudden shutdown, and a volume of water sufficient to provide four water turnovers per hour per tank is required.

o Mechanical Systems

A heat exchanger system to raise minimum temperature (32°F) river water to at least 60°F is needed at maximum design flow. In addition, the ability to heat minimum temperature river water to at least 50°F for prolonged periods by boiler is needed in case of plant shutdown.

- o Rearing Units

Atlantic salmon need rearing space, not rearing volume, or they become aggressive and disease results. They also need relatively swift-flowing water. Several salmon culturists recommended circular tanks as being most efficient and easiest to maintain. Since a "permanent" facility was desired, concrete tanks are specified.

- o Buildings

It is most cost-effective to have the heat exchangers and boilers near the pumps, at the discharge canal. Two buildings are therefore needed, one for the mechanical equipment, and one for the rearing facilities. Due to low winter temperatures, the rearing tanks should be covered, therefore, the main rearing building needs to house all tanks, visitor lobby, restrooms, crew rooms, laboratory and storage.

- o Waste Disposal

Domestic waste will be piped to a septic tank on-site. Since the circular tanks used throughout the rearing facility are essentially continuously self-cleaning, there should not be any build-up or concentration of pollutants in the fish-rearing effluent. According to the regulations of the Vermont Water Resources Board, no treatment should be needed for discharge into Class C, Type III waters.

2.7

power plant site

LEGEND

- PROPERTY LINE
- x- FENCE

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Kramer, Chin & Mayo, Inc.
Consulting Engineers, Architects, Applied Scientists
1917 First Avenue, Seattle, Washington 98101
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2.1

power plant site aquaculture program

LEGEND

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2.2

aquaculture program: commercial trout- rearing aqualab

LEGEND

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2.3

aquaculture program: commercial trout-rearing facility

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2.5

CHAPTER 3

HORTICULTURE PROGRAM

1. COMMERCIAL GREENHOUSES (See Appendix C)

1.1 General

Thirty years ago a significant portion of the grocery market in the Northeast was supplied by produce grown in commercial greenhouses. In recent years, however, most New England greenhouse industries have converted to specialty foods and ornamentals. This has been a direct result of the development of large, economically-refrigerated highway freight systems. Today, high fuel costs are tending to reverse the situation, and hot-house food production may again be economical in New England if low cost space heating can be provided. The objective of this study was to examine the possibility of using waste heat from large electrical generating stations for this purpose. The Vermont Yankee Nuclear Power Station is a nominal 500 megawatt steam-turbine electrical generating plant. At full power operations, it produces some three billion BTU's per hour that are discarded to the environment from the main condenser system. The temperature of this water varies from about 72°F in winter months to as much as 110°F in summer months. One of the major difficulties in utilizing power plant waste heat is that the temperature of this water during winter months is so low as to make its direct use for heating purposes of marginal value. However, if economical ways can be found to utilize this low thermal quality water, the enormous quantities of heated water available from large generating stations (370,000 gallons per minute from Vermont Yankee) offer the potential for extensive thermally enhanced programs.

Temperature enhancement schemes that have been examined in this study include electrically-operated heat pumps, thermal assistance from direct solar insolation and storage in appropriate ceramic heat reservoirs, and the use of biogas heaters fueled by gas produced from anaerobic digesters preheated by condenser waste heat.

1.2 Greenhouse Design

The basic greenhouse structure is 26 feet wide by 60 feet long and is designed with energy conservation in mind. The design incorporates a shape and construction materials that optimize the collection of solar energy while reducing the heat loss from the structure.

The basic greenhouse is a large, south-facing transparent surface (double layer of polyethylene) and an insulated north wall with high, light-reflective interior surfaces which provide increased light levels. Basic design criteria are as follows:

Temperature

- o Winter design temperature outside = -15°F
- o Greenhouse inside temperature = 65°F (day)
- o Wastewater heat from power plant = 70°F

Physical Criteria

- o Insulation north wall greenhouse = R-16 (a measure of thermal resistivity)
- o South wall slope elevation = 38 degrees from horizon
- o Sunshine during winter = 40% of total theoretically available

1.3 Heating Systems

- o Greenhouse No. 1: Solar

This greenhouse is equipped to store excess solar energy in gravel storage benches located inside the structure. The heat is recovered from the gravel storage for nighttime heating. In addition to the solar collection and storage, a commercial water-to-air heat exchanger is utilized. A backup 9.5 kw electric resistance heater is included in the design.

No external solar collectors are utilized as the greenhouse itself acts as the collector. The gravel storage units inside the greenhouse double as the growing benches. An air handling unit was designed to collect excess heat and deliver it to the gravel storage.

o Greenhouse No. 2: Heat Pump

The same basic greenhouse design is utilized without the solar storage units. In this house, a water-to-air heat pump is utilized with a constant source of 70°F water supplied by the power plant. The operating coefficient of performance (COP) for the water-to-air heat pump is higher than for the air-to-air units now commonly used.

In addition to the heat pump, one water-to-air heat exchanger (commercial unit) is utilized for base load heating. The heat pump will be utilized as an assist during the coldest operating periods. There is no other backup heating provided for this house, as the heat pump is designed to meet the greenhouse design temperature requirements for the outdoor design temperature of -15°F.

o Greenhouse No. 3: Rutgers' Design

In this greenhouse, low temperature, low-cost heat exchangers fabricated from plastic sheets draped over porous pipes have been designed. The porous pipes and plastic sheets (5 rows) extend the full length of the house. Water flows from the porous pipe down between the plastic sheets and through a porous concrete floor, to an underlying gravel bed drain system.

The plastic-sheet-draped pipes can be raised at night for maximum heat exchange and lowered during the day when less heat is required.

Also, one commercial water-to-air heat exchanger is used to assist the plastic sheet heat exchangers. The two exchangers are designed to maintain a minimum 50°F in the greenhouse on the coldest nights.

Because of the limited temperature conditions, it is suggested that this house be utilized for cooler temperature potted plants such as snapdragons and chrysanthemums. Federal and State regulations may prohibit direct use of the warmed water heat. If so, a heat exchanger similar to the one at the aquaculture unit may be used instead.

o Greenhouse No. 4: Methane

In this house, heating is provided by methane gas. Manure from about 200 dairy cows is converted to methane gas in an anaerobic digester located on the site. The gas is piped to the greenhouse by underground pipeline. Two (2) gas unit heaters are utilized to provide the total heating of this structure. Sufficient gas will be produced to maintain maximum temperatures of 65°F to 70°F on a continuous basis. Because of the capability of maintaining the higher temperatures, either roses or cucumbers are suggested as ideal crops for this house.

1.4 Service Building

In addition to the greenhouses, a 40-foot by 100-foot service building will provide space for research offices and the greenhouse and methane generator support facilities.

2. METHANE GENERATOR (See Appendix B)

2.1 Process Description

The methane generation process is as follows: The manure from approximately 200 dairy cows is delivered from a neighboring farm to the methane-generating holding tank located at the nuclear plant site. This solid waste is then deposited into a premix tank where 60°F water from the heat exchangers is mixed with it to create a

sludge. Many variables, such as temperature, organic residence time, and solids retention period, affect the volatility of the bacterial anaerobic fermentation process. In the cold weather of the Vermont climate, the temperature of the manure exposed to the winter climate may be as low as 35°F. The temperature of the sludge must be increased to produce methane. If no external heat is utilized, the majority of the energy of the decomposing manure would be used to maintain the natural reaction temperature of 95°F, thereby greatly reducing the methane gas production. However, by utilizing the nuclear plant's discharge water to preheat the residue, efficiency of the bacterial fermentation process is increased. This external heat source will maintain a sludge temperature of $\pm 65^{\circ}\text{F}$ in the premix tank. The sludge is then pumped through a heat exchanger which uses methane gas to increase the sludge temperature an additional 30°F. This supplemental heating is done to increase the rate of the digestive process. At 95°F the sludge enters the digester where natural fermentation processes change the liquid to methane gas. The gas will not only serve to heat one of the greenhouses, but will also supply supplemental heat to the sludge water. Any excess gas would be utilized to heat other facilities. The remaining sludge effluent is held in a storage holding pond for a specified length of time before being distributed to farm fields as fertilizer.

2.2 Facilities

Facilities for the methane generator consist of a manure-holding premix tank capable of holding 800 cubic feet of cow manure. This insulated rectangular concrete tank would be below ground and would have a pumping system to provide a transfer of the sludge from the premix tank to the sludge heater. The sludge heater would be a methane-fired boiler located inside of a concrete structure. The digester, located underground so as to reduce heat loss, is sealed to prevent methane gas from escaping. The volume of this tank will be approximately 5,000 cubic feet. Methane gas would be pumped and condensed in a nearby tank to assure more than one week of gas reserve. Service for the methane generation system as well as administrative needs are provided.

A detailed site map of the Vermont Yankee Nuclear Power Plant. The map shows the following features:

- CONNECTICUT RIVER**: Located at the top of the map, indicated by a wavy line pattern.
- CONDENSER WATER INTAKE STRUCTURE**: A structure on the riverbank, indicated by an arrow.
- CONDENSER WATER DISCHARGE STRUCTURE**: A structure on the riverbank, indicated by an arrow.
- EXISTING STORM SEWER**: A line extending from the left towards the river.
- GASEOUS RELEASE STACK**: A small square structure near the river.
- REACTOR AND TURBINE BUILDINGS**: A large, complex of several interconnected rectangular buildings.
- EXISTING RAILROAD**: A line with cross-ticks running horizontally across the middle of the site.
- COOLING TOWERS**: Two tall, rectangular structures to the right of the main buildings.
- METEOROLOGICAL TOWER**: A small structure on the left side of the map.
- HORTICULTURE COMPLEX**: A group of small buildings on the left side of the map.
- GOVERNOR HUNT ROAD**: A road running horizontally below the main site area.
- VERMONT ROUTE 142**: A road running diagonally from the bottom left towards the bottom right.
- VERNON DAM**: Located at the bottom right of the map, near the river.

LEGEND

—•— PROPERTY LINE
—X— FENCE

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3.1

CHAPTER 4

SUPPORT SYSTEMS

1. PUMP STATION

1.1 General

The pump station provides 8,390 gpm of ambient river water to the aquaculture and horticulture facilities. It is located approximately 300 feet upstream of the power plant intake structure in order to obtain high quality river water. This is because of the possibility of recirculation of plant discharge water back to the plant intake structure during periods of prolonged low river flow into the Vernon pond. A bar screen prevents logs and large floating debris from entering the pump house, while a travelling motorized screen filters particles greater than 1/4-inch in size and returns them to the Connecticut River. Four pumps of varying capacities are used to meet varying water requirements and to provide a measure of back-up pumping capacity in the event of partial pumping system failure.

Standby power will be provided from the Heat-Exchanger Building. A bubbler system will insure ice-free operation during severe winter weather. The structure will be enclosed but not heated. Cooling and/or ventilation will be provided to ensure proper equipment operation. The pump station will be constructed of concrete and concrete blocks.

1.2 Criteria

Maximum required discharge	8,390 gpm
Minimum required discharge	2,000 gpm
Intake Elevation	220 feet
Discharge Elevation (approx.)	270 feet

1.3 Facilities

Traveling screen for debris removal:

- o Four pumps

- One of 100 hp

- Two of 50 hp

- One of 15 hp

- o Pumphouse building is approximately 25 x 35 feet in size.

2. HEAT-EXCHANGER BUILDING

2.1 General

The heat-exchanger building will be located adjacent to the power plant discharge channel. Water is pumped from the power plant discharge channel and heat is exchanged through four plate, rather than cylinder, surfaces, as with "tube type." This circulated water is then returned to the discharge channel slightly downstream of the heat exchanger pumps.

Ambient river water from the pump station is pumped through the heat exchanger, providing up to 8,000 gpm of 60°F water for the rearing of fish.

The purpose of a heat exchanger between condenser discharge water and the fish environment is to protect the fish from chemicals added to the condenser water for cleaning and corrosion control. It also adds an additional barrier against any radio-nuclides that may be in the primary (reactor) coolant loop. Although the results of the regulatory study (Appendix A) suggest that the heat exchanger will not be necessary for commercial food production, it is planned to include it in the operation of the test facility (aqualab and greenhouse complex). This will allow comparison studies to be performed which are necessary for clearly establishing the safety of food growing activities at the Vermont Yankee site and the inapplicability of the Delaney Amendment.

2.2 Criteria

Temperatures:

Minimum river water	32°F
Minimum discharge from power plant	70°F
Optimum rearing water	60°F
Minimum rearing water for Aqualab (boiler back-up water)	50°F
Circulating boiler water	190°F

Flows:

Maximum flow from power plant discharge (El. 220) to heat exchanger (El. 256)	10,000 gpm
Power plant discharge to Aqualab	50 gpm
Power plant discharge to methane generator and greenhouses	250 gpm

2.3 Facilities

- o Four pumps at 50 hp
- o Four heat exchangers at 27,984,000 Btu/hour
- o One standby generator at 400 kva
- o One steel, insulated building 1,750 square feet

When the power plant shuts down, standby boilers will supply the aqualab with 50°F water. The commercial fish hatchery and the greenhouses will operate at the ambient river water temperature during a shutdown. The heat-exchanger building will also house the standby generator to supply power to the pumps during a power outage.

The pumps that supply the plant-discharge water to the heat exchangers will be attached to the side wall of the plant-discharge structure to minimize reconstruction.

Construction of the heat-exchanger building will consist of slab-on-grade with masonry walls. The roof will be of insulated metal construction. This construction technique will be compatible with the existing structures and the Vermont climate. The building will not be heated, but ventilation will be provided for the proper function of the equipment. Storage will be provided for maintenance equipment. A monitoring and electrical panel vault will also be housed within the heat-exchanger building. Overhead doors will permit the removal and replacement of heat-exchange elements within the building.

3. WASTEWATER TREATMENT FACILITIES

The aquaculture program will provide three types of wastewater:

- 1) Domestic wastewater
- 2) Fish-rearing/lab overflow wastewater
- 3) Fish-rearing/lab cleaning wastewater

The domestic wastewater will be treated through the use of a septic tank and an underground drain field.

The fish-rearing/lab overflow wastewater will not require pretreatment prior to discharge into the polishing pond.

The fish-rearing/lab cleaning wastewater will be pretreated prior to its introduction into the polishing pond. The combined overflow and pretreated cleaning wastewater will be of such quality that the total effluent discharged from the polishing pond will meet all applicable State and Federal guidelines and standards.

The overflow from the polishing pond will flow to a natural drainage ditch and subsequently into the Connecticut River.

Plant discharge water, supplied to the aqualab for experimental use, will be returned to its source.

The horticulture program will produce only three types of wastewater:

- 1) Domestic wastewater
- 2) Greenhouse drainage wastewater
- 3) Digested sludge from the methane generator

The domestic wastewater will be treated by a septic tank and drain field system.

The drainage wastewater will be presettled and introduced into a leaching field. An underdrain from the drain field will be diverted to an existing ditch that flows into the Connecticut River.

The stabilized sludge from the digested sludge lagoon will be disposed of by direct land application.

4. ON-SITE AND OFF-SITE WORK

o Grading

Very little grading will be required because the site is level and the facilities have been located to fit the existing topography. Funds have been included in the cost estimate for erosion control and for a small amount of landscaping.

o Roadways

Roads will be constructed to the aquaculture facilities and the horticulture facilities. Access to the pump station and the heat-exchanger building is by existing roads.

Roadway Criteria

Materials: 2 inches of asphalt concrete paving
9 inches of gravel base

Widths:	One-lane traffic	12 feet
	Two-lane traffic	22 feet
	Parking areas	43 feet

Cross-drainage will be carried by culverts. No storm sewers are anticipated. Parking areas and entries will have security lighting.

o Utilities

Electric power and telephone lines are available at the site. Major power services will be at the pump station, heat-exchanger building, and horticulture facility. A well will be constructed at both the aquaculture facility and the horticulture facility.

5. PLANT DISCHARGE WATER

Plant discharge water, taken from the power plant discharge structure, is used as the heat medium for the heated, ambient-water heat exchangers, for heating the manure required for the methane generator for supplemental heat at the greenhouses and for experimental purposes at the aqualab. All plant discharge water is returned to the power plant for discharge. All supply piping will be insulated. The minimum temperature of the plant discharge water is 70°F.

6. HEATED AMBIENT WATER

Heated ambient water is river water that is heated by heat exchangers to 60°F. This water is used to rear fish in both the aqualab and fish hatchery. All heated ambient water piping will be insulated. When the power plant is shut down, sufficient water to operate the aqualab will be heated to 50°F by oil-fired boilers.

7. RAW AMBIENT WATER

Raw ambient water is river water that is not heated. The only treatment of the raw ambient water is debris screening at the pump house. Raw ambient water is used at both the aqualab and the fish hatchery for rearing fish and service water.

8. WELLS

Two wells will be constructed, one near the aquaculture facilities and one near the horticulture facilities. The aquaculture well will be used only for drinking water and toilet facilities. The horticulture well will be used for both potable water and service water for the greenhouses.

4.9

power plant site support systems

LEGEND

- — — — — PROPERTY LINE
- X- FENCE
- — — — — AMBIENT WATER LINE
- · - · - · - PLANT DISCHARGE WATER SUPPLY & RETURN
- RAW & HEATED AMBIENT WATER LINES
- ~~~~~ WASTE LINES

VERMONT YANKEE AQUACULTURE AND HORTICULTURE ENERGY PROGRAMS VERNON, VERMONT

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4.2

A

APPENDIX

CHAPTER 5

COST ESTIMATES

1. CAPITAL COSTS INCLUDING CONSTRUCTION

1.1 Purpose

The purpose of this preliminary cost estimate at the feasibility stage is to provide initial cost information for the construction program budget. It includes costs for all items needed to complete the full project program.

1.2 Cost Factors and Assumptions

Forty-year building life is assumed for mechanical equipment systems, while 25-year design life is assumed for building enclosures.

o Overtime

No allowance has been made for overtime work.

o Weather Conditions

Normal conditions are assumed. No consideration has been given to unusual weather extremes.

o Labor

Prices reflect the work being performed by one licensed and bonded general contractor.

- o Overhead and Profit

The unit prices used include all labor, material and equipment, and the overhead and profit of the general contractor and subcontractors.

- o Remoteness

Due to the type of construction and proximity to urban areas, the remoteness factor would be less than one percent and is therefore not included in calculating.

- o Mobilization

This item consists of furnishing all bonding, licensing, plant, labor, materials and equipment necessary to mobilize the Contractor's equipment to the project site and, upon completion of the work, to demobilize the equipment from the site. Based on past experience, five percent (5%) of the construction cost will be used.

- o Construction Contingency

A ten percent (10%) contingency factor is used to account for unforeseen conditions and changes during the remaining engineering phases, also for changes encountered during construction.

- o Design Services - Design Contingencies

An allowance must be provided for design, construction observation, Operations and Management Manuals and design contingencies. Due to the indeterminate nature of the final design elements, only approximations can be made to indicate the range of costs. Due to all elements being dependent to some degree on the support systems, clear separation of the programs with their portions of the cost of the support systems is not reasonable at this time. Therefore, it is recommended that preliminary professional services costs and fees be determined for the selected programs and that these then be added to the construction cost estimates to determine the project costs.

The Construction Cost Summary, Table 5.1, does not include design services. Information for design services and cost allowances are included in Table 5.2, item 12.

2. OPERATION AND MAINTENANCE COSTS

The following estimate of operation and maintenance cost is based on Fall 1977 prices. A mark-up for inflation will be required when the construction date is known.

Other important factors of this estimate are:

- o The O & M costs for the aqualab are for a full year, while the costs for the fish rearing facility are for nine months.
- o The estimated pumping cost for the aqualab may be high. Additional engineering has been done on the heat exchangers, which indicate these costs may be about 25% high.
- o The maintenance costs include a facility replacement cost equal to 2% of the capital cost of the facility.

TABLE 5.1
CAPITAL COSTS
CONSTRUCTION COST SUMMARY

SUPPORT SYSTEMS:		
SITWORK	107,110	
UTILITIES	43,500	
PUMP STATION	224,000	
HEAT EXCH. BUILDING	629,800	
SUPPORT SYSTEMS	258,300	
WASTEWATER TREATMENT	140,000	
		1,402,710
AQUACULTURE PROGRAM		
AQUALAB	415,300	
COMMERCIAL FISH HATCHERY	786,000	
		1,201,300
HORTICULTURE PROGRAM		
HORT. SERV. BUILDING	134,000	
GREENHOUSES	40,000	
METH. GENERATOR	40,500	
		214,500
	SUBTOTAL	\$ 2,818,510
MOBILIZATION 5%		
CONTINGENCY 10%		+ 437,790
(OH & PROFIT IS INCLUDED IN UNIT COSTS)		
		<u>\$ 3,256,300</u>

Cost estimate reflects a bid date of autumn 1977 and is related to the Engineering News Record (ENR) Const. Cost Index of 2532 for Boston. It relates to a whole integral design concept described within the text and drawings and is based only on the drawings and details shown. Other uses of this estimate (such as extrapolations or uses in part) can result in misleading results.

TABLE 5.2
CAPITAL COST ESTIMATE
(UNIT COSTS)

ITEM	QUALIFICATIONS	QTY.	UNIT	UNIT COST \$	COST \$
1. <u>Sitework</u>					
Grading			TOT.		31,470
Erosion control		74,560	SF	.03	2,240
Soil treatment		1.84	AC	1300	2,390
Landscaping and signs			TOT.		8,000
Fencing		920	LF	8.40	7,730
Pavement		7,120	SF	7.00	49,840
Drainage		60	LF	24.00	1,440
Site Lighting			TOT.		4,000
					<u>107,110</u>
2. <u>Utilities</u>					
Well		2	TOT.		13,500
Dom. Septic tank & drain field		2	EA	5000	10,000
WWT drain field		1	EA	7500	7,500
Electrical service			TOT.		12,000
Telephone			TOT.		500
					<u>43,500</u>
3. <u>Pump Station</u>					
Substructure and superstructure			TOT.		100,000
Mechanical					
Gates			TOT.		10,000
Travelling screen			TOT.		70,000
Pumps			TOT.		31,000
Piping & valves			TOT.		11,500
Electrical				TOT.	2,500
					<u>224,000</u>

(Continued)

ITEM	QUALIFICATIONS	QTY.	UNIT	UNIT COST \$	COST \$
4.	<u>Heat Exchanger Building</u>				
	Building shell	4275	SF	40.00	171,000
	Mechanical				
	Heat exchanger		TOT.		326,000
	Pumps, Mounting & Installation (4)		TOT.		42,000
	Standby generator, 400 KV		TOT.		45,000
	Piping & Valves		TOT.		25,000
	Electrical		TOT.		5,800
	Furnishings & special equipment		TOT.		15,000
					<u>629,800</u>
5.	<u>Aqualab</u>				
	Building shell	6600	SF	37.00	246,000
	Mechanical		TOT.		81,800
	Piping & valves		TOT.		17,500
	Tanks		TOT.		18,500
	Electrical		TOT.		18,500
	Furnishings & special hatchery equipment		TOT.		35,000
	Vehicles & rolling stock		TOT.		12,500
	Heating, Ventilation, Air-conditioning		TOT.		4,000
					<u>415,300</u>
6.	<u>Commercial Fish Hatchery</u>				
	Building shell	18,000	SF	25.00	450,000
	Mechanical		TOT.		133,000
	Equip., piping & valves				
	Raceways	8	EA	17,250	138,000
	Electrical		TOT.		10,500
	Furnishings & special equipment		TOT.		30,000
	Vehicles & rolling stock		TOT.		12,500
	Heating, Ventilation Air-conditioning		TOT.		12,000
					<u>786,000</u>
7.	<u>Horticulture Service Building</u>				
	Building shell	4000	SF	25.00	100,000
	Mechanical				
	Piping & valves		TOT.		5,000
	Electrical		TOT.		9,000
	Furnishing & special equipment		TOT.		5,000
	Vehicles & rolling stock		TOT.		12,000
	Heating, Ventilation Air-conditioning		TOT.		3,000
					<u>134,000</u>

(Continued)

ITEM	QUALIFICATIONS	QTY.	UNIT	UNIT COST \$	COST \$
8.	<u>Greenhouses</u>				
	4 Complete Greenhouses (See Appendix for Cost Breakdown)		TOT.		<u>40,000</u> 40,000
9.	<u>Methane Generator</u>				
	Structure		TOT.		28,500
	Mechanical, Equip., Piping & valves		TOT.		10,000
	Electrical		TOT.		<u>2,000</u> 40,500
10.	<u>Support Systems</u>				
	Plant discharge water piping		TOT.		68,700
	Heated ambient water piping		TOT.		121,700
	Raw ambient water piping		TOT.		49,500
	Wastewater dis- charge piping		TOT.		8,400
	Monitor & alarm systems		TOT.		<u>10,000</u> 258,300
11.	<u>Wastewater Treatment</u>				
	Pretreatment		TOT.		60,000
	Polishing Pond	3200	SF	2.50	<u>80,000</u> 140,000
12.	<u>Design Services and Contingencies</u>				

Based upon the conceptual system's preliminary construction estimates above, the following is provided for guidance in estimating project completion funding. Please note these are approximations subject to final project definition and scoping.

Program Element	Design Allowance	Const. Phase Allowance	O&M Manual Prep.	Est. Allow. Program
- Support System	\$150,000	\$ 60,000	\$ 50,000	\$260,000
- Aquaculture Program	145,000	50,000	70,000	265,000
- Horticulture Program	40,000	10,000	20,000	70,000
- Special Services, etc.	75,000			75,000
	<u>\$410,000</u>	<u>\$120,000</u>	<u>\$140,000</u>	<u>\$670,000</u>

TABLE 5.3
OPERATION & MAINTENANCE COSTS

	Aqua Lab (12-month operation)	Hatchery (9-month operation)	Greenhouse and Service Building	Methane Generator	TOTAL
Water Pumping (0.015/kwh)	\$ 27,000	\$ 23,500	\$ 150	\$ 50	\$ 50,700
Boiler Heating					
Stand-by	11,000	0	0	0	11,000
20-Day Scram	37,500	0	0	0	37,500
Building Utilities	3,000	12,000	3,000	600	18,600
Supplies (including feed)	7,000	40,000	4,000	0	51,000
Insurance (auto, fire, etc.)	2,000	3,000	300	0	5,300
Maintenance @ 2%/year (vehicular, building, etc.)	28,000	26,000	6,000	500	60,500
Labor					
Manager	12,500	12,000	12,000	0	36,500
Assistants	10,500	18,000	9,000	600	38,100
TOTALS	\$138,500	\$134,500	\$34,450	\$1,750	\$309,200

APPENDIX A
FEDERAL LAWS AFFECTING
VERMONT YANKEE WASTE HEAT PROJECT

by
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FEDERAL LAWS AFFECTING
VERMONT YANKEE WASTE HEAT PROJECT

The Vermont Yankee nuclear power plant at Vernon uses circulating water drawn from the Connecticut River to absorb heat from the primary coolant in the condenser, and discharges the heated water back into the river.

With funding from the Environmental Protection Agency (EPA) and the Energy Resources and Development Administration (ERDA), Vermont Yankee is exploring the possibility of using this waste heat for aquaculture or horticulture. We have been asked to investigate any obstacles under federal law to such projected uses.

While there are some familiar federal requirements (e.g., a pollution discharge permit for a fish hatchery), the only significant source of concern, and the area in which the federal grant agencies have expressed the most interest, is the impact of the federal Food, Drug and Cosmetic Act. Our analysis indicates that this law should not be an obstacle to the proposed projects, under the circumstances as we understand them.

I. FOOD, DRUG AND COSMETIC ACT

A threshold question for the viability of any waste heat project at Vermont Yankee is raised by the specter of radioactivity from the nuclear plant contaminating the fish or vegetables. Obviously a "contaminated" product would totally

undermine what is intended as a public-spirited project; and this applies equally to lower-profile possible contaminants such as residue from the pipes and cleaning agents used to flush them. Indeed, the analysis may be extended to consideration of the composition of the river water itself, especially in light of the fact that evaporation of that water in the cooling towers when on closed cycle increases the concentration of certain of its ingredients. A product which is unhealthy from any source could, of course, expose Vermont Yankee to liability under basic state law tort or contract principles.

The healthiness of food products in interstate commerce is one object of the Federal Food, Drug and Cosmetic Act, 21 U.S.C. §§ 301 et seq. (FDCA); Vermont has a parallel but not identical statute covering intrastate products, which will be touched upon later. The application of the FDCA requires some close legal analysis and some understanding of the operation of Vermont Yankee and of the proposed project.

A. Scope of the Food, Drug and Cosmetic Act.

In general, the FDCA regulates unhealthy foods by excluding from commerce foods deemed to be adulterated. A threshold question is whether the planned project will be within the interstate commerce clause, which generally has broad reach. Although cases dealing with the interpretation of "interstate commerce" under the FDCA all involve business activity, "commerce" for the purposes of the commerce clause need not be business activity. See Maryland v. Wirtz, 269 F. Supp.

826, 832-33 (D.Md. 1967), aff'd 392 U.S. 183 (1968), and cases cited. Thus, in Thornton v. United States, 271 U.S. 414, 425 (1926), the Court held that cattle ranging across state borders were within interstate commerce even though the cattle were not driven across the border, no instrumentality of interstate commerce was used, and no commercial purpose was involved in the border crossing. Fish introduced into the Connecticut River are sufficiently analogous to the cattle in Thornton to suggest that, even if the products of the Vermont Yankee Waste Heat Project are not sold commercially, they could be considered to be in interstate commerce.

B. FDCA Statutory Scheme - An Overview.

Analysis of the effect of the FDCA on the Vermont Yankee Waste Heat Project requires a general understanding of the Act. This is not easily achieved, as the FDCA is made up of different, sometimes overlapping, legislation. The FDCA was initially enacted in 1938. 52 Stat. 1042. The provisions dealing with food additives, however, were added in 1958. 72 Stat. 1785. The interaction between these portions of the FDCA is not always clear. In general, the FDCA prohibits the introduction into interstate commerce of any food that is adulterated. 21 U.S.C. § 331. The statutory definition of "adulteration" includes several different categories, added over the years, which are of potential relevance to the proposed projects.

The first prohibition, dating from the Food and Drug Act of 1906, is of food "bearing or containing any poisonous or

deleterious substance" (natural or added) which may render the food injurious to health. Thus, if a particular batch of fish or vegetables were contaminated so as to be unhealthy, it would not be marketable. The burden is on the government to prove that the particular food product, by itself, poses a health hazard. § 342(a)(1). See United States v. Lexington Mill & Elevator Co., 232 U.S. 399 (1914).

In 1938 the Food, Drug and Cosmetic Act introduced a prohibition of "any poisonous or deleterious substance added to food, except where such substance is required in the production thereof or cannot be avoided by good manufacturing practice..." §§ 342(a)(2)(A), 346. This prohibition was interpreted rigidly to ban all unnecessary substances which the government could show to be poisonous or deleterious as such, even though used in amounts which could not possibly render the product unsafe (although there was an apparently extra-legal system of informal use tolerances). See Markel, The Food Additives Amendment of 1958, 14 The Business Lawyer 514 (1959); United States v. Ewig Bros. Co., 502 F.2d 715 (7th Cir. 1974). If an added unhealthy substance was found to be necessary, the government was supposed to set tolerance limits (taking into account cumulative effects beyond the particular item of food involved), within which the additions were considered safe. The Food Additives Amendment of 1958 has now limited this category to "added poisonous or added deleterious substances (other than . . . food additives)". § 342(a)(2)(A). Since

the comprehensive definition of food additives includes poisonous or deleterious substances except when added on an accidental basis (see below), and since the accidental addition of poison is unlikely to be considered necessary to, or unavoidable in, food production, it is not clear whether this category retains any viability; but see part I.D., below.

Finally, further prohibitions were incorporated by the Food Additives Amendment of 1958. In general terms, this amendment disallows the presence of additives in food, § 342(a)(2)(C), or the subjection of food to radiation, § 342(a)(7), absent the blessing of a Food and Drug Administration (FDA) regulation upon a petition in which the applicant must demonstrate that the intended use is safe under the proposed conditions, § 348. Further, the 1958 amendment introduced the so-called Delaney Clause, flatly prohibiting FDA approval as a food additive of any carcinogen in any amount.

C. Regulation of Food Additives.

The Food Additives Amendment of 1958 requires an FDA regulation or exemption with respect to any food additive, defined as:

any substance the intended use of which results or may reasonably be expected to result, directly or indirectly, in its becoming a component or otherwise affecting the characteristics of any food (including any substance intended for use in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting or holding food; and including any source of radiation intended for any such use), if such substance is not generally recognized, among experts qualified by scientific training and experience to evaluate

its safety, as having been adequately shown through scientific procedures (or, in the case of a substance used in food prior to January 1, 1958, through either scientific procedures or experience based on common use in food) to be safe under the conditions of its intended use [with certain exceptions not presently relevant].

21 U.S.C. § 321(s). According to the legislative history of the Food Additives Amendment of 1958, this provision

covers substances which are added intentionally to food. These additives are generally referred to as "intentional additives." The legislation also covers substances which may reasonably be expected to become a component of any food or to affect the characteristics of any food. These substances are generally referred to as "incidental additives."

S.Rep.No. 2422, 85th Cong., 2d Sess., 1958 U.S. Code Cong. & Admin. News 5303-04. The legislative history also draws a distinction between these "intentional" and "incidental" additives and a category of "accidental additives." The latter are defined as "substances [which] if properly used may not reasonably be expected to become a component of food or otherwise affect the characteristics of a food." Id. at 5304.

The 1958 Amendment also requires an FDA regulation or exemption for "intentionally subject[ing food] to radiation".

21 U.S.C. § 342(a)(7). There is no requirement that radioactivity affect or become a component of the food.

The Food Additives Amendment accordingly requires a regulation or exemption from the FDA for the use of the plant's circulating water in the waste heat project if subjection of fish or produce to radiation is intended or if any substances affecting the fish or produce are intentional or incidental

additives not generally recognized as safe. Exemptions are available only for scientific testing. Regulations are available only upon a petition in which the applicant undertakes to establish, upon scientific data, the safety of the proposed additive under the conditions of proposed use. (Requirements for such petitions may be found in § 348 and 21 C.F.R. Part 171.) The key provision, containing the proviso known as the Delaney Clause, is § 348(c)(3):

No such regulation shall issue if a fair evaluation of the data before the Secretary fails to establish that the proposed use of the food additive, under the conditions of use to be specified in the regulation, will be safe: Provided, that no additive shall be deemed to be safe if it is found to induce cancer when ingested by man or animal, or if it is found, after tests which are appropriate for the evaluation of the safety of food additives, to induce cancer in man or animal.

There is an exception to the proviso with respect to animal feeds as to which no additive residue will remain in the ultimate food product; although the practical situation of some possible contaminants in the growing environment projected here is certainly analogous, it is unlikely that this exception would apply here.

The Delaney Clause has come under criticism because it forbids the government to weigh the possible public health benefits from low-level use of any substance which is found to be carcinogenic under any conditions. Scientific anomalies in this provision are asserted in Blank, The Delaney Clause: Technical Naivete and Scientific Advocacy in the Formulation

of Public Health Policies, 62 California Law Review 1084 (1974).

The latest crisis, of course, is this year's abortive ban on saccharin.

(i) Radioactivity.

Much concern has been expressed during the development of the waste heat proposals about the limiting effects of the Delaney Clause with respect to the Vernon station's nuclear character. It is assumed that radioactive emissions can, at some level, be carcinogenic. However, there is no basis for concluding that radioactivity will become a food additive at Vermont Yankee under the proposed conditions.

The radioactivity at Vernon emanates from the nuclear fission material in the core of the reactor. It is predictable that failures in the cladding around this material will allow fission products to enter into the surrounding primary coolant. In addition, high radiation flux in the core region can produce tritium in the primary coolant and cause certain corrosion products there to become radioactive. The plant is designed, however, so that none of this radioactivity is permitted to get into the circulating water system. The exchange of heat between the primary coolant system and the circulating water system in the condenser occurs through the condenser piping which prevents mixing of the fluids. Also, the difference in operating pressures of fluids on either side of the main condenser tubing is such as to cause circulating water to flow into the primary coolant system, rather than vice-versa, should leaks develop.

Moreover, instead of discharging controlled amounts of radioactive liquid waste into the river (as permitted by the terms of its NRC and FWPCA permits), Vermont Yankee has chosen to dispose of it otherwise. Radioactive inert gases are separated from the primary coolant, processed, and released into the atmosphere; other radioactive gases are permanently trapped or retained until their radioactivity decays to inconsequential levels; radioactive corrosion products are filtered out and transported away for burial; and other radioactive isotopes that become chemically bound to the primary coolant are stored in tanks to decay. Even if the plant were to discharge such items through its "radwaste" system, the effluents from that system are mixed with the circulating water only at the brink of discharge into the river: that is, the water for the proposed projects would be drawn out of the circulating water system at a point above the entry of any discharge of radioactive material being released through the radiological decontamination system.

Thus, quite apart from the extra barrier which could be provided by a heat exchanger, it appears clear that there will be no intentional subjection of the food to radiation, making § 342(a)(7) inapplicable to the project. The only way radionuclides could get into the circulating water discharge being diverted to the proposed projects would be from a failure in the condenser and associated pumping systems: such a failure

would be unintentional; therefore, the resulting possibility of exposure would be unintentional. (The legal doctrine which in some contexts holds someone to "intend" the foreseeable consequences of his actions would appear inappropriate here. First, the definition of food additive expressly includes this variety of intention in its coverage of "incidental additives", raising the inference that the omission of an explicit inclusion here was intended as an exclusion. Second, the § 342(a)(7) statutory language prohibits "subjecting" the food to radiation, a wording which imports a positive act of directing radiation upon the food.)

A similar analysis applies to the question whether radioactivity could under any circumstances be an "intentional additive" under §§ 321(s) and 342(a)(2)(C). The statutory definition includes "any substance the intended use of which results or may reasonably be expected to result" in its becoming a component of or affecting the food. § 321(s). It is Vermont Yankee's clear intention not to expose the food to radioactivity: under the conditions of its intended use, radioactivity will not enter the circulating water at all. Although the words of the statute may admit of some ambiguity, this natural interpretation is verified by the legislative history, in which "intentional additives" are defined as "substances which are added intentionally to food." Under the circumstances presented, radioactivity is clearly not such a substance.

The question remains whether radioactivity might be an "incidental additive," that is, a substance "which may reasonably

be expected" to become a component of or affect the fish or vegetables. The legislative history contrasts such included substances with "accidental additives," substances which "if properly used may not be reasonably expected to become a component . . ." S. Rep. No. 2422, supra, at 5304 (emphasis added). Proper functioning of the Vernon plant, as it is designed, will not result in the presence of radioactivity in the circulating water. Any introduction of radioactivity into the water would be the result of a failure in the system. Thus under this definition radioactivity could not be an "incidental additive".

The statutory standard of reasonable expectation is to some extent a function of probabilities. Thus, if experience at the plant showed that failures in the condenser were frequent, so that it was reasonable to expect the presence of radioactive contamination in the circulating water, then further steps of analysis concerning heat exchangers, whether exposure would result in contamination, and possible general recognition of safety would be necessary. However, the experience of the Vermont Yankee plant has been that over five years of operation, only one leak of radioactivity into the circulating water has occurred (due to the rupture of a gasket in March, 1977, when a pressure differential causing any leaks to flow the other way was not being maintained, as operating procedures now require). This statistic supports the conclusion that any

presence of radioactivity in the circulating water would correctly be considered an accident, rather than an incident to proper operation.

Thus, it should be concluded without further analysis that radioactivity from the plant will not be a "food additive" with respect to any of the products of the proposed projects.

(However, the analysis considered below with respect to chemicals could also be applied: e.g., the presence of heat exchangers would reduce considerably the statistical probability of exposure, supporting the determination that any radioactivity would be an "accidental" additive; moreover, it is understood that many of the radioactive products would pass through rather than accumulate in fish, etc.) The situation at other nuclear plants may be different. For example, the Northeast Utilities plant at Millstone apparently discharges radioactive wastes into the growing environment of its mariculture experiment. The application of the "food additives" provision to such a situation (apart from the possible lack of interstate commerce) would appear to turn primarily upon whether the resulting concentrations of radioactivity in the oysters produced could be shown to be generally recognized as safe by scientific experts. (The highest concentrations measured at Northeast Utilities, under circumstances more likely to produce high concentrations than would similar discharges at Vermont Yankee, reportedly were on the order of a few percentage points over background and therefore, given the variation in background

radiation from place to place, generally below concentrations naturally occurring in much of the food that we eat. Cf. Section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act, 42 U.S.C. §§ 300 g-1, 300 g-3, 300 j-4 and 300 j-9, and the EPA national interim primary drinking water regulations, 40 C.F.R. Part 141.) The fact that the Delaney Clause could prohibit the FDA from finding radioactivity to be safe within any tolerances with respect to authorizing its use as a food additive should not legally affect the analytically prior determination of whether it is generally recognized as safe under the conditions of its intended use, because if it is so recognized it is not a food additive and therefore does not come under the Delaney Clause.

(ii) Chemicals and Corrosion Products.

Two categories of substance are added to the river water as it circulates through the Vernon plant, and will be contained in the circulating water which is drawn off to the proposed projects. These are (1) chemicals added as cleaning agents, demineralizers, biocides and corrosion controllers and (2) corrosion products from the pipes through which the water runs. Will these constitute "food additives" requiring an FDA regulation?

The legislative history uses as an example of accidental additives "paints or cleaning solutions used in food processing plants". This example may appear comparable to the use of chemicals at Vermont Yankee since their purpose is analogous

to cleaning solutions. However, at Vermont Yankee the chemicals are added intentionally to the very circulating water which will carry the heat to the project and, absent heat exchangers, will come into direct contact with the food. Indeed, it is partly because of the potential deleterious effects of such direct contact that biologists working on the aquaculture project have recommended the use of heat exchangers. Assuming that such contact would result in chemicals becoming a component or affecting the characteristics of the resulting food product (which seems likely), the next question would be whether such chemicals could be shown to be "generally recognized as safe" under these conditions.

Presumably this determination would vary with respect to Vermont Yankee's use of particular chemicals. (Cf. EPA effluent limitations as to steam generating plants, 40 C.F.R. Part 423, which include metal cleaning wastes, §423.11(j): proposed EPA effluent standards for toxic pollutants under 33 U.S.C. §1317(a)(1), 38 Fed. Reg. 35388 (1973).) However, general recognition of safety under conditions of intended use is not easily satisfied, because it requires a consensus of experts based upon scientific testing or (as to substances used in food prior to 1958) upon experience based upon common use in food.

Absent heat exchangers, the "generally recognized as safe" standard would also have to be satisfied with respect to pipe corrosion residues. (This item highlights the impact of advancing technology which now can measure small amounts which

would have gone undetected only a few years ago.) This material is not intentionally added to the circulating water, but it should reasonably be expected to get into that water in small quantities, even under normal and proper use of the plant. If this results in its becoming a component of or affecting the food, only a general recognition of safety would prevent it from being a food additive.

Perhaps as to some of the chemicals or corrosion products some testing has occurred. Or perhaps it could be determined that greenhouse or hatchery operations predating 1958 introduced the same substances to their products, constituting an identifiable experience of common use upon which a scientific judgment of safety could be based. If not, and if no heat exchangers are used, it would appear to be necessary to conduct tests and (unless the tests gave rise to a "general recognition of safety") to seek an FDA regulation setting conditions for use. Standards may be found in 21 U.S.C. § 348 and 21 C.F.R. Part 171. The alternative to this is to use heat exchangers.

Heat exchangers change the "food additives" analysis by constituting a barrier between the circulating water and the growing environment, a barrier which may, in addition, be pressurized to cause any leaks to be directed away from the food environment into the circulating water. Precisely because such a barrier provides protection from any contaminants which might be in the circulating water, neither the chemicals nor the corrosion products would be reasonably expected to be exposed

to the food, and therefore they would not be "food additives" within § 342(a)(2)(C). (This would apply also to any radioactivity which found its way into the circulating water.) It is understood that heat exchangers are projected for the entire aquaculture project, and contemplated for three of the four greenhouse designs. Moreover, the remaining greenhouse ("Rutgers Design") is, for environmental reasons, being recommended for raising plants rather than food, and the lack of heat exchanger there would be of no legal significance if that recommendation is followed.

In short, given the presence of heat exchangers isolating the circulating water from each proposed food-growing environment, none of the items under consideration would be "food additives" requiring an FDA regulation.

D. Other Food and Drug Provisions.

In distinguishing accidental additives from intentional and incidental additives, the legislative history of the Food Additives Amendment states that "[i]f accidental additives do get into food, the provisions of the [FDCA] dealing with poisonous and deleterious substances would be applicable". S.Rep.No. 2422, supra, at 5304. The sections of the FDCA which mention "poisonous and deleterious substances" are those (referred to in the overview above) which predated the 1958 Amendment.

Section 342(a)(1) provides that food containing substances which are poisonous or deleterious such that it may be injurious

to health is adulterated (unless the substance is not "an added substance" and the quantity of the poisonous or deleterious substance in the food does not ordinarily make it injurious to health). Thus, a specific batch of actually unhealthy food would be covered.

Section 342(a)(2)(A) provides that an added substance (other than a food additive) which is poisonous or deleterious is safe only if, under § 346, the substance is "required in the production [of a food] or cannot be avoided by good manufacturing practice", and then only pursuant to tolerances established by the FDA. Sec. 21 C.F.R. Part 122. It could be argued in this respect that the use of a heat exchanger was required in the waste heat project as "good manufacturing practice" under the circumstances. Although a heat exchanger is expensive, it is readily available technology which could prevent the exposure of fish or produce to substances, including radioactivity, chemicals and corrosion, which might otherwise result in adulteration. If so, the use of heat exchangers could be required in order to avoid the prohibition of § 346 as to any substances which might accidentally get added to the food.

Assuming the presence of heat exchangers, however, there could still be failures which allowed, e.g., toxic chemicals into the growing environment. If as a result traces of such chemicals found their way into the food, the literal terms of § 346 would prohibit the introduction of that food into interstate commerce absent the existence of a tolerance

promulgated by the FDA. Presumably at this point some practicality of approach may take over for de minimis additions: the FDA apparently has a system of informal tolerances under this section. See United States v. Ewig Bros. Co., 502 F.2d 715, 720 (7th Cir. 1974). Perhaps this would apply also in the absence of heat exchangers if the level of exposure to contaminants were sufficiently small. It should be remembered that this section applies only to added substances which are poisonous or deleterious.

Other provisions of the FDCA declare food which is filthy or decomposed, or the product of a diseased animal, or the like, to be adulterated. These prohibitions would be relevant to the actual day-to-day operation of the project, but do not present limitations upon the design of the project.

Consideration should also be given to the possible presence of contaminants in the upstream river water which is contemplated as the source for the growing environment whether or not heat exchangers are used. It has been held that mercury in swordfish is an "added substance" within the meaning of § 342(a)(1) on the theory that it does not occur naturally in the fish, but is acquired through its external food supply. United States v. An Article of Food Consisting of Cartons of Swordfish, 395 F. Supp. 1184 (S.D.N.Y. 1975). But see Note, 85 Harv. L. Rev. 1025 (1972). Similarly, the presence in fish of DDT has been held to support seizure, once the fish were smoked, as a food additive. Ewig Bros., supra. Pesticides on raw agricultural

products are governed separately under the FDCA, see §§ 342(a)(2)(B) and 346a, and tolerances have been promulgated, see 21 C.F.R. Part 193.

Vermont's Labeling of Foods, Drugs, Cosmetics and Hazardous Substances Act, Title 18 V.S.A. §§ 4501 et seq., prohibits the adulteration of any food within the state. § 4502. Adulterated food is defined, in § 4059, in terms parallel to the FDCA prior to the 1958 Amendment. Thus, food is adulterated if it contains a poisonous or deleterious substance which may render it injurious to health. If the substance is added, it adulterates the food unless it is required in production, in which case the state authorities should promulgate tolerances. § 4062. This act should not apply to the extent that provisions of the FDCA conflict with it.

II. EPA RESTRICTIONS AND PERMIT REQUIREMENTS

A. Aquaculture Regulations.

Section 318 of the Federal Water Pollution Control Act ("FWPCA"), 33 U.S.C. § 1328, authorizes the Administrator of the Environmental Protection Agency (EPA) "to permit the discharge of a specific pollutant or pollutants under controlled conditions associated with an approved aquaculture project under Federal or State supervision." Subsection (b) of section 318 empowers the Administrator to establish procedures and guidelines which he deems necessary to carry out section 318. The EPA has promulgated regulations pursuant to this provision. 42

Fed. Reg. 25,478 (1977) (to be codified at 40 C.F.R. § 115.1 et seq.).

These regulations do not apply to the Vermont Yankee aquaculture project. The scope of the aquaculture regulations is limited "to those projects which are located in navigable waters. . . ." 40 C.F.R. § 115.2(d). The regulations define "aquaculture project" as "a defined managed water area which uses discharges of pollutants into the designated project area. . . ." 40 C.F.R. § 115.1(d); "designated project area" is in turn defined as "those portions of the navigable waters within which the applicant . . . proposes to confine the cultivated species." 40 C.F.R. § 115.1(e). Also, the Supplementary Information accompanying the promulgation of the regulations states that "[a]quaculture activities not covered by these regulations are those facilities operated in ponds, silos, and other structures not within the navigable waters." 42 Fed. Reg. 25478 (1977). The Vermont Yankee hatchery is to be located in a separate building outside the Connecticut River, and therefore falls within the category of "structures not within navigable waters," and is not subject to the requirements of a permit under section 318 of the FWPCA.

B. Pollution Discharge Permits

Section 402 of the Federal Water Pollution Control Act, 33 U.S.C. § 1342, establishes the National Pollutant Discharge Elimination System ("NPDES"). This provision authorizes the Administrator of the EPA, or, where applicable, the appropriate

state permit-granting authority, to issue a permit for the discharge of any pollutant into navigable waters, provided doing so meets statutory conditions. 33 U.S.C. §§ 1342(a)(1), (b). Although "approved aquaculture projects" are excluded from this requirement, 40 C.F.R. §§ 124.21(c) and 125.4(c), other "discharges from an aquatic animal production facility" are specifically included in the requirement of an NPDES permit. 40 C.F.R. §§ 124.21(g)(2) and 125.4(i)(2), as amended, 41 Fed. Reg. 28496 (1976). Since the present project is not subject to regulations governing aquaculture projects, but is involved in production of aquatic animals, it would constitute a point source from which the discharge of pollutants requires an NPDES permit. A pollutant within the meaning of the FWPCA includes, inter alia, solid waste, chemical waste, biological materials, radioactive materials, and heat. 33 U.S.C. § 1362(6). Since the fish tanks would discharge heat, fish waste and food residues (and possibly contaminants from the circulating water system) into the Connecticut River, an interstate waterway, the aquaculture project involves discharge of pollutants into navigable waters, and requires a permit. As the result of an agreement between the EPA and the State of Vermont, the NPDES program administration is delegated to the Department of Water Resources of the Vermont Agency of Environmental Conservation. 2 State Water Regs. 93:0581 (BNA) (1974). Full guidelines for state permit requirements are set out at 40 C.F.R. § 124.1 et seq.

III. NRC LICENSING REQUIREMENTS

A. Modification of Existing Use and Production Permit.

Vermont Yankee must obtain modification of its Nuclear Regulatory Commission (NRC) license in order to use its waste heat in either project, if this use is inconsistent with procedures described in the facility's safety analysis report to the NRC, if the change in the disposal of circulating water involves a change in the technical specifications incorporated in Vermont Yankee's license, or if the change presents an unreviewed safety question. 10 C.F.R. § 50.59(a)(1). The change will be deemed to present an unreviewed safety question if it will increase the probability of the occurrence or the consequences of an accident, or if it creates the possibility of an accident or a malfunction of a different type than any previously evaluated. 10 C.F.R. § 50.59(a)(2). Vermont Yankee in any event would be required to maintain records of the changes to the facility and resultant changes in procedures, and to prepare a written safety evaluation of the change demonstrating that the latter does not present an unreviewed safety question. A description of the change and the safety evaluation must be furnished to the NRC Regional Office. 10 C.F.R. § 50.59(b). It would appear that change in the specifications of the circulating water discharge system will require a license amendment even if Vermont Yankee sees no safety problem, because the activity affects the environmental technical specifications.

B. NRC Environmental Review.

The National Environmental Policy Act of 1969 requires all Federal agencies to prepare detailed environmental impact statements on major federal actions affecting the quality of the environment. 42 U.S.C. § 4332. The NRC's policies and procedures for such environmental review in connection with the agency's licensing and regulatory activities are set out at 10 C.F.R. Part 51. These regulations require preparation of an environmental impact statement in connection with, inter alia, any action which the Commission determines is a major Commission action significantly affecting the quality of the human environment. 10 C.F.R. § 51.5(a)(10). Included among actions considered to be major Commission actions significantly affecting the quality of the human environment is any permit or license amendment which "would authorize a significant change in the types or significant increase in the amounts of effluents" 10 C.F.R. § 51.5(b)(4).

The FWPCA vests primary jurisdiction for the control of water pollution in the Environmental Protection Agency. 33 U.S.C. § 1251(d). Recognizing this, the NRC requirements for environmental review are made subject to the limitations contained in an interim policy statement published at 40 Fed. Reg. 60115 (1975); cf. 10 C.F.R. § 51.1 (c). This "second memorandum of understanding and policy statement" states that with respect to water quality standards, maximum daily loads for pollutants, and thermal loads the NRC will not impose

different limitations or requirements as a condition to any permit or license from those imposed by the EPA, provided, however, that the NRC does reserve the option to impose more stringent limitations or requirements as imposed by state law, pursuant to § 510 of the FWPCA. In addition, the NRC declaration of policies states that no alternative pollutant discharge systems will be considered by the Commission where a permit has been received or effluent limitations imposed pursuant to the FWPCA. Thus, with respect to pollution control considerations stemming from the aquaculture project, it appears that the NRC's environmental review yields to NPDES permit requirements, even where the NRC might otherwise impose more stringent standards.

The NRC, however, considers effluent limitations for nuclear material to remain within its primary jurisdiction. NRC environmental review of any change in the Vermont Yankee discharge system may therefore be required. Although the aquaculture and horticulture projects will not result in any additional radiological discharge, the proposed uses of condenser effluent may result in hazards from the accidental discharge of effluents into unrestricted areas not previously reviewed by the NRC. It therefore seems advisable to seek NRC review. Such review will not necessarily require filing of an environmental impact statement. If, upon evaluation of the proposed action, the NRC determines that an environmental impact statement need not be prepared, it may issue a "negative

declaration" explaining why an environmental impact statement is not required and that a general environmental appraisal will be made. 10 C.F.R. §51.5(c)(1).

IV. CONCLUSIONS

Since the use of nuclear power plant waste heat for aquaculture and horticulture is a relatively new phenomenon, there is little law which directly establishes standards applicable to the Vermont Yankee Waste Heat Project. The requirements affecting the project are chiefly case-by-case permit requirements of the Environmental Protection Agency and the Nuclear Regulatory Commission.

The planned discharge of pollutants into the Connecticut River will require a National Pollutant Discharge Elimination System permit from Vermont authorities. This will be a "new source" and therefore require environmental review. Amendment of Vermont Yankee's Nuclear Regulatory Commission license will be required, because of the detailed specifications in that license for discharging circulating water. NRC review of environmental questions raised by the project will be secondary to EPA and state review.

The precise application of Food, Drug and Cosmetic Act depends largely upon whether heat exchanger systems are used, and, if they are not, upon the probability that the circulating water will contain potentially unhealthy substances. If heat exchangers are used, as is generally contemplated, the FDCA

will not apply unless food accidentally becomes contaminated with poisonous or deleterious substances. If heat exchangers are not used, the Delaney Clause setting zero tolerance levels for carcinogens will still not be implicated to the extent that exposure to radioactivity is not to be expected, despite the fact that Vernon is a nuclear station: but a regulation may be required for certain chemicals or pipe residues contained in the circulating water. The Food, Drug and Cosmetic Act also would be implicated if particular food produced at the project became contaminated so as to present a health hazard.

B
APPENDIX

APPENDIX B

WASTE HEAT BOOSTING
FOR ANAEROBIC FERMENTER
EFFICIENCY IMPROVEMENT

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WASTE HEAT BOOSTING FOR ANAEROBIC FERMENTER EFFICIENCY IMPROVEMENT

Background

Bioconversion of photosynthetically fixed solar energy in existing agricultural residues has been projected to be capable of generating about one quad annually.¹ The obvious attraction of this possibility is that this is a clean, renewable source of energy, which would make use of animal wastes and other materials which have a pollutant creating potential. Energy farming has the capability of adding another 10 quads while generating several million tons of new protein in the form of bacterial cells. Thus, there is considerable interest in this topic. The objective of this summary review is to examine the potential of using the substitute natural gas generated from the residues produced on a 200 cow dairy farm to heat nuclear power plant cooling water to a level suitable for operation of greenhouses in Vermont. This analysis will be divided into a review of the feasibility of dairy residue generation, estimate of the quantity of energy available, and a determination of the quantity of cooling water which would be combined with the biogas to bring the temperature from 70°F to 85°F. Much of the quantitative data for these analyses has been reported in Jewell et al. (1976).

Historical Aspects

Anaerobic fermentation has been applied to sewage solids for digestion and stabilization for decades. However, until recently it has not been applied to animal wastes. To the best of this author's knowledge, the first full scale methane generation system in the U.S. was built by a private company in Michigan in 1974. Currently, U.S. ERDA is involved in several large scale efforts to demonstrate the feasibility of adapting this technology to agriculture. A 3 million dollar demonstration plant is now under consideration for a 10,000 head beef feedlot operation, and Cornell University has been given authority to demonstrate the technology for dairies at its research facility in Harford, New York under the direction of the author.

1. One quad is equal to 10^{15} BTU

In general, methane fermentation of agricultural residues appears to be justified only in large scale operations (greater than 1000 head) if the net methane produced is the only benefit attributed to the system. Other potential benefits include:

- conservation of nutrients
- labor reduction
- odor control
- runoff control

It can be shown that when pollution control is needed with a liquid manure handling system, and all gas can be utilized, the fermentation system can generate energy at a very low cost even in dairies with 40 cows. The feasibility is site specific in the present state of understanding.

Estimate of Agricultural Residues

One agricultural operation is located close to Vermont Yankee Nuclear Power Corporation's Vernon Plant. This is Mr. Paul Miller's dairy which appears to be one of the best operated, medium scale (200 cows) dairies in the Northeast U.S. It is also the oldest farm with registered Holstein cattle in the U.S., according to the owner.

The attached table summarizes the dairy manure production characteristics. These estimates assume that the waste is removed efficiently on a daily basis, and that the animals are confined 100 percent of the time. Although Mr. Miller does not include the milking room wastewater, it would be possible to include this in the wastes. Bedding material use in the Miller dairy includes hay and limestone. If the manure were to be used in a fermentor, the use of limestone may cause some material handling problems and may have to be modified. Limestone is most often used to prevent animals from slipping on concrete surfaces.

The make-up of a dairy with about 100 milking cows at any one time would have the characteristics illustrated in Figure 1. The average daily waste characteristics are as follows for this size of operation (all values in kg/day):

Total solids (87.8% water by weight)	8240
Total dry solids	1000
Volatile solids (82% total)	840
Total nitrogen	34
Ammonia nitrogen	18
Phosphorus	13
Potassium	29

The Miller farm has the above number of cattle with capability for increasing its numbers up to double the stated residue quantities, depending on the total numbers of animals on the farm. Note that the values quoted are for the 100-cow dairy actually represent the residue generation rate from 163 cows, with only 100 being milked at any given time. Other sizes of dairy operations can be scaled up from this data.

Fermentor Design

The bacterial anaerobic fermentation process is a complex process. Many variables such as temperature, organic residence time, and solids retention period affect the feasibility of the process. One set of design criteria which would be successful when applied to dairy wastes is as follows:

Waste volume generation rate for 100	
Milking cow operation	10.1 m ³ /day
Premix tank volume	20 m ³
Pump, rate of about	0.2 m ³ /min of about 3 gpm

Reactor Design

Hydraulic retention time	10.0 days
Temperature	35.0°C
Solids loading rate	8.3 Kg VS/m ³ -day (0.5 lb/ft ³ -day)
Total solids entering system	10.0%
Tank volume	124 m ³

Energy Production

Volatile solids destruction	32.0%
Gas produced	223 m ³ /day
Methane content	65.0%

Energy Production Potential

As indicated in the earlier table, the process operates at 35°C. Thus, in cold weather when the feed is coming into the reactor at 0°C, a substantial portion of the energy that is produced must be used to maintain the reactor temperature. The total production for the 100 cow dairy is estimated to be between 500×10^6 and 600×10^6 K cal/year. The energy required to maintain reactor temperature amounts to 200×10^6 to

Table 1: Dairy cow manure production and characteristics (based on 1,000 pound liveweight)

Parameter	Unit	Total Excrement*	
		Avg.	Range
Manure Production	kg/head/day (lbs/head/day)	38.6 (85)	32.2-49.9 (71-110)
Density	kg/ ℓ (lbs/ft ³)	0.97 (60.6)	0.94-1.00 (58.6-62)
Total solids	% TS	12.5	
	kg/head/day (lbs/head/day)	4.81 (10.6)	3.08-6.76 (6.8-14.9)
Volatile Solids	% TS	82	
	kg/head/day (lbs/head/day)	3.95 (8.7)	3.27-5.76 7.2-12.7
BOD ₅	kg/head/day (lbs/head/day)	0.700 1.55	0.44-0.83 0.98-1.84
COD	kg/head/day (lbs/head/day)	4.81 10.6	2.63-7.26 5.8-16
Total Nitrogen	% TS	3.9	
	kg/head/day (lbs/head/day)	0.19 (0.41)	0.16-0.28 0.35-0.62
Ammonia Nitrogen	kg/head/day (lbs/head/day)	0.10 (0.23)	- -
Total Phosphorus	% TS	1.5	
	kg/head/day (lbs/head/day)	0.073 (0.16)	0.032-0.18 0.07-0.39
Potassium	% TS	3.3	
	kg/head/day (lbs/head/day)	0.16 (0.35)	0.068-0.22 (0.15-0.48)

300×10^6 K cal/year or up to half the total production, when the reactors are not insulated well. By adding efficient insulation, this loss can be decreased to about 100×10^6 K cal per year, or about 20% of the produced gas. The added insulation, as polyurethane, costs about \$6000. At a present market value of about \$10 per 10^6 K cal (\$2.50 per 10^6 BTU) for the gas, the total energy savings that can be attributed to the insulation would have an annual value of about \$2000. A continuous source of 70°F water could be used to preheat the residue prior to charging the reactor and also to reduce heat loss from the reactor. Thus, the savings to be obtained from the heated water from the nuclear plant would amount to \$2000 to \$3000 per year.

Estimated Cost of Methane Generation System

A comprehensive study conducted for US ERDA (Jewell et al., 1976) estimated the lowest cost that might be involved in construction of a complete methane generation system for the size of dairy discussed earlier. This system consisted of the premix tank, pumps and piping, and reactor (including gas handling). For these different designs, the range of total expenditures was \$14,500 to \$29,500. These estimates would appear to be reasonable compared to one commercial firm recently established to build systems at this scale. This firm, Agricultural Engineering Incorporated, has quoted this type of system with an internal combustion engine and a 30KW electricity generator at between \$30,000 and \$40,000.

The estimated total annual cost of these systems (amortization, operation and maintenance) varies from \$3300 to \$7650. These estimates include a minimum amount of insulation, but do not include the benefits from having the 70°F water available for minimizing construction and reactor heating costs. At the present energy cost of about \$8 per 10^6 K cal, the annual return without the 70°F water would be about \$2400, and with maximum temperature control the gross value of the energy would be nearly double this amount. Since natural gas prices are projected to double in the near future, the energy value with and without the heated water input would be \$6000 and \$4800. As noted earlier, in some instances comparable manure handling systems that achieve odor control or reduced handling manpower commitments often cost approximately the same as the above. In these instances, the cost of the energy is greatly reduced.

Heat Recovery Potential

The value of an unlimited supply of heated water at minimum of 70°F could be significant in operating a biological fermentor at 95°F. For a 100 cow milking dairy the energy savings could result in enough to make the operation economically attractive.

Figure 1. Flow diagram of feed, milk production, and waste materials on a 100 cow free stall dairy.

There are two general requirements needed to make energy recovery attractive at the scale discussed here:

1. the cost of energy, especially natural gas, must continue to increase in value, and
2. the demand for the biogas must be constant and uniform and equal to the production.

The price of natural gas will probably continue to increase in cost. But matching the demand with the supply is much more difficult. In this case, if it is assumed that the gas can be used to increase the water temperature to a level useful for greenhouse heating, the requirements for a continuing demand may be partially satisfied.

The energy that could be supplied from the Miller farm residues of 500×10^6 K cal per year can be translated into the total quantity of water that could be heated to 85°F if the starting temperature were 70°F . Assuming that the transfer efficiency is 100 percent, the average flow during a winter day that could be heated to 85°F would be equal to 50,000 gallons. The total amount of energy and its relation to greenhouse heating needs to be examined.

Recommendations

The recovery of solar energy fixed in presently unused agricultural residues would appear to be representative of several technologies that are ready to be examined for large scale development to assist in development of new, clear renewable energy sources. However, the lack of full scale applications on common agricultural operations, such as dairies, is preventing development of costing and feasibility information needed to make key cost effective decisions. The development of a system incorporating nuclear cooling water would assist in demonstrating the feasibility of the operation as well as illustrating a useful by-product of nuclear power generation.

REFERENCES

Jewell, W. J. et al. 1976. "Bioconversion of Agricultural Wastes for Pollution Control and Energy Conservation." U.S. ERDA report TIO - 27614. Available from the NTIS system, U.S. Department of Commerce, Springfield, Virginia 22161. 321 pages.

ANNEX

Anaerobic Fermentor Design for a Dairy Farm of 200 Cows (Total)

I. Estimation of Agricultural Residues

A. Assumptions

1. Number of cows: 200 Total
123 Milking
3 Bulls
74 Replacement
2. Wastes Generated
Manure: 84 lb/1000 lb cow/day
Milking: 33.8 lb/cow/day
Bedding: 1.5 lb/replacement cow/day
4 lb/milking cow/day
Feed: 1.5 lb/cow/day
3. Combined Waste Characteristics
Total Solids (TS): 12%
Total Volatile Solids: 85%
4. Waste is removed on a daily basis and the animals are confined 100% of the time.
5. Average animal weight: 1250 lbs.

B. Waste Generation

Daily lbs of Waste Generation (Wet Basis)

	123 Milking Cows	74 Replacement Cows	3 Bulls	Total
Manure	13,161	4,086	178	17,425
Milking Center	4,153	--	--	4,153
Bedding	307	110	4	421
Feed Waste	--	--	--	244
Total Daily Waste (12% TS)				22,243 lbs

Full Strength

22,243 lbs/day $\approx$ 352 ft³/day (10 m³/day) of 12% TS Waste

Diluted to 10% TS

$$352 \text{ ft}^3/\text{day} \times \frac{12}{10} = 422 \text{ ft}^3/\text{day} (11.9 \text{ m}^3/\text{day})$$

Concentration

Volume of Waste Generation Per Day

12%

352 ft³/day (10 m³/da)

10%

422 ft³/day (11.9 m³/da)

II. Fermentor Design

Criteria

Waste flow for 200 cows	11.9 m ³ /day (422 ft ³ /da)
Premix tank volume	20 m ³
Pump rate (Feeding & recirculation)	.4 m ³ /min or 100 gpm
Hydraulic retention time	about 10 days
Temperature	35°C
Solids loading rate	8.3 Kg VS/m ³ -day (.5 lb/ft ³ -day)

Design

- Tank Volume

Hydraulic Retention Time Basis

Liquid Volume = 11.9 m³/day x 10 day HRT = 119 m³

Add about 20% for freeboard

Tank Volume = 118 + .2 x 119 = 143 m³ (5046 ft³)

- Tank Dimensions

Chose a cylindrical tank design, above ground concrete structure:

Wall thickness = 6 inches

Tank Height = 10 ft (3 m)

Tank Diameter = 25 ft (7.6 m)

III. Digester Heating Requirements

Ref: Wastewater Engineering, Metcalf and Eddy, Inc., McGraw-Hill
Book Co., New York, NY 1972 Ed.

Assume the following conditions apply.

1. Concrete digester surfaced with polyurethane insulation, above ground construction, of the following dimensions:

Total Depth 10 ft

Liquid-Depth 8 ft

Diameter 25 ft

Concrete Wall and floor thickness 6"

Concrete cover thickness 6"

Insulation thickness on walls and cover 4"

2. Heat Transfer Coefficients

Slurry - 6" concrete - 4" polyurethane-air, $U = .05 \text{ BTU/hr-ft}^2 \text{ } ^\circ\text{F}$
 Slurry - 6" concrete floor - wet soil, $U = .15 \text{ BTU/hr-ft}^2 \text{ } ^\circ\text{F}$
 Gas - 6" concrete wall or cover - 4" polyurethane-air, $U = .05 \text{ BTU/hr-ft}^2 \text{ } ^\circ\text{F}$

3. Temperatures

	Worse Case	Average Case
Digester	95°F	95°F
Air	0°F	45°F
Earth Below floor	32°F	45°F
Feed from barn	35°F	45°F

4. Areas

Wall in contact with slurry

$$A = 25 \times \pi \times 8 = 628 \text{ ft}^2$$

Wall in contact with digester gas

$$A = 25 \times \pi \times 2 = 157 \text{ ft}^2$$

Floor or Cover

$$A = \pi \left(\frac{25}{2}\right)^2 = 491$$

Calculations

1. Heat Losses

$$Q = A (T_2 - T_1) U$$

Wall in contact with slurry

$$Q = 628 \times (95-0) \times .05 = 2983 \text{ BTU/hr} \text{ Worse Case}$$

$$Q = 628 \times (95-45) \times .05 = 1570 \text{ BTU/hr} \text{ Average Case}$$

Wall and cover in contact with digester gas

$$Q = (157 + 491) \times (95-0) \times .05 = 3078 \text{ BTU/hr} \text{ Worse Case}$$

$$Q = (157 + 491) \times (95-45) \times .05 = 1620 \text{ BTU/hr} \text{ Average Case}$$

Floor

$$Q = 491 \times (95-32) \times .15 = 4640 \text{ BTU/hr} \text{ Worse Case}$$

$$Q = 491 \times (95-45) \times .15 = 3682 \text{ BTU/hr} \text{ Average Case}$$

2. Heating Requirement for the Feed

Without Preheating

$$\text{Worse Case } Q = 22243 \text{ lbs/day} \times (95-35) \times 1 \text{ BTU/lb } ^\circ\text{F} = 1.33 \times 10^6 \text{ BTU/day} \\ (55600 \text{ BTU/hr})$$

$$\text{Average Case } Q = 22243 \times (95-45) \times 1 \text{ BTU/lb } ^\circ\text{F} = 1.11 \times 10^6 \text{ BTU/day} \\ (46200 \text{ BTU/hr})$$

After Preheating to 65° F with waste heat

$$Q = 22243 \text{ lbs/day (95-65)} \times 1 \text{ BTU/lb} \cdot ^\circ\text{F} = .67 \times 10^6 \text{ BTU/day} \\ (28000 \text{ BTU/hr})$$

- Summary of Heating Requirements -

BTU/hr Heating Requirements

		Walls and cover	Floor	Influent Heating	Total
Without Power					
Plant Waste	Worse Case	6060	4640	55,600	66,330
Heat Usage	Average Case	3190	3680	46,200	53,070
With Power					
Plant Waste	Worse Case	6060	4640	28,000	38,700
Heat Usage	Average Case	3190	3680	28,000	34,870

IV. Digester Gas Yield Estimates

Volatile Solids Destroyed	: 32% or 726 lbs/day (330 Kg/day)
Biogas Produced	: 9682 ft ³ /day (275 m ³ /day)
Methane Produced*	: 5809 ft ³ /day (165 m ³ /day)
Gross BTU output	: 242,000 BTU/hr

Digester Energy Balance
BTU/hr

	Gross Production	Digester Heat Losses	Influent Heat Requirement	=	Net BTU/hr Output
Without Power					
Plant Waste	Worse Case 242,000	10,700	55,600		175,700
Heat Usage	Average Case 242,000	6,870	46,200		188,900
Usage					
With Power					
Plant Waste	Worse Case 242,000	10,700	28,000		203,300
Heat Usage	Average Case 242,000	6,870	28,000		207,100

*Gross methane production calculated from the estimated volatile solids destruction:
 $2 \text{ Methane @ STP} = .5 \text{ l/gVS}_D \times \text{g Volatile solids destroyed.}$

V. Holding Pond

Criteria

4 month holding capacity
100% over design

Design

Waste flow = $422 \text{ ft}^3/\text{day} = 50460 \text{ ft}^3/120 \text{ days}$

4 month waste generation = $422 \text{ ft}^3/\text{day} \times 120 \text{ days} = 50640 \text{ ft}^3$

Average rainfall from Vermont - 36 - 48 inches/year

Overdesign to accommodate precipitation = 50%

Total Pond Volume $\approx 50,640 \times 1.5 = 75960 \text{ ft}^3$

Pond Dimensions:

Length 125 ft
Width 125 ft
Depth 8 ft + 2 ft freeboard = 10 ft
3 sides sloped 2:1 (see diagram)
1 side sloped 3:1 (Ramp)

Figure 2. Schematic of Heated Digester System.

(a) Liquids stored in holding pond.

(b) Unloading with horizontal pump.

Figure 3. Diagrams of Holding Pond.

C

APPENDIX

APPENDIX C

WASTE HEAT UTILIZATION
DEMONSTRATION GREENHOUSE
DESIGN CONCEPT

VERMONT YANKEE NUCLEAR POWER CORPORATION
Rutland, Vermont

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July 1977

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WASTE HEAT UTILIZATION DEMONSTRATION GREENHOUSE DESIGN CONCEPT

INTRODUCTION

The concepts designed and described in this report are recommended for developing a demonstration greenhouse complex to use waste heat from the Vermont Yankee Nuclear Power Corp. plant near Vernon, Vermont. The greenhouse complex is part of a total demonstration of waste heat utilization at the site. A companion aquaculture demonstration unit is located at the same site.

Because this concept is for demonstration and testing, four different heating techniques are to be demonstrated. Each of the four greenhouses will be heated either directly or indirectly by warm water 70°F from the nuclear power plant.

A recommended crop and cropping pattern is given for each greenhouse. The greenhouse units may be used by universities or other research groups in the area for experimentation and testing of plants and production schemes.

After initial testing of the heating systems, one or more of the designs may be scaled up to a large commercial production unit. Data collected from the demonstration units will be made available for analysis and used to project large scale operations. The layout of the demonstration units is illustrated in figure 1.

DESCRIPTION OF DEMONSTRATION COMPLEX

The greenhouse heating demonstration concept is divided into four units. Each unit includes a 26' x 60' greenhouse designed for maximum solar utilization and reduced external heat loss. The greenhouse is designed with a large south facing transparent surface (double layer polyethylene) and an insulated north wall with high light reflective internal surface. This design provides for increased light levels inside the greenhouse when compared with conventional greenhouse designs. The heat loss is reduced by approximately 60% over conventional designs. (See figure 1.)

Each of the four greenhouses are heated either directly with the warm water from the power plant or indirectly utilizing the warm water to assist a heat pump and to produce methane gas from an anaerobic digester located on a nearby dairy farm.

GREENHOUSE WASTE HEAT UTILIZATION COMPLEX DEMONSTRATION UNITS

FIG. 1. LAYOUT OF THE GREENHOUSE COMPLEX

Greenhouse No. 1: Solar Greenhouse

This greenhouse is equipped to store excess solar energy collected by the greenhouse in gravel storage benches located inside the greenhouse. The heat is recovered from the gravel storage for nighttime heating. In addition to the solar collection and storage, a commercial water-to-air heat exchanger is utilized. A backup 9.5 kw electric resistance heater is included in the design.

No external solar collectors are utilized as the greenhouse itself acts as the collector. The gravel storage units inside the greenhouse double as the growing benches. An air handling unit was designed to collect excess heat and deliver it to the gravel storage.

Greenhouse No. 2: Heat Pump

The same basic greenhouse design is utilized without the solar storage units. In this house, a water-to-air heat pump is utilized with a constant source of 70°F water supplied by the power plant. The operating coefficient of performance (COP) for the water-to-air heat pump is approximately equal to 3 compared to 1.75-2.0 for air-to-air units now commonly used.

In addition to the heat pump, one water-to-air heat exchanger (commercial unit) will be utilized for base load heating. The heat pump will be utilized as an assist during the coldest operating periods. There is no other backup heating provided for this house, as the heat pump is designed to meet the greenhouse design temperature requirements at the outdoor design temperature of -15°F.

Greenhouse No. 3: Rutgers' Design

This design is likely to be the most controversial and may be omitted if regulations on direct use of the warm water is prohibited. In this house, the floor is constructed from porous concrete and warmed water is flowing through a gravel bed beneath the floor.

Low temperature-low cost heat exchangers are designed to utilize the warm water directly. Porous pipes are draped with polyethylene sheets the full length of the house in five separate rows. Water flows from the porous pipe down between the plastic sheets and through the porous concrete floor.

The pipes draped with plastic may be raised at night for maximum heat exchange and lowered during the day when less heat is required and more light utilized at the plant level.

In this house, one commercial water-to-air heat exchanger is utilized to assist the plastic heat exchangers. The two exchangers are designed to maintain a minimum 50°F in the greenhouse on the coldest nights. Because of the limited temperature conditions, it is suggested that this house be utilized for cooler temperature potted plants.

Greenhouse No. 4: Methane House

This house is the most unique of all and the total heating is provided by methane gas produced on a nearby dairy farm. The manure from about 200 dairy cows is converted to methane gas in an anaerobic digester located on the farm. The gas is piped to the greenhouse by underground pipeline.

Gas unit heaters (2) are utilized to provide the total heating of the greenhouse. Sufficient gas will be produced to maintain maximum temperatures of 65-70°F on a continuous basis. Because of the capability of maintaining the higher temperatures, either roses or cucumbers are suggested as ideal crops for this house.

The warm water from the power plant is utilized indirectly in this instance. The anaerobic digester must be maintained at 90-95°F for maximum gas production. The 70°F water from the power plant assists in maintaining the higher temperature in the digester and more gas is available for outside uses. Without the assistance of the warm power plant water, nearly one-half of the methane gas produced would be required to maintain the 90-95°F in the digester. With the warm water, only 20% of the gas produced will be required by the digester.

In addition to the greenhouses, a head house is required and also space for scientists to collect data from the demonstration units and for visitors to observe the facilities.

DEMONSTRATION GREENHOUSE DESIGNS

Energy Conserving Basic Greenhouse Design

Greenhouses have historically not been designed with energy conservation in mind. The design suggested here incorporates a shape and construction materials to optimize on the collection of solar energy while reducing the heat losses from

the structure. A descriptive sketch for the greenhouse structure is included with this report. The heating systems to utilize the warmed water discharge from the power plant condenser are all utilized within the basic greenhouse design.

For comparison, the heat loss from a conventional greenhouse at the outside design temperature of -15°F and inside design temperature of 65°F is calculated to be about 240,000 BTU/hr. The heat loss from the energy conserving design is calculated to be about 100,000 BTU/hr under the same design conditions or about 60% less than the conventional house.

The key to utilization of low temperature heat such as the power plant discharge or solar energy is to reduce the heat losses to a reasonable level.

Four different experimental greenhouse heating system designs are suggested for the Vernon plant. Each greenhouse will be the basic nominal 26' x 60' and incorporate the proper shape and orientation for maximum solar utilization and minimum heat loss from the structure. The standard greenhouse design is illustrated in Figures 2 and 3.

Each greenhouse except the methane unit will be partially heated with the 70°F discharge water from the power plant condenser discharge. The greenhouse units will utilize water-to-air heat exchanger units similar to the Trane centrifugal air handler with fin tube heat exchanger units used in the Northern States Power demonstration unit. The units may be purchased from the manufacturer with the specifications provided in the design criteria.

The four greenhouses will incorporate a different heating technique. Greenhouse No. 1 will be equipped to collect and store excess solar energy to partially offset the heating requirements. The design for greenhouse No. 1 is illustrated in Figures 4, 5 and 6. Greenhouse No. 2 will include the use of a warm water assisted heat pump to provide for a COP of approximately 3. The heat pump will be assisted by one water-to-air fin tube heat exchanger. The design for greenhouse No. 2 is illustrated in Figure 7. Greenhouse No. 3 will be referred to as the Rutgers design and incorporates the technique of underfloor supply of warm water (70°F) from the power plant using a porous concrete floor. Low cost-low temperature heat exchangers are designed for additional heating using the condenser water. The greenhouse No. 3 design is illustrated in Figures 9, 10, 11 & 12. The final greenhouse design, greenhouse No. 4 will be partially heated using methane gas generated from an anaerobic digester located on a nearby dairy farm. Greenhouse No. 4 design is illustrated in Figure 8.

FIG. 2. END CROSSECTION OF BASIC GREENHOUSE

PLAN VIEW

FIG. 3. PLAN VIEW OF BASIC GREENHOUSE

PLAN

FIG. 4. PLAN VIEW OF SOLAR HOUSE

SECTION

SOLAR ASSISTED WITH WATER TO AIR
HEAT EXCHANGER SYSTEM

FIG.5. END CROSSECTION VIEW OF SOLAR HOUSE

COLLECTION — DISTRIBUTION MODES

FIG. 6. DIAGRAM OF SOLAR COLLECTION AND STORAGE

WATER TO AIR HEAT PUMP SYSTEM

FIG.7. HEAT PUMP PLAN VIEW

METHANE GAS HEATING SYSTEM

FIG.8. PLAN VIEW OF METHANE UNIT

PLAN

FIG. 9. PLAN OF RUTGERS' GREENHOUSE

SECTION

RUTGERS' GREENHOUSE FLOOR AND VINYL CURTAIN
HEAT EXCHANGER SYSTEM

FIG. 10. END CROSSECTION OF RUTGERS' GREENHOUSE

FIG.II. PLASTIC VERTICAL CURTAIN HEAT EXCHANGER

FIG. 12. POROUS CONCRETE FLOOR CROSS SECTION

The greenhouse may be arranged as desired on the Vernon plant property. A suggested layout is given in Figure 1. The warm water supply may be taken directly from the discharge canal for use in greenhouse heating. The exception to this may be the Rutgers design. If the use of the warmed water directly is prohibited by federal or state regulations, the Rutgers design may either be eliminated or water supplied from a heat exchanger similar to the one designed to supply warmed water for the aquaculture unit.

A. Heat Loss Estimates for the Basic Greenhouse Design

Design Criteria:

1. 26' x 60'
2. East-west orientation
3. Climatic conditions for southern Vermont
 - a) winter design temperature = -15°F
 - b) greenhouse inside temperature = 50°F (night)
= 65°F (day)
4. Percent possible sunshine during winter = 40%
5. Insulated north wall R = 16
6. South slope elevation = 38° from horizontal

Heat Loss Estimates:

Floor	9,153.7 BTU/hr
Thermal Radiation Exchange	30,164.1 BTU/hr
Cover Loss: Transparent surface	66,992.1 BTU/hr
Insulated surface	
Infiltration Loss	15,173.7 BTU/hr
(2 air changes/hour)	
TOTAL	121,413.6 BTU/hr

If inside temperature is maintained at 65°F the total heat loss estimate is 152,513 BTU/hr. The use of a black cloth curtain drawn over the transparent surfaces have been shown to reduce nighttime heat loss by up to 50%. Using a more conservative factor of 1/4 reduction, the nighttime heat loss estimate is 91,086 BTU/hr at 50°F minimum and 114,384 BTU/hr at 65°F minimum.

B. Solar Greenhouse Design Specifications (Greenhouse No. 1):

Design Criteria:

1. Latitude 43.6
2. Clear Sky
 - a) insulated surface absorptivity = 0.9
 - b) non-insulated surface = 0.21

Total Daily Solar Gain on a Clear Day:

1. Transparent south surface	= 1,614,693.3 BTU
2. Transparent east and west surface	= 133,433.9 BTU
3. North insulated surface	= 16,422.3 BTU
4. South facing insulated surface	= 46,676.2 BTU
TOTAL DAILY SOLAR GAIN	= 1,811,255.7 BTU

Heat Storage:

1. 60 tons of crushed rock may be stored in the benches
2. Assuming 50°F of useful collection (100°F max rock temperature), the amount of heat that can be put in the rocks is 1,200,000 BTU's.
3. The nighttime heat requirements to maintain the greenhouse at 50°F using the black cloth system was 91,086 BTU/hr.
4. Therefore, reclaiming the stored heat from the rock storage would provide approximately 14 hours of heating.
5. It is evident from the calculation of total solar gain on a clear day that on a typical winter day 1,200,000 BTU's of solar energy will not be available for storage. The gravel storage may provide heat for 3 to 4 hours of nighttime heating during the design winter period; however, during the spring and fall periods up to 100% of the heating may be offset from the solar collection and storage of excess heat.

Water-to-Air Heat Exchangers:

The commercial fin tube heat exchanger with centrifugal air flow delivery will provide 82,000 BTU/hr if the entering water temperature is 70°F and the entering air has a temperature of 50°F. The water flow rate should be 29 gallons per minute and the air flow rate should be 7000 cfm.

If the water temperature is 75°F with all other parameters the same, the heat exchanger could provide 103,000 BTU/hr.

The suggested exchanger units are available from the Trane Company.

Specifications: Fan (L-12, 7000 cfm)
Coil (Series 16 with 3 rows of tubes)
Motor (3 HP)
Filter and mixing (M-90)

Therefore, given the nighttime maximum heat loss rate of 91,086 BTU/hr to maintain 50°F minimum temperatures in the greenhouse, the solar heating with storage and the use of two fin tube water-to-air heat exchanger units should ensure the necessary heating requirements. To maintain 65°F in the greenhouse would also be possible, however, long periods of cloudy weather would place the heating at the very limits of the design.

C. Heat Pump Heated Greenhouse (Greenhouse No.2):

The heat pump will operate at a constant COP of approximately 3 and therefore a commercial heat pump may be selected to supply 160,000 BTU's per hour to maintain the greenhouse at 65°F minimum temperature. Carrier model 2400 or equivalent from Westinghouse or General Electric will be satisfactory.

If the water-to-air heat exchanger is included in the greenhouse design, the heat pump capacity could be reduced by about 1/2. One unit is being recommended to help off-set heating cost.

The value of the warm water supplied to the heat pump would increase the overall winter heating COP from about 1.75 to approximately 3. The electric energy required to heat the greenhouse is obviously 1/3 that of direct resistance heating and a little less than 2/3 that without the 70°F source of water. The heat pump allows for higher operating temperatures in this house for cucumber production.

Annual estimated electrical use for heat pump:

Criteria: 65°F (minimum temperature)
114,384 BTU/hr (max. heat loss)
7800 (degree days)
32°F (average winter temp.)
70°F (average inside temp.)

Annual total electricity required for heating with water-to-air heat pump is:

21,308 Kwhr @ 4¢/Kwhr = \$852.00

Direct resistance electric heating would result in 63,925 Kwhr total and at 4¢/Kwhr the annual cost would be \$2,557.00. Therefore, the annual savings by use of the heat pump over direct resistance heating is about \$1700.00

The air-to-air heat pump would require about 36,500 Kwhr annually at a cost of about \$1461.00. Therefore, the value of the warm water from the power plant for greenhouse heating for the 26' x 60' demonstration greenhouse is \$609.00 annually.

As a further comparison, the annual cost for heating the greenhouse with #2 fuel oil is estimated to be \$1239 if #2 fuel oil costs 50¢/gal. Therefore, the warm water assisted heat pump would save approximately \$400 per year when compared to the use of fuel oil for heating in the No. 2 greenhouse.

The above comparison is given for the situation where all the heating is done by the heat pump. In greenhouse No. 2, the heat pump cost is also offset by the use of the water-to-air heat exchanger. The estimated total electric cost when using both units is \$420 annually.

D. Rutgers Greenhouse Design (Greenhouse No. 3):

The exchanger consists of a single sheet of plastic film draped over a supporting member and hanging down to the floor on each side (see Figure 11). A trickle irrigation device, twin wall hose, is attached to the supporting member under the film. Warm water supplied by the power plant condenser discharge is pumped from the floor storage into the twinwall hose and flows by gravity between and down inside surfaces of the plastic sheet onto the floor. Since the floor is constructed of porous concrete, no collecting device is needed and the water returns to the storage area directly under the floor. Tests conducted by Rutgers on this

exchanger design indicate an overall heat transfer coefficient of 0.95 BTU/hr/ft²/°F when there is a 7°F temperature difference between the average heat exchanger temperature and inside ambient. The plastic exchangers can be elevated or dropped during the day to avoid shading the crops. Minimum pump horsepower is required because the storage is just below the floor and the twinwall hose operates at low pressure. Evaporation is limited because the water runs between the layers of film.

- Criteria:
1. 5 heat exchanger poly curtains
 2. Curtains elevated to 4' maximum
 3. Total curtain area = 2400 ft²
 4. 1/2 floor area is also available for heat exchange
 5. Condenser water at 70°F is available in continuous supply
 6. Total water flow (60 gpm)

Heating supplied by curtain exchanger and floor:

Using the heat transfer coefficient of 1.53 as suggested by Rutgers design:

Total heat transfer = 73,000 BTU/hr.

The Rutgers design alone will not be adequate to provide minimum 50°F night-time heating requirements. Condenser water at 75° would satisfy the heating requirements. The addition of one water-to-air heat exchanger unit will satisfy the heating requirements for the Rutgers design. (See Figures 9, 10, 11 and 12.)

E. Methane Heated Greenhouse (Greenhouse No. 4):

- Criteria:
1. Actual digester design data supplied by Dr. W. J. Jewell.
 2. Estimated daily production for winter conditions for the 200 cow dairy is approximately 200,000 BTU/hr.

Design Requirements:

If 200,000 BTU/hr were to be available on a continuous basis from the dairy farm, the methane greenhouse could be maintained at 65°F or higher on a continuous basis with some additional gas available for water heating or other uses at the dairy farm.

The greenhouse should be designed for two, gas-fired, unit heaters to deliver 100,000 BTU's each. (See Figure 8.)

F. Summer Cooling (Ventilation):

Criteria: 1. Summer design temperature

Dry bulb temperature = 90°F

Wet bulb temperature = 73°F

With these outdoor design conditions and using one air change per minute the inside temperature will rise a maximum of 8 to 10°F over outside temperatures. Inside temperatures could reach as high as 110°F on the hottest summer days.

The recommended fan capacity for one air change per minute for the basic greenhouse design is:

13,200 ft³/min.

G. Maximum total water flow from the power plant to the demonstration greenhouse complex is 200 GPM.

POTENTIAL GREENHOUSE CROPS

Vegetables

Tomatoes, lettuce and cucumbers are the most typical greenhouse vegetable crops. Because of high heating requirements and low light intensities during the midwinter months, very little vegetable greenhouse production still exists in the northeast area. Vegetables are grown in southern and western areas and shipped to the northeast.

Increased transportation costs may gradually cause a shift back to greenhouse vegetable production in the northeast. New Jersey still has a sizable tomato greenhouse production.

Tomatoes have historically been a high yielding, high value crop. In a well managed greenhouse, the potential yield of tomatoes is 80-105 tons per acre per year (two crops). While higher yields have been reported they are rare and cannot be counted on. A figure of about 90 tons/year per acre would seem closer. Yields of the spring crop may be almost twice that of the fall crop. The optimum temperature range of tomatoes is near 70°F. (Optimum temperature of crops is important, not only because it indicates the best growing range, but also because it can save money for the operator if seasonal changes of temperature are accounted for.) The wholesale price for tomatoes varies from 45¢/lb to 60¢/lb.

Lettuce is a cool weather crop. The optimum temperature range is 55-60°F, and it will grow well in mid-winter. It matures in 8-10 weeks in the spring, or up to 15 weeks during the winter. There are several types of lettuce. Bibbs lettuce commonly yields about one 5 lb. basket per 10 sq. ft. of greenhouse and has a value ranging from \$3.00 - \$5.00 per 5 lb. basket. Another variety, Grand Rapids, may yield twice as much as Bibbs but sells for about half the price.

Cucumbers are semi-tropical plants that grow best under conditions of high temperature, high humidity, high light intensity and high moisture. There are two major types of cucumbers, the regular type, and a new seedless type (English seedless). Both have optimum temperatures in the 80-85°F range and thus are usually grown as a late spring crop. The seedless type is rapidly gaining in popularity, and because it cannot be pollenized it must be grown in greenhouses. It thus makes an excellent summer crop for greenhouse production. The seedless sells at a much higher price, 30-40¢/cucumber, compared to 15-20¢/cucumber for the regular type. The yield per acre per crop is approximately 8000-8600 dozen/acre. If grown the year around, one could get about 5 crops for a maximum of 518,000 lbs. of cucumbers per acre.

Other vegetables, such as radishes (optimum temperature 60-70°F) could also be grown. Their value on the market is much less and are not normally included in production schemes.

Cropping Patterns

Using the crop information and incorporating growing time, temperature, planting procedures, etc., several crop patterns are possible. All of the following can be found in greenhouses in the northeast area, although some may be on a very small scale.

Plan	Fall (Early Winter)	Mid-Winter	Spring	Summer
1	Tomato		Tomato	
2	Tomato		Cucumber	
3	Tomato	Lettuce	Cucumber	
4	Lettuce		Tomato	
5	Lettuce	Lettuce	Tomato	
6	Lettuce	Lettuce	Cucumber	
7	Lettuce	Lettuce	Lettuce	
8	Tomato	Lettuce	Tomato	Seedless Cucumber
9	Cucumber Crop Year Around (more than 5 crops)			
10	Tomato	Lettuce	Tomato	

- Plan #1: a) Tomatoes: seed sown Oct. 25 to Nov. 10. Plants set in houses about Jan. 10, vines removed July 1 to Aug. 1.
b) Tomatoes: seed sown June 15 to July 1. Plants set in houses Aug. 1-15, vines removed Dec. 15 to Jan. 1.
- Plan #2: Similar to #1.
- Plan #3: a) Tomato: seed sown July 1-15. Plants set in houses Aug. 15-30, vines removed Dec. 15-31.
b) Lettuce: seed sown Nov. 15-30. Plants set in houses Dec. 15-31. Crop harvested March 15-31.
c) Cucumbers: seed sown Feb. 1-15. Plants set in houses April 1-15, vines removed July 1-15.
- Plan #4: a) Lettuce: anytime early fall or mid-winter.
b) Tomatoes
- Plan #5: a) Lettuce: one early fall planting, seed sown Aug. to Sept., transplanted in late Sept., harvest late Oct. and early Nov.
b) Second crop seeded late Oct., transplanted in mid-Nov., harvester in Feb.
- Plan #6: Similar to #5.
- Plan #7: Same as #5, only continue with lettuce.
- Plan #8: Same as #3, except substitute tomatoes for late spring crop, and grow seedless cucumbers in summer months.
- Plan #9: Self explanatory.
- Plan #10: Derived from Plan #8.

Table 1. Approximate Yields

Plan		Yield
1	Tomato-Tomato	90 tons/acre
2	Tomato	*30 tons/acre
	Cucumber	8600 doz/acre
3	Tomato	30 tons/acre
	Lettuce	43,560 lbs/acre
	Cucumber	8600 doz/acre
4	Lettuce	43,560 lbs/acre
	Tomato	60 tons/acre
5	Lettuce	
	Lettuce	2 x 43,560 lbs/acre
	Tomato	60 tons/acre
6	Lettuce	
	Lettuce	2 x 43,560 lbs/acre
	Cucumber	8600 doz/acre
7	Lettuce	
	Lettuce	
	Lettuce	3 x 43,560 lbs/acre
8	Tomato	30 tons/acre
	Lettuce	43,560 lbs/acre
	Tomato	60 tons/acre
	Cucumber	8600 doz/acre
9	Cucumber (all year)	518,000 lbs/acre
10	Tomato	30 tons/acre
	Lettuce	43,560 lbs/acre
	Tomato	60 tons/acre

*It was assumed spring tomato production to be two times that in the fall.

Other crops

The more common and more profitable use of greenhouses in the northeast in recent years has been for floriculture production. Greenhouse temperatures in the range of 55-60°F is acceptable for growing roses, tree seedlings, snapdragons, and many varieties of potted plants. Roses grow best in a temperature above 65°F but will tolerate periods of temperatures below 50°F.

Under the present market structure, the profit from the production of flowers will generally be greater than vegetable production and involves less fluctuation in market price.

Background on Commercial Flower Production

Managers of greenhouse floriculture firms generally produce crops from propagation material (plant cuttings, bulbs, started plants, seeds) provided by a relatively small number of national propagation firms. These firms have elaborate propagation, production and distribution operations which enable them to provide growers with disease-free, pest-free propagation material of high quality at the precise time the grower requires it for his production program.

A commercial greenhouse flower grower manages production to ensure maximum use of greenhouse production area each week of the year. In order to effectively serve his markets, a grower of cut flowers develops tightly scheduled crop rotations which enable him to place a specified amount of cut flowers in the market each week. He supplements this production with additional units of crops for major holiday and special occasion markets, e.g., Easter, Christmas, peak wedding months, etc.

Roses, orchids and carnations, all major cut flower crops, are produced on 4-year, 3-6 year and 1-2 year rotations, respectively. A rose grower orders planting stock to be grown for his purposes often a year or more before it is required for benching. The cost of plants and of the labor and other activity involved in planting represents a significant cost input. Most growers capitalize their rose plants and depreciate the investment over the 4-year production period. Orchids represent an even greater investment per plant with 3-6 year rotations common. Carnation crops are managed in a similar way but generally only over a 1-2 year period. Loss of these crops as a result of interruption of heat would result in loss of a substantial portion of a multi-year investment.

Chrysanthemums, snapdragons, asters, bulb crops and most other cut flower crops are produced on 3-4 month rotations planned to provide weekly marketings on a year-round basis. While there is considerably less investment in planting stock for these crops than for roses, orchids and carnations, there is nonetheless a considerable financial investment. Producers of potted crops and garden bedding plants are similarly dependent upon national suppliers for the seeds, cuttings, bulbs and stock plants with which crops are initiated. Potted crops grown include poinsettias, Easter lilies, tulips, daffodils, hyacinths, azaleas, chrysanthemums, hydrangeas and geraniums.

In the case of some greenhouse crops and especially geraniums, poinsettias, and foliage plants, stock plants are grown by producers for the purpose of providing propagation material from which to initiate final crops for market. For example, potted geraniums produced for spring sales are often propagated from cuttings taken from large stock plants started the previous summer, and grown through the fall, winter and early spring. Growers essentially store cuttings of the large stock plants so as to have considerable amounts of cuttings available from which to start the major finished crops. A heating interruption that resulted in the loss of these stock plants would essentially eliminate the opportunity for the grower as well as the other growers whom he supplies to have a source of propagation material for these crops.

SUGGESTED PLANTINGS FOR DEMONSTRATION GREENHOUSES (Varieties and Schedule)

A. Greenhouse No. 1

1. Set plants August 1-15 - Tomato (Vendor or Michiana 140)
2. Remove vines Dec. 15-31
3. Set plants Dec. 15-31 - Lettuce (Bibbs)
4. Harvest March 15-31
6. Set plants April 1-15 - Tomato (Vendor or Michiana 140)
8. Vines removed July 1-15

B. Greenhouse No. 2

Cucumber crop year around
5 crops total (English Seedless)

C. Greenhouse No. 3

Potted plants, cut flowers

Variety of species planted to meet special holidays

Chrysanthemums (new variety - cool temp.)

Snappedragons (grow well at low temp.)

Asters

Poinsettias

Easter lilies

Geraniums

Hydrangeas

Best bet: Snapdragons (can grow at 50-55°F)

One bench of chrysanthemums of the new variety that grow well at low temperatures (ask plant salesman for new variety)

D. Greenhouse No. 4

The color and variety of roses grown depends on the needs of the sales outlets in the area. The following may be grown:

1. Red (most standard color)
 - a) Forever Yours (most common variety)
 - b) American Beauty (second most common)
 - c) Samanathe (new variety - very good so far)
2. White - White Butterfly (most common)
3. Yellow
 - a) Golden Fantasy
 - b) Golden Wave
4. Pink
 - a) Sonia (grows well)

Sweetheart varieties suggested are:

1. Red (Mary Devor)
2. Pink (Bridal Pink or Carol Amling)
3. Yellow (Golden Garnett)

Suggested best combination:

2/3 of house - Red (Forever Yours)

1/3 of house - Pink Sweetheart (Bridal Pink)

A period of 6-8 weeks elapses between cuttings from same stem so a limited number of varieties can be effectively grown in one 26' x 60' house.

DEMONSTRATION GREENHOUSES

COST ESTIMATES

(Initial Costs)

The cost of materials and labor for construction of the basic greenhouse is broken down as follows:

1. Materials (26' x 60' unit)	\$2475.00
2. Erection (labor)	1050.00
3. Ventilation Fan (13,000 cfm)	425.00
4. Basic wiring, lighting, etc.	275.00
5. Black cloth for night heat retention	175.00
6. Miscellaneous	125.00
TOTAL	<u>\$4525.00</u>

The individual demonstration greenhouse costs are estimated as follows:

A. Greenhouse No. 1 (Solar, waste heat)

1. Basic greenhouse	\$4525.00
2. Rock storage units (200')	600.00
3. Rocks (No. 3 crusher run)	325.00
4. Air handling duct	275.00
5. Collection fan	225.00
6. Discharge fan	225.00
7. Controls	175.00
8. Centrifugal water-to-air heat exchangers (2) (Trane Co.)	3200.00
9. Pipe and plumbing for Trane units	625.00
10. Miscellaneous	500.00

TOTAL \$10,675.00

B. Greenhouse No. 2 (Heat Pump)

1. Basic greenhouse unit	\$4525.00
2. Heat pump (Carrier Model 2400 or equivalent) 200,000 BTU/hr rating	3750.00
3. Plumbing and controls for heat pump (including wiring)	375.00
4. Polytube air distribution	65.00
5. Centrifugal water-to-air heat exchanger (Trane Co.)	1600.00
6. Plumbing and controls for Trane unit	350.00
7. Miscellaneous	500.00
TOTAL	<u>\$11,165.00</u>

C. Greenhouse No. 3 (Rutger's Design)

1. Basic greenhouse unit	\$4525.00
2. Porous concrete floor	1500.00
3. Vinyl liner	550.00
4. Polyethylene curtain heat exchangers (5)	850.00
5. Centrifugal water-to-air heat exchanger (Trane Co.)	1600.00
6. Plumbing and drains for under floor water reservoir	850.00
7. Plumbing and controls for Trane unit	350.00
8. Miscellaneous	500.00
TOTAL	<u>\$10,725.00</u>

D. Greenhouse No. 4 (Methane)

1. Basic greenhouse unit	\$4525.00
2. Unit gas heaters (2) (100,000 BTU/hr each)	1650.00
3. Wiring and controls	325.00
4. Plumbing for gas supply at greenhouse only	225.00
5. Polytube air distribution	130.00
6. Miscellaneous	500.00
TOTAL	<u>\$7,355.00</u>

E. Headhouse for storage and handling and office space
(Rough estimate) \$18,000.00

F. Greenhouse Operational Equipment

1. Tools	\$ 600.00
2. Watering systems	1200.00
3. Soil	550.00
4. Miscellaneous	1000.00
TOTAL	<u>\$3350.00</u>

TOTAL INITIAL INVESTMENT \$61,270.00

COST ESTIMATES
(Annual Operating)

A. Labor

1. Horticulturist

Salary and Fringes \$9600.00

2. Part-time maintenance 4600.00

3. Part-time workers 2000.00

TOTAL \$16,200.00

B. Fertilizers, pesticides \$375.00

C. Vehicle (dep. and oper.) \$1800.00

D. Electricity \$1250.00

E. Plants, seeds, etc. \$250.00

F. Miscellaneous \$500.00

TOTAL \$20,375.00

ESTIMATE PRODUCTION INCOME

(Annual)

1. Greenhouse No. 1

a) Tomatoes (full crop)

6#/plant, 390 plants/house @ 50¢/lb. \$1170.00

b) Lettuce (winter)

546.00

c) Tomatoes (spring crop)

14#/plant, 390 plants/house @ 50¢/lb. 3276.00

TOTAL \$4992.00/yr.

2. Greenhouse No. 2

Cucumbers (English Seedless)

5 crops (3438 cucumbers/crop)

@ 40¢/cucumber \$6876.00

3. Greenhouse No. 3

Snapdragons

1 Bench of Chrysanthemums \$6380.00

4. Greenhouse No. 4

2/3 Red Roses (Forever Yours)

1/3 Sweetheart Roses (Bridal Pink) \$7962.00

TOTAL GROSS INCOME \$26,210.00

GREENHOUSE HEATING SYSTEMS AND
HEAT LOSS CALCULATION TECHNIQUE

Heating System Efficiencies

The following is a list of efficiencies for various systems, as given by the American Society of Heating, Refrigerating, and Air Conditioning Engineers Guide (the ASHRAE Guide).

Table 2. Heating System Efficiencies

<u>Type of Unit</u>	<u>Efficiency</u>
Gas (designed unit)	70-80%
Gas (conversion unit)	60-80%
Oil (designed unit)	65-80%
Oil (conversion unit)	60-80%
Bituminous coal (hand fired, with controls)	50-65%
Bituminous coal (hand fired, without controls)	40-60%
Bituminous coal (stoker fired)	50-70%
Anthracite coal (hand fired, with controls)	50-65%
Anthracite coal (stoker fired)	60-80%
Coke (hand fired, with controls)	60-80%
Coke (hand fired, without controls)	50-65%
Electric	90-99%

These figures are for efficiency of utilization, not furnace (or conversion fuel) efficiency. These figures reflect the heat actually delivered to the structure after accounting for such things as heating effects from the chimney, flue losses, etc.

It can be seen that due to the large number of overlapping ranges, and from the vast number of alternatives known to exist within each general area, that efficiency alone is not the sole basis for selecting a system.

Choose a system by accounting for the capital cost, and then calculating operating costs based on efficiencies, fuel choice, etc. (The method used to do this will be included.) However, this must be done for specific cases, with specific problems and equipment in mind.

Unit Heaters vs. Central Heating

It is generally agreed that for small greenhouses (under 20,000 sq. ft.) hot air unit heaters are the most economical to operate. The biggest problem with hot air heaters was delivering the heated air uniformly over an area without causing undue drafts. Poly tubing and various venting systems have largely taken care of this problem.

For heating larger areas, (on the order of more than an acre under glass) unit heaters cost about the same as using a central system. (This explains why even large scale operations are often heated with unit heaters.) There is a point, however, when operating one large central system requires less continual maintenance than the constant checking of each unit heater. Since costs may still be similar, this is more of a matter of individual preference for each greenhouse operator.

There are advantages to starting with glass if the capital is available. This is because: (1) the plastic will probably have to be replaced every year, at a cost of about \$.21/sq. ft.; (2) the plastic houses cannot be depreciated as glass houses can because they are often not considered "permanent" structures; and (3) plastic, in general, will not transmit light as well as glass, and may have more condensation problems. (Plastic houses may, on the other hand, have lower heating costs as their heat loss coefficient is lower - .8 BTU/sq. ft. hr. °F as compared to 1-1.2 BTU/sq. ft. hr. °F for glass.)

Central Systems

If a central system is to be installed, there are many options open as to: (1) hot water vs. steam heating, (2) piping arrangements, (3) pumping arrangements, etc.

It is generally thought that for small ranges the hot water systems are the most practical. When the size exceeds 15-20,000 sq. ft. of glass, it is probably better to use a steam system.

Hot water will require larger heating pipes than steam. Due to resistance effects, box coil piping is best for hot water, while trombone (continuous) coils are best for steam. (The normal steam setup is 2/3 side coils, and 1/3 overhead coils evenly distributed. Note that steam systems can sometimes be utilized for providing soil sterilization - giving this added benefit. There is an increasing use of finned piping for both cases (since one length of finned piping is equivalent to using four or more plain lengths).

Modern hot water systems under pressure can allow water temperatures close to that of steam (with a higher capital cost than the normal hot water system). This will allow its acceptance for larger ranges. In either hot water or steam systems, those operating on a gravity flow basis are no longer considered as economical.

As far as the boilers themselves, normally a water-tube boiler is more efficient than a fire-tube boiler. As far as choice of fuels for the boiler, it will depend on the individuals location, and specific heating needs.

Use of Electric Heaters

The high cost of electric heating almost disqualifies it as a major source of full time heating. However, it is a viable alternative when: (1) low cost electric power is available, (2) for very isolated locations where transporting fuels is a problem, (3) for very intermittent use, (4) for supplementary heating - thereby allowing a small heating system to be adequate for a majority of the time in lieu of a large system with a great deal of excess capacity, or (5) a heat pump is utilized with an assist from solar or low-grade waste heat discharged from a power generating station.

Fuel Prices Today

Table 3 is an approximate listing of various fuel costs in the Northeast area and for the most part assumes bulk purchases (as of August 1977).

Table 3. Cost of Common Fuels

Regular Gas	63.9¢/gal
Premium Gas	69.9¢/gal
Unleaded Gas	66.9¢/gal
Kerosene	48.6¢/gal
#2 Heating Oil	48¢/gal
#4 Fuel Oil	41.5¢/gal
#6 Fuel Oil	39.5¢/gal
Diesel	54.3¢/gal
LP Gas	\$20.50/100 lb
Natural Gas	
Residential	23¢/100 cu. ft.
Commercial	20-22¢/100 cu. ft.
Wholesale	11-12¢/100 cu. ft.
*Coal	\$35-\$45/ton

*The coal figure is for bituminous low sulfur coal, delivered by truck.

Estimating Heat Loss

It is useful to be able to calculate the approximate heat losses from a greenhouse and if done correctly the resulting estimate may be used to size the heating system and estimate fuel costs.

The following method is suggested to estimate heat loss when designing for a heating unit. Letting "M" equal the heat loss in BTU/hr.,

$$M = (h_c) (A) (T_d - T_o)$$

[illegible]

A = surface area for each type of cover

t_d = indoor design temperature (normally 60°F)

t_o = outdoor design temperature (-10°F to - 20°F for most areas within the northeast)

After calculating the heat loss add an additional 10% to the final total to account for infiltration. (This procedure should give a satisfactory estimate although there are more exact means.) The heat loss figure obtained at this point is the maximum loss that need to be designed for, and it is this figure that is used to select a furnace unit. The design temperatures are the key to this equation. The outdoor design temperature is the median of extremes based on weather data. The indoor design temperature is just a figure based on normal greenhouse practice depending on the plants grown.

Estimating Fuel Costs for Seasonal Operation

Once the heating requirements have been determined, the next step is to estimate the seasonal costs of heating. The method used here is ASHRAE's "Calculated Heat Loss Method." Basically it takes the design heat loss and adjusts it according to local conditions. In other words, one would not expect to operate at the extreme design point all winter long.

The first step in this method, then, is to take the design heat loss, "M" and plus it into the following equation to obtain an average heat requirement for the period under consideration.

$$X = M \frac{(t - t_a)}{(t_d - t_o)}$$

where: t = average inside temperature grower wants to maintain during the heating period (degrees°F)
 t_a = average outside temperature during estimate period (with October 1 - May 1 heating season). (ASHRAE Guide lists these by city.)
 t_d = inside design temperature (60°F)
 t_o = outside design temperature (-10°F)

Now the quantity of fuel used is equal to F, where

$$F = \frac{XN}{EC}$$

where: X = average heat requirements for the period under consideration
 N = number of heating hours in the estimate period (i.e., October 1 - May 1, figuring 212 days x 18 hours/day for heating needed = 3816 hours).
 E = efficiency of utilization of the fuel over the period expressed as a decimal (Table 1).
 C = heating value of one unit of fuel or energy (See Table 4).

Then, knowing the price of fuels (or using values in Table 3), multiply the price times F and you receive the approximate cost of fuel in a given year.

Table 4. Values of C = heating value of one unit of fuel or energy

Fuel	Average Heat Value		Average Weight lbs/gallon
	BTU/gal.	BTU/lb.	
Gasoline	123,769	20,125	6.15
Kerosene	130,637	19,155	6.82
#2 fuel oil	139,400	19,557	7.128
#4 fuel oil	145,600	19,178	7.592
#5 light fuel oil	148,400	18,994	7.813
#5 heavy fuel oil	150,700	18,873	7.985
#6 fuel oil	153,600	18,616	8.251
Butane	98,832	20,420	4.84
Propane	87,959	20,745	4.24
Methane (natural gas)	1000 BTU/cu. ft.	1000 BTU/cu. ft.	
Coal (bituminous)		12,500	

From 1972 ASHRAE Handbook of Fundamentals, p. 234, 239.

D

APPENDIX

APPENDIX D

ORNAMENTAL HORTICULTURE
USING BIOGAS BOOSTER GREENHOUSES

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APPENDIX D

SIMULATION OF GREENHOUSE OPERATION

The following program analyzes the profits from the growth of roses in Cornell designed greenhouse No. 4. This greenhouse is heated with biogas heaters using fuel from anaerobic digesters which are constructed adjacent to the greenhouses.

Marketing information for the program was provided by the Montgomery Rose Company of Hadley, Massachusetts. Costs for operating an anaerobic digester were obtained from the report "Process Feasibility Study Flow: The Anaerobic Digestion of Dairy Cow Manure at the State Reformatory on a farm in Monroe, Washington." This was prepared by the ECOTOPE Group, Research Consultants, Post Office Box 559, Seattle, Washington, 98105. Other economic data were obtained from the "Waste Heat Utilization Demonstration Greenhouse Design Concept" (see Appendix C).

A detailed flowchart of the model is included. Also included is a list of variables addressed by the model. It should be noted that all of the important cost parameters are not intrinsic to the model. For example, the simulation does not include the initial costs of site preparation, utilities, etc. Also, profits possibly realizable from the sale of by-product fertilizer are not calculated. These variables were omitted because of their dependence upon decisions yet to be made regarding other waste heat efforts which may share common support expenses and the lack of practical marketing data for the sale of fertilizer concentrated by the biogas generator. The model is a useful tool, however, for relative cost comparisons, scaling purposes, and sensitivity analyses.

The program is written in FORTAN; it has been designed to be executed in an interactive mode on the Honeywell Time Sharing System available at the University of Vermont. Results from the program are summarized in Table 1.

In reviewing Table 1, it should be noted that column 2 indicates the number of greenhouses heated year around and the number heated only during winter months. For example, the third line of data is for a three-greenhouse operation during the winter and for a four-house operation during the summer. Also, it should be noted that the annual operating costs of greenhouses and the digester include amortization of the capital investments. The last column (Total Costs) includes pumping costs as well as the operation and maintenance costs of columns 5 and 6.

TABLE 1
SUMMARY OF PROGRAM OUTPUT

Type	No. of Green- houses	Initial Cost of Green- house	Initial Cost of Digester	Annual Operation Cost of Greenhouse	Annual Operation Cost of * Digester	Income From Sale of Roses	Income From Sale of Biogas	Total Income	Total Cost
Heated	2	50,770	71,040	26,131	23,630	25,920	3221	29,141	50,446
Summer	2								
Heated	3	50,770	71,040	27,789	23,630	31,680	2804	34,484	52,170
Summer	1								
Heated	4	50,770	71,040	29,446	23,630	37,440	2666	40,106	54,140
Summer	0								

Summer greenhouse will only operate 20 weeks out of the year. The heated greenhouse will operate year-around. Other income may be derived from the sale of excess methane which may amount to 860,000 cf per year.

Note

* Engineer wages for running digester and methane gas plant have been included.

TABLE 2
DESCRIPTION OF VARIABLES

Variable Name	Initial Value	Meaning
SQFT	1560	Sq. ft. of space in each greenhouse
CSTGRN	7355	Initial cost per greenhouse
CSTHDH	18000	Initial cost of headhouse
CSTOPN	837.50	Cost of operational equipment per greenhouse
CSTGAS	.22	Cost of supplemental natural gas per 100 cubic feet
CSTDIG	71040	Initial cost of digester
CSTPMP	2.08	Cost of pumping 200 gpm of water from plant to digester per day
OPBTU	1000	Number of BTU's generated per hour per cow if plant is operational
NOPBTU	625	Number of BTU's generated per hour per cow if plant is not operational
SALHOR	9600	Salary of one horticulturist
SALPRT	1650	Salary of part time workers per greenhouse
CSTEXT	1043.75	Cost of extras per greenhouse (fertilizers, plants, pesticides, etc.)
SALENG	1200	Salary of an Engineer
PCTSWT	33 1/3%	Percent of roses which are Sweetheart
PCTFOR	66 2/3%	Percent of roses, Forever Yours
NUMROS	672	Number of roses in a greenhouse
NUMSWT	23	Number of Sweetheart blooms per rose per year
NUMFOR	36	Number of Forever Yours blooms per rose per year
PRCSWT	1.25	Price for one Sweetheart rose
PRCFOR	.52	Price for one Forever Yours rose
INTCAP	.095	Interest rate
LIFDIG	50	Estimated life of digester (years)
LIFGRN	25	Estimated life of greenhouse (years)

FLOW CHART OF THE MODEL

FLOW CHART OF THE MODEL (CONT.)

FLOW CHART OF THE MODEL (CONT.)

```

1. C *****
2. C
3. C      GREENHOUSE MODELING PROGRAM
4. C
5. C *****
6. C THIS PROGRAM IS AN ECONOMIC MODEL OF A GREENHOUSE COMPLEX BEING
7. C HEATED BY BIOGAS PRODUCED BY A FARM WHICH HAS A DIGESTER WHICH
8. C IS PREHEATED BY WASTE HEAT FROM A POWER PLANT.
9. C
10. C SOURCES ARE:
11. C   1. WASTE HEAT UTILIZATION DEMONSTRATION GREENHOUSE DESIGN CONCEPT
12. C     PREPARED BY: D. R. PRICE, PHD
13. C   2. PROCESS FEASIBILITY STUDY: THE ANAEROBIC DIGESTION OF DAIRY COW
14. C     MANURE AT THE STATE REFORMATORY HONOR FARM MONROE, WASHINGTON
15. C     PREPARED BY: ECOTOPE GROUP, RESEARCH CONSULTANTS
16. C                   PARAMETRIX INC., PROJECT ENGINEERS
17. C   3. TED JOHNSON, MONTGOMERY ROSE CO. (HADLEY, MA.)
18. C
19. C *****
20. C     REAL INTCAP,MAXACR
21. C     INTEGER Q (52),CODE,CODPRO,INDEX,DAY,WEEK
22. C AVERAGE WEEKLY TEMPERATURES AT GREENHOUSE SITE.
23. C     INTEGER Q/-15,-15,-15,35,30,-15,-15,-15,40,48,35,42,54,40,40,65,
24. C       1      38,43,50,52,52,66,58,66,70,77,70,66,75,70,77,66,68,79,59,
25. C       2      63,60,52,54,62,46,40,40,-15,32,50,-15,-15,-15,-15,32/
26. C DATA FOR SCALING DIGESTER COST
27. C SEE CHART ON PG. 87 OF REF 2 ABOVE
28. C UNITS IS CATTLE UNITS
29. C MULT IS MULTIPLIER
30. C MTHCST IS MONTHLY COST
31. C
32. C     REAL UNITS(5),MULT(5),MTHCST(5)
33. C     DATA UNITS /350,525,700,875,1050/
34. C     DATA MULT /1.0000,1.2754,1.5260,1.7488,1.9545/
35. C     DATA MTHCST /400.76,511.14,611.56,700.85,783.29/
36. C *****

```

37. C
38. C VARIABLES FOR COST OF THE GREENHOUSE
39. C
40. C SQUARE FEET OF GROWING SPACE PER GREENHOUSE
41. C GREENHOUSE SIZE IS 26 FT. BY 60 FT. OR 1560 SQ FT.
42. SQFT = 1560
43. C COST PER GREENHOUSE (DESIGN # 4)
44. CSTGRN = 7355.00
45. C COST FOR THE HEADHOUSE
46. CSTHDH = 18000.00
47. C COST OF OPERATIONAL EQUIPMENT PER GREENHOUSE
48. CSTOPN = 3350.00/4
49. C COST OF SUPPLEMENTAL NATURAL GAS PER 100 CUBIC FEET
50. CSTGAS = .22
51. C*****
52. C
53. C VARIABLES FOR COST OF THE DIGESTER
54. C
55. C COST OF DIGESTER IN WASHINGTON (TOTAL PROJECT COST)
56. C SEE PG. 73-74 OF REF # 2 ABOVE
57. CSTDIG = 71040.00
58. C*****
59. C
60. C VARIABLES FOR DAY-TO-DAY OPERATION
61. C
62. C COST OF PUMPING 200 GPM OF WATER FROM PLANT TO DIGESTER
63. C PER DAY BASED ON N=30 AND .04/KWH
64. C
65. CSTPMP = 2.08
66. C INITIAL COST OF PUMPING WATER TO PLANT IS ZERO
67. Csth20 = 0
68. C NO. OF BTU'S /HR/COW IF PLANT IS OPERATIONAL
69. OPBTU = 1000
70. C NO. OF BTU'S /HR/COW IF PLANT IS NOT OPERATIONAL
71. NOPBTU = 625
72. C*****

```

73.      C
74.      C VARIALES FOR ANNUAL OPERATION OF GREENHOUSE
75.      C
76.      C SALARY OF HORTICULTURIST
77.          SALHOR = 9600.00
78.      C COST OF PART-TIME MAINT AND WORKERS PER GREENHOUSE
79.          SALPRT = 6600.00/4
80.      C COST OF FERTILIZERS, PESTICIDES, VEHICLE, ELECTRICITY,
81.      C PLANTS,SEEDS,ETC. PER GREENHOUSE
82.          CSTEXT = 4175.00/4
83.      C NUMBER OF GREENHOUSES A HORTICULTURIST CAN HANDLE
84.          GRNHRT = 4
85.      C SALARY OF AN ENGINEER
86.          SALENG = 12000.00
87.      C
88.      C VARIABLES FOR ANNUAL INCOME FROM ROSES
89.      C
90.      C ALLOW USER TO INPUT PROFIT PER SQ. FT OR LET PROGRAM CALCULATE
91.      C
92.          WRITE(6,700)
93.      700  FORMAT('ODO YOU WISH TO INPUT PROFIT PER SQ. FT. OR HAVE',
94.          1  ' THE PROGRAM CALCULATE AN ESTIMATED PROFIT'/
95.          2  ' ENTER 1 FOR ESTIMATING NOW OR 2 FOR PROGRAM CALCULATION')
96.      705  READ(5,45) CODE
97.          IF (CODE .EQ. 1) GO TO 710
98.          IF (CODE .EQ. 2) GO TO 720
99.          WRITE (6,35)
100.         GO TO 705
101.      C USER WISHES TO INPUT PROFIT PER SQ. FT.
102.      710  WRITE (6,730)
103.      730  FORMAT('OENTER ESTIMATE OF PROFIT PER SQ. FT'/'
104.          1  ' ENTER NUMBER WITHOUT DOLLAR SIGN AS DOLLARS AND CENTS')
105.          READ(5,45) PROFIT
106.
107.      C INDICATE SQ FT PROFIT ESTIMATE
108.          CODPRO = 1
109.      C

```

```

110.      GO TO 740
111.      C CALCULATE PROFIT INTERNALLY
112.      720      CODPRO = 0
113.      C PER CENT OF ROSES WHICH ARE SWEETHEART
114.      PCTSWT = .3333333
115.      C PER CENT OF ROSES WHICH ARE FOREVER YOURS
116.      PCTFOR = .6666667
117.      C NUMBER OF ROSES PER GREENHOUSE SPACING AT 12 INCHES
118.      C (IF SPACING IS 11 INCHES THIS SHOULD BE 725)
119.      NUMROS = 672
120.      C NUMBER OF FLOWERS PER PLANT PER YEAR (SWEETHEART)
121.      NUMSWT = 23
122.      C NUMBER OF FLOWERS PER PLANT PER YEAR (FOREVER YOURS)
123.      NUMFOR = 36
124.      C PRICE FOR SWEETHEART ROSES
125.      PRCSWT = 1.25
126.      C PRICE FOR FOREVER YOURS ROSES
127.      PRCFOR = .52
128.      C
129.      C CALCULATE AMORTIZATION RATES
130.      C INTEREST RATE FOR CAPITAL RECOVERY FACTOR
131.      740      INTCAP = .095
132.      C LIFE OF THE DIGESTER (YEARS)
133.      LIFDIG = 50
134.      C LIFE OF THE GREENHOUSES (YEARS)
135.      LIFGRN = 25
136.      C
137.      C R1 IS FOR DIGESTER; R2 IS FOR GREENHOUSES
138.      C
139.      R1 = INTCAP * (1 + INTCAP) ** LIFDIG/((1 + INTCAP)**LIFDIG -1)
140.      R2 = INTCAP * (1 + INTCAP) ** LIFGRN/((1 + INTCAP)**LIFGRN -1)
141.      C*****

```

```

142. C
143. C FIGURE OUT HOW MANY GREENHOUSES YOU CAN OPERATE
144. C
145. C ALLOW NO. OF COWS AND NO. OF GREENHOUSES TO VARY
146. C
147. WRITE(6,10)
148. 10 FORMAT('OHOW MANY COWS ARE THERE ON THE FARM (1 COW = 1250 '
149. 1'LB. OF CATTLE)')
150. READ(5,45) NOCOWS
151. C NEED 200 COWS PER GREENHOUSE
152. MAXGRN = NOCOWS / 200
153. WRITE(6,15) MAXGRN
154. 15 FORMAT('OYOU MAY SUPPORT',I5,' GREENHOUSES')
155. MAXACR = (MAXGRN * SQFT)/43560.
156. WRITE(6,20) MAXACR
157. 20 FORMAT(' THIS IS EQUIVALENT TO ',G,' ACRES')
158. C
159. 100 WRITE(6,25)
160. 25 FORMAT('OWOULD YOU LIKE TO ENTER THE DESIRED AREA IN ACRES (1)'
161. 1,' OR GREENHOUSES (2)'/T10,'(ENTER 1 OR 2)')
162. READ(5,30) CODE
163. 30 FORMAT(I1)
164. IF (CODE .EQ. 1) GO TO 110
165. IF (CODE .EQ. 2) GO TO 120
166. C CODE ENTERED IN ERROR
167. WRITE(6,35)
168. 35 FORMAT('OCODE MUST BE ENTERED AS A 1 OR 2'/
169. 1,'PLEASE REENTER')
170. GO TO 100
171. C PROCESS AREA IN ACRES
172. 110 WRITE(6,40)
173. 40 FORMAT('OHOW MANY ACRES DO YOU WISH TO CULTIVATE')
174. READ(5,45) ACRREG
175. 45 FORMAT(G)
176. NOGRN = (ACRREG*43560)/SQFT +.5
177. GO TO 130

```

178. C PROCESS AREA IN NUMBER OF GREENHOUSES
 179. 120 WRITE(6,50)
 180. 50 FORMAT('OHOW MANY GREENHOUSES WOULD YOU LIKE')
 181. READ(5,45) NOGRN
 182. 130 WRITE(6,55) NOGRN
 183. 55 FORMAT('OYOU HAVE',I5,' GREENHOUSES')
 184. C SEE IF MORE THAN WE CAN SUPPORT
 185. IF(NOGRN .GT. MAXGRN) WRITE(6,60) MAXGRN
 186. 60 FORMAT('ONOTE: YOUR SYSTEM CAN ONLY SUPPORT ',I5,
 187. 1 ' HEATED GREENHOUSES WITHOUT SUPPLEMENTAL HEAT')
 188. C CHECK FOR SUMMER GREENHOUSES - NO EXTRA HEAT REQUIRED
 189. 140 WRITE(6,65)
 190. 65 FORMAT('OWOULD YOU LIKE ANY SUMMER GREENHOUSES (THESE ARE '
 191. 1 ',HOUSES WHICH ONLY OPERATE IN THE SUMMER, WHICH IN TURN, '
 192. 2 ', REQUIRE NO EXTRA HEAT)')/' ENTER 1 FOR YES, 2 FOR NO')
 193. NOSUM = 0
 194. READ (5,30) CODE
 195. IF (CODE .EQ. 1) GO TO 150
 196. IF (CODE .EQ. 2) GO TO 170
 197. WRITE(6,35)
 198. GO TO 140
 199. C PROCESS SUMMER GREENHOUSES
 200. 150 WRITE(6,25)
 201. READ(5,30) CODE
 202. IF (CODE .EQ. 1) GO TO 160
 203. IF (CODE .EQ. 2) GO TO 180
 204. C CODE ENTERED IN ERROR
 205. WRITE(6,35)
 206. GO TO 150
 207. C PROCESS SUMMER GREENHOUSES IN ACRES
 208. 160 WRITE(6,40)
 209. READ(5,45) ACRSUM
 210. NOSUM = (ACRSUM * 43560)/ SQFT + .5
 211. GO TO 170
 212. C PROCESS SUMMER GREENHOUSES IN NUMBER OF GREENHOUSES
 213. 180 WRITE(6,70)
 214. 70 FORMAT('OHOW MANY SUMMER GREENHOUSES WOULD YOU LIKE')
 215. READ(5,45) NOSUM
 216. 170 WRITE(6,75) NOSUM
 217. 75 FORMAT('O YOU HAVE',I5,' SUMMER GREENHOUSES')


```

218.      C
219.      C INPUT THE NUMBER OF HORTICULTURISTS
220.          WRITE(6,80) GRNHRT
221.      80      FORMAT('OHOW MANY HORTICULTURISTS DO YOU WANT FOR THE YEAR ',
222.          1'ROUND GREENHOUSES (1 PER',I5,' GREENHOUSES IS RECCOMENDED')
223.          READ(5,45) REGHOR
224.      C CHECK IF SUMMER GREENHOUSES
225.          IF (NOSUM .EQ. 0) GO TO 200
226.      C HAVE SUMMER GREENHOUSES
227.          WRITE(6,85)
228.      85      FORMAT('OHOW MANY HORTICULTURISTS DO YOU WANT FOR THE '
229.          1,' SUMMER GREENHOUSE')
230.          READ(5,45) SUMHOR
231.          GO TO 210
232.      C NO SUMMER GREENHOUSES
233.      200      SUMHOR = 0
234.      210      WRITE(6,90) REGHOR,SUMHOR
235.      90      FORMAT('OYOU HAVE ',I3,' HORTICULTURISTS FOR THE ',
236.          1'YEAR ROUND GREENHOUSES AND 'I3,' HORTICULTURISTS FOR THE ',
237.          2'SUMMER GREENHOUSES')
238.      C*****
239.      C
240.      C ALL DATA ENTERED - NOW START THE SIMULATION
241.      C
242.      C INITAILIZE RANDOM NUMBERS FOR POWER PLANT UP CALCULATIONS
243.      C
244.          CALL RANDOM(1,IY,RAND)
245.          IX=IY
246.      C
247.      C INITIAL COST OF ALL GREENHOUSES
248.      C
249.          INTGRN = CSTHDH + (NOGRN + NOSUM) * (CSTGRN + CSTOPN)
250.      C
251.      C
252.      C INITIAL COST OF DIGESTER - REFER TO PG.85-89 OF REF. # 2 ABOVE
253.      C
254.      C CONVERT COW UNITS TO DIGESTER CATTLE UNITS
255.      C NOTE: ONE DIGESTER COW UNIT IS 1000 LB OF CATTLE
256.      C ORIGINAL COW ASSUMED AT 1250 LBS

```

257. C
 258. CATUNT = (1250./1000) * NOCOWS
 259. SAVUNT = CATUNT
 260. C CALCULATE HOW MANY SEPARATE UNITS ARE NEEDED
 261. C
 262. C FIRST ASSUME ONE DIGESTER
 263. C
 264. NODIG = 1
 265. C
 266. 215 DO 220 INDEX = 1,5
 267. IF (CATUNT .LE. UNITS(INDEX)) GO TO 230
 268. 220 CONTINUE
 269. C NEED MORE DIGESTERS - TRY ONE MORE
 270. C
 271. NODIG = NODIG + 1
 272. C MODIFY CATTLE UNITS TO REFLECT NEW DIGESTER
 273. CATUNT = SAVUNT / NODIG
 274. GO TO 215
 275. C
 276. C INDEX POINTS TO SIZE OF THE DIGESTER
 277. C CALCULATE INITIAL DIGESTER COST
 278. C
 279. 230 INTDIG = NODIG * (MULT(INDEX)*CSTDIG)
 280. C*****
 281. C
 282. C SIMULATE DAY-TO-DAY OPERATION
 283. C
 284. C NOTE: THESE COMPUTATIONS ARE FOR ONE GREENHOUSE
 285. C
 286. C BTUNAV - BTU'S NEEDED IN EXCESS OF DIGESTER OUTPUT (FOR 1 GREENHOUSE)
 287. C BTUHRS - # OF HOURS OF PUMPING GAS FROM DIGESTER TO 1 GREENHOUSE
 288. C (1 HR. IS PUMPING 200000 BTU TO 1 GREENHOUSE)
 289. C BTUEXS - EXCESS BTU'S PRODUCED BY THE DIGESTER
 290. C
 291. C SET COUNTERS TO ZERO
 292. BTUNAV = 0
 293. BTUHRS = 0
 294. BTUEXS = 0
 295. C

```

296. C TOTDAY - TOTAL NUMBER OF DAYS
297.     TOTDAY = 0
298. C DWNDAY - TOTAL NUMBER OF DAYS PLANT IS DOWN
299.     DWNDAY = 0
300. C PROCESS FOR ALL WEEKS IN A YEAR
301.     DO 310 WEEK = 1 , 52
302. C
303. C CALCULATE HEAT LOSSES
304.     TMP1 = 57.5 - Q(WEEK)
305. C CHECK IF NO BTU'S REQUIRED
306.     IF (TMP1 .LE. 0) GO TO 250
307.     TMP2 = 30
308.     IF (Q(WEEK) .LE. TMP2) GOTO 240
309.     TMP2 = Q(WEEK)
310. C CALC HEAT LOSS BY HEAT LOSS FORMULA IN APPENDIX
311. 240     BTU = 80*(57.5-TMP2)+TMP1*(212.4+457+53+219)
312.     GO TO 260
313. C NO HEAT REQUIRED
314. 250     BTU = 0
315. 260     CONTINUE
316. C
317. C GO THROUGH SEVEN DAYS PER WEEK
318. C
319.     DO 310 DAY = 1 , 7
320. C INCREMENT DAY COUNTER
321.
322.     TOTDAY = TOTDAY + 1
323. C IS PLANT UP TODAY
324.     CALL RANDOM(IX,IY,RAND)
325.     IX=IY
326.     IF (RAND*100 .LE. 90) GO TO 270
327. C NO -- PLANT IS DOWN - BOOST DOWN DAYS
328.     DWNDAY = DWNDAY + 1
329. C AND AMOUNT OF BTU'S /COW PRODUCED IS REDUCED
330.     DAYBTU = NOPBTU
331.     GO TO 280
332. C PLANT IS UP -- PUMP WATER FROM PLANT TO DIGESTER
333. 270     CSTH20 = CSTH20 + CSTPMP
334.     DAYBTU = OPBTU

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335. C CALC NUMBER OF BTU'S AVAILABLE FOR GREENHOUSE
336. 280      TEMP = NOCOWS * DAYBTU / NOGRN
337.          IF (BTU .NE. TEMP) GO TO 290
338. C BTU NEEDED AND AVAILABLE ARE THE SAME
339. C      MORE GAS TO THE GREENHOUSES
340.          BTUHRS = BTUHRS + 24 * BTU * NOGRN
341.          GO TO 310
342. C BTU NEEDED AND AVAIL ARE NOT THE SAME
343. 290      IF (BTU .LT. TEMP) GO TO 300
344. C # BTU'S REQUIRED ARE MORE THAN AVAILABLE
345. C      PUMP AS MUCH AS POSSIBLE TO GREENHOUSES
346.          BTUNAV = BTUNAV + 24 * ((BTU*NOGRN)-(NOCOWS*DAYBTU))
347.          BTUHRS = BTUHRS + 24 * (NOGRN *TEMP)
348.          GO TO 310
349. C # BTU'S REQUIRED LES THAN THE AVAILABLE -
350. C      CALC EXCESS GAS
351. 300      BTUEXS = BTUEXS + 24 * ((NOCOWS*DAYBTU)-(BTU*NOGRN))
352.          BTUHRS = BTUHRS + 24 * NOGRN * BTU
353. 310      CONTINUE
354. C
355. C ANNUAL COST OF GREENHOUSES
356. C
357.          ANGRN = SALHOR * REGHOR + SALHOR * (20./52) +
358. 1          NOGRN * (SALPRT + CTEXT) +
359. 2          NOSUM*(SALPRT+CTEXT)*(20./52) +
360. 3          R2 * INTGRN
361. C
362. C ANNUAL COST OF DIGESTER
363. C
364.          ANDIG = NODIG * (12 *MTHCST(INDEX)) + SALENG + R1 * INTDIG
365. C
366. C COST OF SUPPLEMENTAL FUEL
367. C
368.          ANSUP = BTUNAV / 1000 * CSTGAS / 100
369. C
370. C ANNUAL INCOME FROM ROSES
371. C
372. C IS ESTIMATE PER SQ FT OR INTERNALLY CALCULATED

```

```

373. C
374. IF (CODPRO .EQ. 1) GO TO 330
375. C
376. ANINC = NOGRN * (PCTSWT * NUMROS * NUMSWT * PRCSWT +
377. 1 PCTFOR * NUMROS * NUMFOR * PRCFOR)
378. C
379. C ANNUAL INCOME FROM SUMMER GREENHOUSES
380. C
381. ANSUM = NOSUM * (PCTSWT*NUMROS*(20./52)*NUMSWT*PRCSWT +
382. 1 PCTFOR*NUMROS*(20./52)*NUMFOR*PRCFOR)
383. GO TO 340
384. C CALCULATE PROFIT BY SQ. FT.
385. C
386. 330 ANINC = NOGRN * SQFT * PROFIT
387. ANSUM = NOSUM * SQFT * PROFIT * (20./52)
388. C
389. C CALCULATE INCOME FROM SALE OF EXCESS GAS
390. C
391. C AT 2.50 PER 10 TO THE SIXTH BTUS
392. C
393. ANGAS = 2.50 * (BTUEXS / 1.E6)
394. C
395. C
396. C PRINT THE RESULTS
397. C
398. C COSTS FIRST
399. C
400. 340 WRITE(6,500) INTGRN
401. 500 FORMAT('0THE INITIAL COST FOR THE GREENHOUSE COMPLEX IS $',I8)
402. WRITE(6,510) NODIG,INTDIG
403. 510 FORMAT('0THE INITIAL COST FOR THE DIGESTER COMPLEX OF ',
404. 1 I4,' DIGESTERS IS $',I8)
405. WRITE(6,520) ANGRN
406. 520 FORMAT('0THE ANNUAL RUNNING COSTS FOR THE GREENHOUSES IS $',I8)
407. WRITE(6,530) ANDIG
408. 530 FORMAT('0THE ANNUAL RUNNING COSTS FOR THE DIGESTER IS $',I8)
409. WRITE(6,540) CSTH2O
410. 540 FORMAT('0THE ANNUAL COST FOR PUMPING WATER FROM THE PLANT TO ',
411. 1 'THE DIGESTER IS $',I8)

```

412. WRITE(6,550) ANSUP
 413. 550 FORMAT('0THE ANNUAL COST OF SUPPLEMENTAL FUEL IS \$',I8)
 414. TOT = ANGRN + ANDIG + Csth20 + ANSUP
 415. WRITE(6,560) TOT
 416. 560 FORMAT('0THE TOTAL ANNUAL COST OF OPERATION IS \$',I8)
 417. C
 418. C NOW COMPUTE THE INCOMES
 419. C
 420. TOT = ANINC + ANSUM
 421. WRITE(6,570) TOT
 422. 570 FORMAT('0 THE ANNUAL INCOME FROM ROSES IS \$',I8)
 423. WRITE(6,582) ANGAS
 424. 582 FORMAT('0THE ANNUAL INCOME FROM BIOGAS IS \$',I8)
 425. WRITE(6,580) BTUHRs
 426. 580 FORMAT('0THE NUMBER OF BTU''S WHICH WERE PUMPED FROM THE',
 427. 1 ' DIGESTER TO ALL THE GREENHOUSES IS :',G)
 428. WRITE(6,590) BTUNAV
 429. 590 FORMAT('0THE NUMBER OF BTU''S NEEDED THAT WERE NOT ',
 430. 1 'AVAILABLE WERE',G)
 431. WRITE(6,600) BTUEXS
 432. 600 FORMAT('0THE NUMBER OF EXCESS BTU''S PRODUCED ',
 433. 1 'BY THE DIGESTER WERE:',G)
 434. WRITE(6,610) DWNDAY,TOTDAY
 435. 610 FORMAT('0THE PLANT WAS NOT OPERATIONAL ',I5,' OF THE TOTAL',I5,
 436. 1 ' DAYS')
 437. C
 438. PERCNT = 100. * (DWNDAY/TOTDAY)
 439. C
 440. WRITE(6,620) PERCNT
 441. 620 FORMAT('0',T10,'THIS AMOUNTS TO ',I5,' PERCENT OF THE TIME')
 442. WRITE(6,630)
 443. 630 FORMAT('0INCOME NOT INCLUDED IN THE SIMULATION INCLUDES THE'
 444. 1 ' SALE OF EXCESS METHANE AND THE DRIED SLUDGE AS FERTILIZER')
 445. CALL EXIT
 446. END

1. SUBROUTINE RANDOM (IX,IY,YFL)
2. IY=IX*65539
3. IF(IY)5,6,6
4. 5 IY=IY+2147483647+1
5. 6 YFL=IY
6. YFL=YFL*.4656613E-9
7. RETURN
8. END

ANNEX TO APPENDIX D
HEAT LOSS CALCULATIONS FOR GREENHOUSE NO. 4
by Joe Kent

General Heat Loss Equation

$$Q = UA \Delta T$$

$$\Delta T = T_o - T_i$$

$$U = \frac{1}{R_{Tn}}$$

$$R_T = \sum_{i=1} R_i$$

Floor Losses

Air	R = 0.62
3" porous conc	R = 3.33
6" of 5/8" Blue Stone	R = 0.87
vinyl liner	R = 1.09
2" styrofoam	R = 12.5
polyethylene	R = 1.09
earth

$$\bar{R} = 19.50$$

Minimum temp. for earth = 30°F

$$Q = UA (T_A - T_G) \quad \text{Min. value}$$

$$Q_F = \frac{1}{19.5} (26)(60)(57.5 - 30)$$

$$Q_F = 80 (57.5 - Q(W)) \quad \text{BTU/hr}$$

Q(W) For earth not less than 30°F

$$T_G = 30^\circ\text{F for greater}$$

Ground Temp.

Minimum = 30°F

Losses for Green House

Insulated roof

$$A = (16)(60) = 960 \text{ sq.ft.}$$

$$\begin{aligned} \text{Heat loss } Q_R &= UA (T_i - T_A) = \frac{1}{4.52} (960) (T_i - T_A) \\ &= \underline{212.4 (T_i - T_A)} \leftarrow Q_{\text{roof}} \\ &\text{BTU/hr} \end{aligned}$$

Glass or Plastic Lined

$$\begin{aligned} \text{Area} &= (21)(60) + 15 \\ &= 1275 \text{ sq.ft.} \end{aligned}$$

$$\begin{aligned} \text{Heat loss} &= \frac{1}{2.79} (1275) (T_i - T_A) = \underline{457 (T_i - T_A)} \leftarrow \text{Roof liner} \\ &\text{BTU/hr} \end{aligned}$$

Base Wall

$$\text{Same } R \text{ as roof } R = 4.52 \quad \text{Area} = 2(60)(2) = 240 \text{ sq. ft.}$$

$$Q_{EW} = \frac{1}{4.52} (240) (T_i - T_A) = 53 (T_i - T_A)$$

Infiltration losses

Specific Heat Air = .240
BTU/16/°F

(50°F)

$$p v_s = RT$$

$$v_s = \frac{RT}{p} \quad \frac{1}{\gamma} = \frac{RT}{p} = \frac{(14.7)(144)}{(53.3)(460+50)} = 0.078 \text{ cf}$$

Infiltration ~ /change/hour

$$\text{Volume} = 26(2)(60) + \frac{26(11)(60)}{2} = \underline{11,700 \text{ cf}}$$

Heat lost to infiltration

$$\begin{aligned} &= (0.24)(11,700)(.078)(T_i - T_A) \\ &= \frac{219(T_i - T_A)}{\text{BTU/hr}} \end{aligned}$$

SUMMARY OF LOSSES

$$\text{Floor } Q_F = 80 [57.5 - Q(W)] \quad Q(W) \geq 30$$

$$\text{Roof } Q_R = 212.4(T_i - T_A)$$

$$\text{Glass } Q_G = 457 (T_i - T_A)$$

$$\text{Base Wall } Q_{BW} = 53 (T_i - T_A)$$

$$\text{Infiltration } Q_I = 219 (T_i - T_A)$$

$$Q_{\text{Total}} = 80 [57.5 - Q(W)] + (T_i - T_A) [212.4 + 457 + 53 + 219]$$

E
APPENDIX

APPENDIX E

VERMONT YANKEE FISH FARMING SIMULATION
COMMERCIAL APPLICATION

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Programming Assistance by:
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VERMONT YANKEE FISH FARMING SIMULATION:

The Economic Feasibility of Using Vermont Yankee Nuclear Power Station Waste Heat in Commercial Aquaculture

Introduction

This report culminates an investigation of the economic feasibility of utilizing waste heat from the Vermont Yankee Nuclear Power Station in Vernon, Vermont as a source of supplemental heat in commercial scale aquaculture of food products. Several factors contributed impetus to the research. First, preliminary work gave support to the contention that within the Northeastern quadrant of the United States there exists unfilled though latent market demand for superior aquatic food products, obtainable through environmentally controlled aquaculture. Second, cold winters and relatively warm summers inhibit the development of a commercial aquaculture industry in Northern New England. Third, the presently unutilized waste heat that is a by product of electrical power generation at Vernon seemed to offer a realistic opportunity to control one of the most expensively manipulated environmental variables in commercial aquaculture, specifically temperature. In sum, commercial aquaculture appeared, and still appears, a reasonable vehicle to transform an effluent of 8 billion B.T.U.'s per hour into a profitably exploited economic resource with the concomitant challenge this presents to Yankee ingenuity and thrift.

The major component of the research reported upon here was the construction of an original interactive computer model which simulates the salient features of a proposed commercial scale aquaculture facility designed for the Vernon site by the consulting firm of Kramer, Chin and Mayo.¹ The first section of this report, however, focuses upon the potential market for aquacultured food products in the Northeastern United States since the absence of relevant demand would clearly preclude commercial operation. Following this, the second section of the report considers the computer model with particular stress upon the inputs which it requires, its operating characteristics as they reflect those of the proposed facility, and its bioeconomic numerical outputs. The final section of the report evaluates the model's numerical outputs in relation to their

implications for the profit potential of the proposed facility. The specific engineering characteristics of the proposed facility are not treated in our report, except insofar as they directly appertain to economic feasibility, in order to avoid redundancy with the Kramer, Chin, and Mayo report.

Market Potential

The revenues obtainable through commercial aquaculture at Vernon are conditional upon the marketing potential of alternative products suitable for production at the Vernon site. Thus, the first question to explore in considering the economic feasibility of developing a commercial aquaculture facility to exploit the heat effluent from the Vermont Yankee Nuclear Power Station involves the American consumer's palate and purse. Also involved are the environmental characteristics of the available site since the habitat requirements of alternative aquacultured organisms give rise to different production techniques and thus to alternative production costs which must necessarily be reflected in the prices at which various products can be offered to consumers. Since the link between demand and price is an inexorable one, the question of product selection is a complex conjunction of the biological characteristics of alternative production facilities and consumer preferences. The former issues were addressed by John Ryther in his earlier report on "Commercial Application of Waste Heat from the Vermont Yankee Nuclear Power Station".² His conclusions and recommendations have been drawn upon to expedite and narrow the focus of the present study.

The species most promising for commercial aquaculture at Vernon, according to Ryther, is the brook trout (Salvelinus fontinalis), a species native to New England. As far as the present writers have been able to ascertain the brook trout is not now and has not in the past been commercially reared on a large scale for direct sale to consumers. However, the species is a favorite of sport fisherman and for a number of years, has been successfully reared for recreational stocking purposes by both public and private hatcheries. The technology exists, therefore, to adapt the brook trout to domestic aquaculture on a commercial scale. Further, brook trout, because of their definite appeal as a sport fish, may be able to command a premium price in the market place. There are however, the risks which are attendant to the offering of a product unknown to many consumers.

Because brook trout are an item unknown to many consumers and certainly unknown to the commercial distribution system, it was decided to include a second product option within the scope of this research. Since it is more hazardous to attempt to draw comparisons between two products which are unknown in the present marketplace than between one which is and one which is not, the second species chosen for investigation is the familiar rainbow trout (Salmo gairdneri). While the Ryther report justly argues that there is already a stiff competition among domestic and foreign (chiefly Japanese and Danish) producers of rainbow trout, there are nonetheless compelling reasons for their inclusion. Most notably, rainbow trout have been successfully reared in commercial aquaculture facilities for over one hundred years within the United States.³ Thus, not only is there an existant requisite technical know how to rear them commercially but, in addition both supply (i.e. feed, equipment, etc.) and distribution (i.e. wholesale and retail) networks are already in operation.

From both production and marketing standpoints rainbow and brook trout would appear to be relatively close competitors. Both are salmonids with habitat requirements close enough that they may be reared in identical facilities. Indeed, the model described below is adaptable to either species since growth and other parameters are incorporated for both rainbow and brook trout. In comparison rainbow trout appear to be somewhat faster growing, and a bit more tolerant of temperature and water quality variations⁴ as well as of the repeated handling required in commercial facilities than brook trout. Thus, brook trout can be expected to exhibit somewhat higher mortality levels than rainbow trout under commercial aquaculture.⁵ The two species are similar enough, however, that for both⁶ the same growth, and weight-length relationships are often used.

On the marketing side, the argument that brook trout would represent a premium product in comparison with rainbow trout because of the high regard in which they are held by sport fishermen has appeal. However, it is worth giving attention to an analogously relevant experiment which has been conducted on the west coast involving pan size salmon. In 1972 pan size chinook (Oncorhynchus tshawytscha) and coho (Oncorhynchus kisutch) salmon, thought to incorporate the advantages of a "single serving" fish like the trout, with the highly desirable taste and color traits of the larger salmon began to enter the Pacific Coast market with some sales success. The first commercial pan size salmon

operation was in Puget Sound, Washington. Soon, other operations appeared in Oregon, Idaho, and even Canada, with financial support from such international firms as Union Carbide, Ralston Purina, and Weyerhaeuser. After considerable early success, pan size salmon sales have begun to decline. "When interviewed, marketing managers close to the industry indicated their belief that consumers were treating pan size salmon and trout (i.e. rainbow trout) as close substitutes and that salmon could not compete successfully with trout because of the lower unit price associated with the latter."⁷ West coast consumers, in other words, apparently regard trout and pan size salmon as close enough substitutes for one another to choose between them on the basis of relative price alone. Should east coast consumers behave similarly with respect to brook versus rainbow trout, the more delicate biological attributes of the brook trout would not enhance its appeal to commercial aquaculturalists. The issues raised by the Pacific Coast experiment unfortunately cannot be settled without the sort of empirical market data which can come only from actual market experimentation. Nevertheless, these issues contributed to the decision to include rainbow trout within the scope of this investigation.

The total demand for food products in the United States is closely tied to population growth since Americans are already comparatively well fed. There is, however, considerable room for expansion and contraction of demand among different segments of the food industry as a whole. It is well known, for example, that per capita consumption of meats including beef, pork, and veal has increased by almost 25 percent from 1950 to 1975 while per capita consumption of grains has declined during the same period by about 7 percent.⁸ Over the same time interval, U.S. per capita consumption of fishery products has risen slightly from 11.8 to 12.1 pounds per year.⁹

Since 1970, U.S. fishery product consumption has varied from 11.8 to 12.9 pounds per capita per year. The highest value was reached in 1973 when retail meat prices increased at a very rapid rate encouraging consumers to substitute fishery products for meat products as sources of protein in their diets.¹⁰ Such substitution, together with the specific observation that per capita consumption of all fishery products has shifted as much as 7.8 per cent from one year to the next during the past decade reinforce Whitaker's comment that "The consumption of any sea food may be affected by hundreds of factors, including

the prices of all other foods."¹¹ With this important caveat, one may hazard the forecast that fishery products are apt to become an increasingly important part of the American diet. A number of agencies, including the U.S. Department of Agriculture and the U.S. Trout Farmers Association are actively promoting fish as a product of high nutritional value, and recent popular pronouncements regarding the low cholesterol content of fish can be expected to have an impact. Many industry spokesmen, however, continue to bemoan the consumer's lack of familiarity with fish and fish dishes; as one industry spokesman stated "Our biggest job is to get people to eat fish".¹²

One particularly bright sidelight to the general fishery products picture, from the stand point of the market potential of aquacultured trout, is that such trout are a product of superior quality. This is important because the pattern of fishery product consumption has shifted during the last quarter century. In 1950 only slightly over one-half of all fishery products consumed in the United States were fresh or frozen, but in 1975 almost two-thirds were fresh or frozen. Although this doubtless reflects production-side considerations as much as it does consumer preferences, it is quite consistent with an expectation that fresh and frozen trout are gaining in consumer appeal. However, even the president of the U.S. Trout Farmers Association acknowledges that "We need to do a tremendous selling job and get the consumers better acquainted with our product".¹³

With regard to trout specifically, it must be pointed out that with the scarcely significant exception of some lake trout (Salvelinus namaycush) virtually none of the fresh water salmonids which enter commercial channels are harvested from wild stocks. The market in trout, therefore, is a market in a domestic aquaculture product. Total production and sales figures for the industry are difficult to obtain since on the one hand aquaculture products are excluded from the U.S. Census of Agriculture while on the other hand they do not appear in the statistics published by the National Marine Fisheries Service. It is necessary, therefore, to rely on possibly unreliable industry estimates. According to Clay Robertson, past Executive Secretary of the U.S. Trout Farmers Association, United States production of market-size trout was 16 to 20 million pounds live weight in 1974, with an estimated market value of \$25 million.¹⁴ Estimates of the live weight harvest for more recent years are also in the neighborhood of about 20 million pounds.¹⁵ Nevertheless, many

experts believe that the industry is in for a period of considerable expansion. One forecast for 1982, for example, is that 59 million pounds of domestic trout will be sold by then.¹⁶

Just as past aggregate production volume statistics are difficult to obtain for the trout industry, so too are past sales prices. It is possible, however, to cite sales prices, f.o.b. processing plant, for the years 1972, 1973, and 1974 (Table 1). Two issues stand out from these values. First, the prices of dressed, boned, and filleted trout increased by almost 16 percent between 1972 and 1974. Second, the price differential between live and processed (dressed, boned or filleted) trout is considerable with dressed trout alone being over twice as valuable as live trout. Since processing, packaging and freezing costs per pound of frozen processed trout are estimated to have been about 14 cents per pound in 1974,¹⁷ the roughly 75 cents per pound price differential between live and dressed trout is significant.

Table 1. Prices per pound of trout f.o.b. processing plant, 1972, 1973 and 1974.*

	1972	1973	1974
Live	0.52-0.55	0.65-.70	.60-.65
Dressed	1.20-1.24	1.12-1.20	1.33-1.46
Boned	1.42-1.48	1.34-1.43	1.61-1.69
Filletts	1.79-1.82	1.85-1.90	2.10-2.18

* Source: Klontz and King, Aquaculture in Idaho and Nationwide, p. 31.

U.S. trout production is heavily centralized in one geographical location and dominated by relatively few firms. About 90 percent of all trout produced for food in the United States are grown in the "Magic Valley" of Idaho.¹⁸ And among 14 independent companies and 28 production facilities in Idaho, no more than three or four major integrated operations account for 80% of the state's total output. It is no wonder, then, that demand analysis and market research have received so little attention (actually, market research is meager for the fishery products industry as a whole).¹⁹ Some 85 percent of the trout raised in Idaho is shipped in the frozen state.²⁰ Thus while it is impossible to

determine the proportion of U.S. demand accounted for by foreign imports, a bit of quick calculation suggests that at least three-fourths of the trout which reaches U.S. consumers is in a frozen state. Since all imported trout is frozen, the actual proportion is probably higher.

The facts that (1) most of the food trout marketed in the United States is frozen, and (2) most of the supply is created in one relatively isolated location quickly give rise to the likelihood that much of the expected industry expansion will occur outside Idaho and that some of it will occur in fresh package trout. Evidence for this speculation is, of course, difficult to produce, but at least one specific example is relevant. For the last twelve years, the Troutdale Ranch at Gravois Mills, in Missouri's Ozark Mountains has prospered by supplying live trout to sportsmen's fishout facilities, and fresh unfrozen trout to Kansas City and St. Louis markets.²¹ Much of this latter trade is restaurant oriented and involves 10 to 14 ounce dressed trout. A similar market could almost certainly be created from the proposed Vernon facility.

It is virtually impossible to find published sources to accurately gage the extent of the potential market for the food trout which could be raised at Vernon. Certain facts can be ascertained, however. First the current (September, 1977) quoted wholesale price of frozen processed trout is just under \$2.00 per pound. Second, the current quoted wholesale price of fresh processed trout is just over \$2.00 per pound at New York's Fulton Fish Market. These are wholesale prices for distributors from brokers so that the prices received by producers from brokers at these locations would be somewhat less (perhaps 30 to 40 cents less). Third, the projected capacity of the proposed Vernon facility is somewhat more than 100,000 pounds live weight. This is less than one-half of one percent of total current U.S. domestic trout production. Such an amount is unlikely to have a depressing effect upon the market.

It is not necessary, however, to project from these industry values in determining the sale price which would apply if an aquaculture facility producing fresh and frozen trout were now operating at Vernon. During the research for this report, the purchasing agent for a major New England grocery wholesaler was contacted. If the writers had been sales agents for such a facility with

processed trout "in hand", they could have sold 50,000 pounds on the spot for \$1.75 per pound. This is an amount equal to one-half of the yearly output of the proposed facility. In sum, there is strong evidence that there is definitely a market for the proposed product in the proposed quantity if the price is right. In the remaining sections we address the question of whether it is feasible to produce trout at a competitive price in the proposed facility.

The Model

The model is interactive throughout and allows the user to manipulate 20 variables as listed in Table 2. The model is written in DTSS Basic and is designed to be run by an operator at an on-line terminal. The size of the program is such that 24K of core is required for its operation on the DTSS Honeywell system.

Standard figures on sample data are included at almost every stage of the program and may be accepted or rejected by the operator in varying combinations. Standard figures include the capital cost data as developed by Kramer, Chin and Mayo and figures for interest rate and annual payment as estimated by leading local bankers. Data on a wide range of expense items such as cost of feed and of fingerlings was acquired from regional suppliers and the current wholesale price of cold pack fish was obtained from national, regional and local distributors. In every case the operator is informed of the standard figure and must act to accept or to substitute for the standard data.

Sample data for mean monthly water temperature assume mean ambient river temperatures for the months of June through September when such temperatures are above 60°F. and that the raceways are heated to 60°F. using heat effluent from the Vermont Yankee Nuclear Power Station during the remainder of the year.

At all times the fish are fed at a level to achieve maximum growth without waste given the fish size, volume of water flow, temperature, and oxygen availability. Data for calculating the optimum feed level at various temperatures and fish size are from tables provided by Gene R. Bussey, President, Life Support Systems, Inc. These tables are built into the program as are similar tables dealing with oxygen levels and rate of fish growth.

TABLE 2

20 USER MANIPULATABLE INPUTS

Biological or Operational:

Choice of species - Brook or Rainbow
No. of raceways to be stocked
Size of fingerlings to be stocked
No. of fingerlings stocked by raceway
Minimum allowable oxygen level at outflow.
Flow rate for raceways
Mean water temperatures for each of 12 months
Number of fish to be transfered between raceways
Time of harvest and number of fish harvested by raceway

Economic:

Investment level - plant and equipment
Investment level - land
Interest rate for borrowed capital
Longevity of loan
Cost of labor

- a. Manager
- b. Assistant - full time
- c. Part time help

Cost of fingerlings
Cost of feed
Cost of electric power
Wholesale price for product

Stochastic portions of the program over which the operator has no direct control are the functions for fish mortality and for generating plant shutdown with the resultant loss of heat to the raceways. The impact of this latter event is not of great significance to fish production as its chief impact is to slow the rate of growth and thus to lengthen the period required to reach market size.

The simulation operator may choose one of four forms for the final biological results of a particular production cycle. Results may be presented by raceway by month, by month by raceway, a total of all raceways by month, or simply a yearly summary. In every case the operator will learn: 1) the total number of pounds of feed used 2) total mortalities 3) number of fish loaded, 4) weight of fish loaded 5) number of fish harvested 6) weight of fish harvested 7) Feed conversion ratio 8) weight of harvested but unmarketable fish 9) weight of small marketable fish 10) weight of large marketable fish.

The profit or loss statement provides at the end of each run, a packet of financial data in 3 categories. First a revenue analysis is presented, followed by a cost analysis and finally a net profit or loss statement summarizing the season's operations.

Results

The best timing for trout production in terms of the system design and the ambient temperature conditions appears to be a season which begins in September with harvestable size fish available for market from the end of February through the end of June. While it is true that, historically, river temperatures on September 1 have ranged all the way from 63 to 80 degrees F., they fall rapidly during the month. Four inch fish can safely be stocked without danger of depleting the oxygen by mid-September even in the warmest years.

By slightly overstocking the system with 4" fingerlings in September a careful manager can cull out a few undersize fish in January and begin the harvest of 9 inch fish at the end of February. By the end of June when all raceways are empty the system can produce 160,000 pounds (live weight) of marketable size fish at a feed conversion ratio of slightly better than 1.5-to-1.

The maximum output achieved by the model is somewhat in excess of the design parameters specified by Kramer, Chin, and Mayo but this output was achieved under close to ideal temperatures. The maximum production accords very well with the conclusion reached by Harvey Willoughby in his extensive study of,

"Freshwater Fish Culture in the United States" in which he states that under ideal conditions, "--most salmonids can be reared at densities exceeding 50 Kg./m.³." ²² At maximum output this model will allow production at the level of almost 95 Kg./m.³ for the entire season but at any given time the maximum in any raceway is about 50Kg./m.³. This is achieved by continual harvesting over a five month period.

With costs at the September 1977 level, production at this maximum level will produce an income of roughly \$236,000.00. Unfortunately, total expenses are considerably greater. The plant and equipment, as designed by the engineers, is estimated to have a September 1977 price tag of 1.88 million dollars. If this is borrowed at 9 percent for 20 years, the most favorable conditions available at this time, the annual cost is almost \$206,000. At the same time operating costs will be on the order of \$165,000 and the minimal annual loss is a staggering \$135,000. The model suggests two major areas of possible savings: 1) debt repayment and 2) cost of fingerlings.

If it were possible to greatly simplify the engineering and reduce the cost to 1 million dollars then the annual repayment, at the conditions above, would be reduced to \$109,546. If at the same time it were possible to cut the cost of fingerlings from \$60,000 to \$30,000 then annual income and expenses would balance. Such reduction in the cost of fingerlings could be achieved if an "in house" production facility were to be developed using 58°F. ground water during the summer months, or as an alternative, using surplus methane from the green houses to power a refrigeration unit.

One further way to make the economics of the operation more attractive would be to use a portion of the facilities for the production of bait fish during the September - December period. During that period it is never necessary to use more than 5 of the 8 raceways to achieve full production of trout. The three underutilized raceways could be used to raise roughly 200,000 bait fish each. The required extra pumping would cost roughly \$10,800.00. Additional labor would be more than \$4,000.00 and feed perhaps \$2,000.00. Bait fish at a size range of from 3 to 4 inches bring about five cents each on the wholesale market and an average of one dollar a dozen at retail.

Thus, for an additional \$17,000 in annual operating costs, an extra \$30,000 in income might well be realized if the product were to be sold at wholesale

prices. At the present time there is a serious shortage of bait fish in Vermont and there is considerable importation both from Arkansas and from Quebec.

Conclusions:

The fish farming facility at Vermont Yankee will produce a high quality product which will reach a marketable size during the months from mid-winter to early summer. Trout harvested and sold as iced fish, not frozen, during this period, when fresh fish are relatively scarce and prices high, should find an excellent market and would certainly demand a higher price than fish sold during summer and fall, the more conventional market period.

Although an excellent case can be made for choosing brook trout as the featured species we feel more confident with rainbows. This conclusion is based on the rainbow's greater tolerance for environmental variations, a generally lower mortality rate and a current market structure which does not adequately reward the producer of what many sports fishermen believe to be a superior fish.

The economics of a rainbow trout operation is not at all promising in light of the heavy capital investment postulated by the engineers. Some savings may be possible in the facility construction. Additional savings may be possible through local production of fingerlings and extra income might be generated through the production and sale of bait fish. One item which was not possible to price in the model was the possible savings to Vermont Yankee of some of the costs involved in operating the cooling towers. When this reduced cost is included and other income maximizing options undertaken it is probable that the proposed facility could be constructed and operated at a break-even level.

It is most encouraging to find that a considerable market does in fact exist in New England for a quality human food product which would make use of a portion of what otherwise would be wasted energy. As population continues to increase, as quality protein food continues to become more expensive and as the cost of energy continues to mount the economic and social value of the proposed facility at Vernon can only rise.

Footnotes

1. Kramer, Chin, and Mayo, Inc., Vermont Yankee Aquaculture and Horticulture Energy Programs, (Seattle, Washington: Kramer, Chin and Mayo, Inc., Consulting Engineers, Architects, Applied Scientists, September, 1977)
2. Marine Environmental Services, "Commercial Application of Waste Heat from the Vermont Yankee Nuclear Power Station", (Hanover, New Hampshire; Marine Environmental Services, December, 1976)
3. George W. Klontz and John G. King, Aquaculture in Idaho and Nationwide (Boise, Idaho: Department of Water Resources, March, 1975), pp. 29.
4. John E. Bardach, John H. Ryther, and William O. McLarney, Aquaculture: The Farming and Husbandry of Freshwater Marine Organisms (New York: Wiley-Interscience, 1972), pp. 389-399.
5. "Missouri Trout: Restaurants, Fee Fishing Provide Top Markets for Troutdale Products", The Commercial Fish Farmer, 1 # 5, (May-June, 1975), p. 25-6. Also, personal communications with James MacMartin, Senior Staff Biologist, Vermont Fish and Game Department, Montpelier, Vermont; and, Peter Brezowsky, Pathologist, New Hampshire Fish and Game Commission, Concord, New Hampshire.
6. J. T. Bowen and N. Stoddard, Manual of Fish Culture: Trout Feeds and Feeding, Appendix A. I., English and Metric Length - Weight Relationships for Rainbow, Brown and Brook Trout (Washington, D.C.: Bureau of Sport Fisheries and Wildlife, July 23, 1970).
7. Lewis E. Queirolo and Richard S. Johnston, "Market Analysis of Domestically Produced Rainbow Trout and the Impact of the Introduction of Pan Size Salmon", Paper presented at the 1976 meeting of the Northwest Fish Culture Conference, P. 5-6. See also, Lewis E. Queirolo, "Substitutional Relationships Between Rainbow Trout and Pan Size Salmon: A Market Demand Analysis", (unpublished M.S. Thesis; Oregon State University, Corvallis, Oregon, 1977); and, Richard L. Saunders, "Heated Effluent for the Rearing of Fry-For Farming and for Release", in O. Derik, ed., Harvesting Polluted Waters (New York: Plenum Press, 1976), pp. 213-236.

8. Calculated from U.S. Bureau of Census, U.S. Statistical Abstract, 97 ed., Table No. 155. "Civilian Per Capita Consumption of Major Food Commodities: 1950 to 1975", (Washington, D.C.: U.S. Government Printing Office, 1976), p. 95.
9. Ibid., Table No. 1175. "Fishery Products - Per Capita Consumption: 1950 to 1975", p. 688.
10. Frost and Sullivan, Inc., Fish Farming in the U.S.A., (New York: Frost and Sullivan, Inc., 1974), p. 41.
11. R. Whitaker, "Analysis and Characteristics of United States Demand for Fishery Products", in Rudolf Krevzer, ed., Fishery Products, United Nations Food and Agriculture Organization Conference Report. (Surrey, England: Fishery News (Books), 1974), p. 353.
12. "Heated Effluent System Produces Profits For Leo Ray in Idaho", The Commercial Fish Farmer, 2 4, (May, 1976), p. 23.
13. "Trout Industry Goal: Food Market Expansion", The Commercial Fish Farmer 1 #1, (September - October, 1974), p. 18.
14. George W. Klontz and John G. King, op. cit., p. 29.
15. "Faith is a Necessity for Trout Farmer", The Commercial Fish Farmer 3 # 5 (July, 1977), p. 15.
16. Frost and Sullivan, op. cit., p. 4.
17. George W. Klontz and John G. King, op. cit., p. 30.
18. "Faith is a Necessity...", op. cit., p. 15.
19. R. Whitaker, op. cit., p. 353 and Passim.
20. "Trout Industry Goal...", op. cit., p. 19.
21. "Missouri Trout...", op. cit., p. 25-6.
22. Harvey Willoughby, "Freshwater Fish Culture in the United States", Proceedings of The First U.S.-Japan Meeting on Aquaculture at Tokyo, Japan, October 18-19, 1971. NOAA, Technical Report NMFS CIRC-388 (Seattle, Washington; 1974), p. 71.

BIBLIOGRAPHY

=====

ACKERMAN, JERRY. 'fish farms - success may lie in warm power plant water.' BOSTON SUNDAY GLOBE. (JULY 17, 1977) P.52.

ALLEN, P.G. and W. E. JOHNSON. 'research direction and economic feasibility: an example of systems analysis for lobster aquaculture.' AQUACULTURE. VOL.9; (NOVEMBER 1976). PP. 155-180.

AQUATEC, INC. 'ecological studies of the Connecticut River at Vernon, Vermont, report V.' SOUTH BURLINGTON, VERMONT; AQUATEC, INC. 1976.

AVALT, J. W., 'aquaculture research report: studies check costs, returns of mountain trout production.' THE COMMERCIAL FISH FARMER. VOL.3,NO.6; (SEPTEMBER 1977). P.36.

BARDACH, J. E., J. H. RYHER, and W. O. McLARNEY. 'aquaculture: the farming and husbandry of freshwater and marine organisms. NEW YORK; WILEY-INTERSCIENCE, 1972.

BOWEN, J. T. and N. STODDARD. 'manual of fish culture: trout feeds and feeding.' WASHINGTON D. C.; BUREAU OF SPORT FISHERIES AND WILDLIFE, JULY 1970.

BURROWS, R. E. and B. D. COMBS. 'controlled environments for salmon propagation.' THE PROGRESSIVE FISH CULTURALIST VOL.30,NO.3; (JULY 1968) PP.123-136.

BUSSEY, GENE R. 'how to grow trout in your backyard.' ALBUQUERQUE, NEW MEXICO; LIFE SUPPORT SYSTEMS, 1972.

'catfish processing: a rising Southern industry.' WASHINGTON, D. C.; ECONOMIC RESEARCH SERVICE, DEPARTMENT OF AGRICULTURE. 1973.

'demand for farm-raised channel catfish in supermarkets.' WASHINGTON, D. C.; ECONOMIC RESEARCH SERVICE, DEPARTMENT OF AGRICULTURE, 1973.

DERIK, O. ED. 'harvesting polluted waters: waste heat and nutrient loaded effluents in the aquaculture.' NEW YORK; PLENUM PRESS. 1976.

EDDY, S. and J. C. UNDERHILL. 'northern fishes.' MINNEAPOLIS; UNIV. OF MINNESOTA PRESS. 1974.

ELLIOTT, JOSEPH W. 'the oxygen requirement of chinook salmon.' THE PROGRESSIVE FISH CULTURALIST. VOL.31,NO.2; (APRIL 1969) PP. 67-73.

'faith as a necessity for trout farmer.' THE COMMERCIAL FISH FARMER. VOL.3,NO.5; (JULY 1977). P.14-17.

'for aquaculture: greater utilization of waste heat from power plants is envisioned.' THE COMMERCIAL FISH FARMER. VOL.2,NO.4; (MAY 1976). P. 25-26.

FROST AND SULLIVAN, INC. 'fish farming in the U. S. A.' NEW YORK; FROST AND SULLIVAN, INC., 1974

GALLATIN CATFISH PROJECT. 'utilization of waste heat from power plants for aquaculture, 1974 annual report.' TENNESSEE VALLEY AUTHORITY, POWER RESEARCH STAFF, 1974.

GATES, J. M., G. C. MATTHIESSEN and C. A. GRISCAN. 'aquaculture in New England.' KINGSTON, R. I. SEA GRANT; UNIV. OF RHODE ISLAND, MARINE TECHNICAL REPORT SERIES, No. 18, 1974.

GAUCHER, THOMAS. 'aquaculture: a New England perspective' KINGSTON, R. I. SEA GRANT; UNIV. OF RHODE ISLAND, 1971.

GUERRA, C. R., B. L. GODFRIAUX, and A. F. EBLE. 'Power Plant waste heat utilization in aquaculture - workshop I papers.' NEWARK, N. J.; PUBLIC SERVICE ELECTRIC AND GAS COMPANY, 1975.

HAYENGA, WAYNE and JACK C. PARKER. 'investment analysis of shrimp mariculture.' MIMED DRAFT, TEXAS AGRICULTURAL EXTENSION SERVICE APRIL 12, 1974.

'heated effluent system produces profits for Leo Ray in Idaho.' THE COMMERCIAL FISH FARMER. VOL.2, NO.4; (MAY 1976) PP.4-8.

HENDERSON, U. B. 'economic assessment of waste water aquaculture treatment systems.' ADA, OKLAHOMA; ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY, OFFICE OF RESEARCH AND DEVELOPMENT, U. S. ENVIRONMENTAL PROTECTION AGENCY, REPORT EPA-600/2-76-293, DECEMBER, 1976.

HUET, M. and J. A. TIMMERMANS. 'textbook of fish culture: breeding and cultivation of fish.' SURREY, ENGLAND. FISHING NEWS (BOOKS) LTD., 1970.

HUKE, ROBERT E. and ROBERT W. SHERWIN, JR. 'a fish and vegetable grower for all seasons.' NORWICH, VERMONT; NORWICH PUBLICATIONS. 1977.

'Idaho's water rich Magic Valley; heart of the food trout industry.' THE COMMERCIAL FISH FARMER. VOL.2, NO.4; (MAY, 1976) PP.4-8.

JEWELL, W. J. 'energy, agriculture, and waste management.' ANN ARBOR, MICHIGAN; SCIENCE PUBLISHERS, INC., 1975.

KLONTZ, G. W. and J. G. KING. 'aquaculture in Idaho and nationwide.' BOISE, IDAHO; DEPT. OF WATER RESOURCES. 1975.

KRAMER, CHIN, AND MAYO, INC. 'Vermont Yankee aquaculture and horticulture energy programs.' SEATTLE, WASHINGTON; KRAMER, CHIN, AND MAYO, INC. SEPTEMBER, 1977.

KREUZER, R., ED. 'fishery products, U. N. F. A. O. conference report.' SURREY, ENGLAND; FISHERY NEWS (BOOKS) LTD., 1974.

LEITRITZ, EARL and ROBERT C. LEWIS. 'trout and salmon culture: hatchery methods' STATE OF CALIFORNIA, DEPT. OF FISH AND GAME 1976.

LIAO, P. B. and R. D. MAYO 'salmonid hatchery water reuse systems.' AQUACULTURE. VOL.1; (1972) PP. 317-335.

MacCRIMMON, H. R., J. E. STEWART and J. R. BRETT. 'aquaculture in Canada: the practice and the promise.' OTTAWA; BULLETIN OF THE FISHERIES RESEARCH BOARD OF CANADA. 1974.

MARINE ENVIRONMENTAL SERVICES. 'commercial application of waste heat from the Vermont Yankee Nuclear Power Station' HANOVER, N.H.; MARINE ENVIRONMENTAL SERVICES. 1976.

MEADE, THOMAS L. 'the technology of closed system culture of salmonids' KINGSTON, R.I.; UNIV. OF RHODE ISLAND; MARINE ADVISORY SERVICE, 1974.

'Missouri trout: restaurants, fee fishing provide top markets for troutdale products.' THE COMMERCIAL FISH FARMER. VOL.1, NO.5; (MAY-JUNE 1975). PP. 25-26.

NATIONAL MARINE FISHERIES SERVICE. 'the fishery market news service.' WASHINGTON, D. C.; U. S. DEPT. OF COMMERCE; NOAA, NATIONAL MARINE FISHERIES SERVICE.

DRAVETZ, C. A. 'marketing tips for the fish farmer.' THE CATFISH FARMER AND WORLD AQUACULTURE NEWS. VOL.6, NO.4; (JULY-AUGUST 1974). PP.25-26.

PRICE, D. R. and R. M. PEART. 'simulation model to study the utilization of waste heat using a combination reservoir and greenhouse complex.' JOURNAL OF ENVIRONMENTAL QUALITY. VOL.2, NO.2; (APRIL-JUNE 1973), PP.216-224.

QUEIROLO, LEWIS E. 'substitutional relationships between rainbow trout and pan size salmon: a market demand analysis.' UNPUBLISHED M. S. THESIS, OREGON STATE UNIVERSITY. 1977.

QUEIROLO, LEWIS E. and RICHARD S. JOHNSON. 'market analysis of domestically produced rainbow trout and the impact of the introduction of pan size salmon.' PAPER PRESENTED AT THE 1976 MEETINGS OF THE NORTHWEST FISH CULTURE CONFERENCE.

SEDGWICK, S. DRUMMOND. 'trout farming handbook, rev. edition. LONDON: SEELEY, SERVICE & CO. 1976.

'trout industry goal: food market expansion.' THE COMMERCIAL FISH FARMER. VOL1, NO.1; (SEPTEMBER-OCTOBER 1974) P.18.

U. S. BUREAU OF CENSUS. 'U. S. statistical abstract, 97 ed.' WASHINGTON, D. C.; U. S. GOVERNMENT PRINTING OFFICE, 1976.

VONDURSKA, JOHN. 'aquacultural economics bibliography.' WASHINGTON, D. C.; DEPT. OF COMMERCE, NOAA, NATIONAL MARINE FISHERIES SERVICE, 1976.

WILLOUGHBY, HARVEY. 'a method for calculating carrying capacities of hatchery troughs and ponds.' THE PROGRESSIVE FISH CULTURALIST, VOL.30,NO.3; (1968). PP.173-174.

WILLOUGHBY, HARVEY. 'freshwater fish culture in the United States.' PROCEEDINGS OF THE FIRST U.S.-JAPAN MEETING ON AQUACULTURE AT TOKYO, JAPAN OCT.18-19,1971. NOAA, TECHNICAL REPORT NMFS CIRC-388. SEATTLE, WASHINGTON. 1974. P.71.

YEE, W. C. 'thermal aquaculture: engineering and economics.' ENVIRONMENTAL SCIENCE AND TECHNOLOGY. VOL. 6,NO.3 (1972). PP.232-237.

0.500 CRU 1.182 SEC
READY

LIST

FISHFA1 15 DEC 77 13:51

1 MARGIN 100

2 ' THIS PROGRAM IS TOO LARGE TO RUN ON 16K - IT MUST HAVE 24K.

3 ' PROGRAM WRITTEN BY DOUGLAS CAULDWELL, PROF. CLARK ARCHER AND PROF. ROBERT HUK

4 ' ALL OF THE DEPARTMENT OF GEOGRAPHY, DARTMOUTH COLLEGE.

5 '

6'

100 PRINT "*****"

110 PRINT

120 PRINT "VERMONT YANKEE COMMERCIAL FISH FARMING SIMULATION"

130 PRINT

140 PRINT "*****"

150 PRINT

160 PRINT

170 PRINT "This program will allow the user to raise a crop of trout at"

180 PRINT "Vernon, N.H. in water from the Connecticut River. Water temp., the"

190 PRINT "rate of pumping, the number of raceways in use and the minimum oxygen"

200 PRINT "threshold may be varied by the user. Eight raceways and equipment are as"

210 PRINT "designed by Kramer, Chin and Mayo. Raceway capacity is roughly 43,000 sals."

220 PRINT "Raceway measurements are 12' by 80' by 3'. To change water twice"

230 PRINT "each hour requires a pumping rate of about 715 sals. per minute."

240 PRINT "Program will feed fish at the optimum level and user may start the fish at"

250 PRINT "whatever length he wishes to purchase and harvest at the end of any month"

260 PRINT "when fish are 15 inches or smaller. Program will harvest automatically when"

270 PRINT "fish size exceeds 15 inches."

280 PRINT

290 PRINT

300 PRINT

310 PRINT

320 PRINT

330 PRINT

340 LET T2=20

350 LET Q2 = 1.88

360 LET Q3 = 9

370 print

380 PRINT "ARE YOU WILLING TO ACCEPT THESE TERMS? (1 = YES, 2 = NO)"

390 INPUT Q1

400 PRINT

410 IF Q1 = 1 THEN 760

420 IF Q1 = 2 THEN 470

430 PRINT "PLEASE ANSWER '1' OR '2'"

440 GO TO 390

450 LET Q9 = 0

'Q9 = COUNTER ONLY USED OFTEN

460 print

```

470 PRINT "HOW MUCH WILL YOU BORROW OR RAISE PUBLICLY TO PAY FOR"
480 PRINT "CONSTRUCTION (expressed in millions (1.00) as above)"
490 INPUT Q2
500 PRINT
510 IF Q2 = 1 THEN 610
520 IF Q2 > 2.5 THEN 550
530 IF Q2 < .5 THEN 580
540 GO TO 610
550 PRINT "TOO COSTLY - YOU LOOSE MONEY - PLEASE REPEAT!!!"
560 LET Q2 = 1
570 GO TO 470
580 PRINT "TOO LITTLE INVESTMENT - WON'T WORK - PLEASE REPEAT!"
590 LET Q2 = 1
600 GO TO 470
610 PRINT
620 PRINT "HOW MANY YEARS WILL YOU TAKE TO REPAY THE LOAN (AN INTIGER)?"
630 INPUT T2
640 LET Q2 = 0
650 PRINT "NOW - WHAT INTEREST RATE SHALL WE WORK WITH?"
660 PRINT "(expressed in the form '9.66' or '10.5' for example)"
670 INPUT Q3
680 PRINT
690 IF Q3 = 1 THEN 760
700 IF Q3 < 6.51 THEN 720
710 GO TO 760
720 PRINT "IN THIS ECONOMY - ARE YOU KIDDING? LEAD ME TO YOUR BANKER!"
730 PRINT "please repeat"
740 LET Q3 = 1
750 GO TO 650
760 PRINT "I ASSUME THAT THE LAND IS DONATED BY VERMONT YANKEE AT NO COST!"
770 PRINT
780 PRINT "IS THIS O.K. WITH YOU? (1 = YES, 2 = NO)"
790 INPUT Q1
800 IF Q1 = 1 THEN 840
810 IF Q1 = 2 THEN 860
820 PRINT "PLEASE ANSWER '1' OR '2'"
830 GO TO 780
840 LET Q4 = 0
850 GO TO 1010
860 LET Q4 = 0
870 PRINT "WHAT WILL YOU PAY FOR THE 10 ACRES NEEDED"
880 PRINT "express in dollars without using commas)"
890 INPUT Q4
900 PRINT
910 IF Q4 = 1 THEN 1020
920 IF Q4 < 9000 THEN 950
930 IF Q4 > 60001 THEN 980
940 GO TO 1010
950 PRINT "LESS THAN $1000 PER ACRE? I DON'T BELIEVE IT! PLEASE REPEAT."
960 LET Q4 = 1
970 GO TO 870

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980 PRINT "MORE THAN $6000 PER ACRE? MIGHTY COSTLY -PLEASE REPEAT!"
990 LET R9 = 1
1000 GO TO B70
1010 PRINT
1020 PRINT "CAPITAL INVESTED - NOW TO THE OPERATIONS!"
1030 PRINT
1040 ' DIMENSION STATEMENTS
1050
1060 DIM S(12)
1070 DIM B(11)
1080 DIM A(10,300)
1090 DIM T(13)
1100 DIM I$(12)
1110 DIM Q(20)
1120
1130
1140 ' INITIAL INPUTS
1150
1160 PRINT
1170 PRINT
1180 PRINT
1190 PRINT "DO YOU WISH TO USE SAMPLE DATA FOR THE NUMBER AND SIZE OF RACEWAYS,"
1200 PRINT "MONTHLY TEMPERATURES, THE NUMBER AND SIZE OF FISH STOCKED, "
1205 PRINT "COST OF FEED, ELECTRICITY AND LABOR?"
1210 PRINT " (1=YES, 2=NO)"
1220 INPUT X1
1230 PRINT
1240 IF X1=1 THEN 1280
1250 IF X1=2 THEN 1750
1260 PRINT "PLEASE ANSWER 1 OR 2"
1270 GO TO 1190
1280
1290 ' SAMPLE DATA SECTION
1300
1310 LET R9=1
1320 PRINT
1330 IF R9=1 THEN 1380
1340 PRINT "PLEASE ANSWER 1 OR 2"
1350 GO TO 1310
1360
1370
1380 ' WILLOUGHBY SAMPLE DATA
1390
1400 LET R4=2
1410 LET K=8
1420 LET O2=6
1430 LET F7=715
1440 LET F1=4
1450 LET S1 = .20
1460 LET N = .1710
1470 LET N2 = .0155

' FISH SIZE DUMMY VECTOR TO SWITCH HARVEST SIZE CLASSES
' HOLD INITIAL CONDITIONS AND PASS TO "RESULT"
' RACEWAYS, DATA RECORDS
' MONTHLY TEMPERATURES
' NAMES OF MONTHS
' EXPENCE DATA FOR PRINT OUT

' RAINBOW TROUT IN SAMPLE DATA
' K=1 OF RACEWAYS
' O2=OUTGOING OXYGEN (PPH), MINIMUM THRESHOLD
' F7=FLOW RATE (GPH)
' F1=FISH SIZE (") AT LOADING
' COST OF EACH FINGERLING
' COST / LB. OF FEED
' PRICE / K. M. H.

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```

1480 FOR I=1 TO 12
1490   READ T(I)
1500   DATA 68,60,60,60,60,60,60,60,60,66,73,74
1510   READ T(I)
1520   DATA SEPTEMBER,OCTOBER,NOVEMBER,DECEMBER,JANUARY
1530   DATA FEBRUARY,MARCH,APRIL,MAY,JUNE,JULY,AUGUST
1540 NEXT I
1550
1560 PRINT
1570 PRINT "*** SAMPLE DATA ***"
1580 PRINT
1590 PRINT "RAINBOW TROUT"
1600 PRINT
1610 PRINT "† OF RACEWAYS =" ; K
1620 PRINT "OUTGOING OXYGEN CONTENT OF WATER (PPM) =" ; O2
1630 PRINT "FLOW RATE (GPM) =" ; F7
1640 PRINT "FISH SIZE (IN INCHES) AT LOADING =" ; F1
1650   PRINT
1660   PRINT "MONTH","WATER TEMPERATURE"
1670   PRINT "-----","-----"
1680   FOR I=1 TO 12
1690     PRINT T(I);TAB(21);T(I)
1700   NEXT I
1710   PRINT
1711   LET L7=13000
1712   LET L8= 8000
1713   LET L9= 900
1720   GO TO 2830
1730
1740
1750 ' INITIAL INTERACTIVE INPUTS
1760
1770 PRINT
1780 LET R9=1
1790 PRINT
1800   IF R9=1 THEN 1850
1810   PRINT
1820   PRINT "PLEASE ANSWER 1 OR 2"
1830   GO TO 1770
1840
1850 ' INPUTS FOR WILLOUGHBY METHOD
1860
1870 PRINT
1880 PRINT "DO YOU WISH TO STOCK BROOK OR RAINBOW TROUT? (1=BROOK, 2=RAINBOW)";
1890 INPUT R4
1900 PRINT
1910   IF R4=1 THEN 1960
1920   IF R4=2 THEN 1960
1930   PRINT
1940   PRINT "PLEASE TYPE 1 OR 2, TRY AGAIN,"
1950   GO TO 1880

```

'MONTHLY WATER TEMP (F)
 'MONTH NAMES
 'MANAGERS SALARY, SAMPLE DATA
 'WORKERS SALARY, SAMPLE DATA
 'HARVEST WORKER, SAMPLE DATA
 'IF R4 ALLOWABLE, CONTINUE
 'IF R4 ALLOWABLE, CONTINUE

```

1960 PRINT
1970 PRINT "    THE COST OF FINGERLINGS IS AS FOLLOWS:"
1980 PRINT "    BROOK TROUT $200/1000 FISH AT 4 INCHES"
1990 PRINT "    RAINBOW  $250 /1000 FISH AT 4 INCHES"
2000 PRINT
2001 PRINT "DO YOU WANT TO CHANGE THE COST OF FINGERLINGS? (YES OR NO)"
2002 INPUT A$
2003 IF A$="NO" THEN 2019
2004 PRINT
2005 PRINT "WHAT PRICE ARE YOU WILLING TO PAY FOR 1000 FINGERLINGS?"
2006 PRINT "(Input in form 200 or 275, for example)"
2007 INPUT S1
2008 LET S1=S1/1000.
2009 IF S1<.70 THEN 2019
2010 PRINT "YOUR INPUT FINGERLING PRICE IS UNREASONABLY EXPENSIVE, TRY AGAIN."
2012 GO TO 2005
2019 IF R4 = 1 THEN 2040
2020 LET S1 = .25
2030 GO TO 2055
2040 LET S1 = .2
2050 PRINT
2055 PRINT
2060 PRINT "HOW MANY RACEWAYS DO YOU WISH TO USE (UP TO 10)";
2070 INPUT K
2080 PRINT
2090 IF K<=10 THEN 2140 "IF RACEWAY # ALLOWABLE, CONTINUE
2100 PRINT
2110 PRINT "YOU MAY ONLY USE UP TO 10 RACEWAYS. TRY AGAIN."
2120 GO TO 2060
2130
2140 PRINT "WHAT MINIMUM VALUE DO YOU WISH TO USE FOR THE OXYGEN CONTENT (PPM) AT DISCHARGE?"
2150 PRINT "(6=OPTIMUM FOR FISH GROWTH, 5=MINIMUM SAFE THRESHOLD FOR FISH GROWTH)";
2160 INPUT O2
2170 IF O2=5 THEN 2230 "IF O2 ALLOWABLE VALUE, CONTINUE
2180 IF O2=6 THEN 2230 "IF O2 ALLOWABLE VALUE, CONTINUE
2190 PRINT
2200 PRINT "PLEASE TYPE 5 OR 6"
2210 GO TO 2140
2220
2230 PRINT
2240 PRINT "WHAT IS THE FLOW RATE (IN GPM)";
2250 INPUT F7
2260 PRINT
2270 PRINT "THE PRESENT (SEPT.,1977) CHARGE FOR ELECTRIC ENERGY IS $0.0155"
2280 PRINT "PER K.W.H. WILL YOU ACCEPT THIS RATE? (YES OR NO)"
2290 PRINT
2300 INPUT A$
2310 IF A$ = "YES" THEN 2370
2320 IF A$ = "NO" THEN 2340
2330 GO TO 2270
2340 PRINT "WHAT RATE DO YOU WISH TO TEST? Input in the form .054"

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2350 INPUT N2
2360 GO TO 2371
2370 LET N2 = .0155
2371 PRINT
2372 PRINT "THE STANDARD LABOR COSTS ARE AS FOLLOWS: MANAGER $13000 PER YEAR;"
2373 PRINT "WORKER $8000 PER YEAR; AND HARVEST ASSISTANT, $900 FOR TWO MONTHS."
2374 PRINT "DO YOU WISH TO CHANGE THESE VALUES? (YES OR NO)."

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2670 NEXT I
2680 PRINT
2690 PRINT
2700 PRINT "THE STANDARD COST OF FEED BASED ON PURCHASES OF 500 LBS. OR MORE"
2710 PRINT "IS $17.10 PER 100 LBS."
2720 LET N1 = 17.10
2730 PRINT
2740 PRINT "IS THIS PRICE ACCEPTABLE?? YES OR NO"
2750 INPUT A$
2760 IF A$ = "YES" THEN 2810
2770 PRINT
2780 PRINT "WHAT WILL YOU PAY FOR 100 LBS. OF FEED"
2790 PRINT "(input in the form 5.50 or 6.66)"
2800 INPUT N1
2810 LET N = N1/100
2820 PRINT
2830 ' CALCULATION OF POND CAPACITY (IN LBS) USING WILLOUGHBY METHOD
2840
2850 CALL "OXYGEN":T(1),O1 'O1=OXYGEN CONTENT (PPM) OF INCOMING WATER
2860
2870 LET G8=(O1-O2)*.0545*F7 'G8=FOOD/DAY (IN LBS) TO FEED FISH
2880
2890 CALL "FEED":F1,T(1),D1 'CALCULATE % BODYWEIGHT TO FEED FISH
2900
2910 LET C3=G8/(D1*.01) 'POND CAPACITY (IN LBS)
2920
2930 GO TO 3260
2940
2950
2960 PRINT
2970
2980 'CALCULATION OF POND CAPACITY (IN LBS) AT ELEVATION -- 5000 FT
2990 ' TEMPERATURE 50 DEG F. AND 9" FISH
3000
3010 CALL "SUPPORT":S,O,L1 'L1=SUPPORT (IN LBS)/90 FT
3020
3030 LET C1=A1/L1 'C1=POND SUPPORT(IN LBS)
3040
3050 ' POND CAPACITY AT USER ELEVATION, USER TEMP, 9" FISH
3060
3070 CALL "LABRAT1":T(1),P1 'P1=POUNDRAGE RATIO FOR FULLY
3080 'AERATED 50 GPM FLOW
3090
3100 LET C2=C1*P1 'C2=POND CAPACITY (IN LBS) AT
3110 'USER TEMP, 9" FISH
3120
3130 ' POND CAPACITY (IN LBS) AT USER ELEVATION, USER TEMP,
3140 ' USER SIZE FISH
3150
3160 LET L2=9/F1 'L2=LOADING FACTOR
3170

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3180 LET C3=C2/L2                                'C3=POND CAPACITY (IN LBS) AT USER
3190
3200
3210 ' CALCULATION OF POND CAPACITY (# OF FISH) FOR WILLOUGHBY AND DUSSEY METHOD
3220
3230
3240 LET F4=F1
3250
3260 CALL 'FISHLB':F1,G1                          'G1=#FISH/LB
3270
3280 LET N1=INT(C3*G1)                            'N1=POND CAPACITY (# OF FISH)
3290
3300 ' INITIAL LOADING OF THE RACEWAYS
3310
3320 PRINT
3330 PRINT 'WOULD YOU LIKE AN ESTIMATE OF THE RACEWAY CAPACITY FOR ANY GIVEN MONTH (YES OR NO)?'
3340 INPUT J$
3350 IF J$='YES' THEN 3410
3360 IF J$='NO' THEN 4060
3370 PRINT
3380 PRINT 'PLEASE TYPE YES OR NO. TRY AGAIN'
3390 GO TO 3330
3400
3410 PRINT
3420 PRINT 'INPUT THE NUMBER OF THE MONTH FOR WHICH YOU WISH TO KNOW THE CAPACITY'
3430 PRINT '(FOR EXAMPLE, IF YOU START YOUR SEASON IN SEPTEMBER AND WANT TO KNOW'
3440 PRINT 'THE FISH SIZE IN MAY, TYPE 9, FOR THE 9TH MONTH IN YOUR CYCLE)')
3450 INPUT X7
3460 IF X7<=12 THEN 3510
3470 PRINT
3480 PRINT 'YOU DON'T HAVE THAT MANY MONTHS. TRY AGAIN.'
3490 GO TO 3420
3500
3510 ' CALCULATION OF POND CAPACITY (LBS) AT USER DESIGNATED MONTH
3520
3530
3540 LET U5=F1
3550 LET U9=T(1)
3560
3570 IF X7=1 THEN 3680
3580
3590 FOR I=1 TO X7-1                                'LOOP TO FIND FISH SIZE AT USER DESIG MO
3600 LET U9=T(I)
3610 CALL 'GROWTH':U9,F2
3620 LET U5=U5+F2
3630 IF I<X7-1 THEN 3650
3640 LET U9=T(I+1)
3650 NEXT I
3660
3670
3680 IF R9=2 THEN 3840                                'IF BUSSEY THEN

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```

'SUM OF FISH GROWTH TO DATE
'IF NOT AT END, CONTINUE
'SET U9 AHEAD IF END OF USER DESIG PERIOD

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3690
3700
3710 ' WILLOUGHBY CALCULATION
3720
3730 CALL 'OXYGEN':U9,D1
3740
3750 LET G8=(D1-D2)*.0545*F7          'G8=FOOD/DAY (IN LBS) TO FEED FISH
3760
3770 CALL 'FEED':U5,U9,D1             'D1=% BODYWGT TO FEED FISH
3780
3790 LET C6=G8/(D1*.01)               'C6=NEXT MONTH'S CAPACITY (IN LBS)
3800
3810 GO TO 3940
3820
3830
3840 ' BUSSEY CALCULATION
3850
3860 CALL 'LABRAT1':U9,P3
3870
3880 LET C5=C1*P3                     'C5=NEXT MO POND CAPAC AT USER TEMP, 9 * FISH
3890
3900 LET L2=9/U5                      'L2=LOADING FACTOR
3910
3920 LET C6=C5/L2                    'C6=NEXT MONTH'S CAPACITY (IN LBS)
3930
3940 'CALCULATION OF POND CAPACITY (#) FOR USER DESIGNATED MONTH
3950
3960 CALL 'FISHLR':U5,H5
3970
3980 LET N3=INT(C6*H5)                'N3=NEXT MONTH'S CAPACITY (#)
3990
4000
4010 PRINT
4020 PRINT 'PROJECTED RACEWAY CAPACITY (# OF FISH) IN 'IT$(X7)';' =';N3
4030
4040
4050
4060 PRINT
4070 PRINT
4080 PRINT
4090 PRINT 'INITIAL CAPACITY (# OF FISH)PER RACEWAY =';N1
4100 PRINT
4110 PRINT 'TYPE IN THE # OF THE RACEWAY TO BE STOCKED (TO STOP TYPE 50)';
4120 INPUT R
4130 PRINT
4140
4150 IF R=50 THEN 4360                'FLAD TO STOP LOADING
4160 IF R<=K THEN 4220                'IF R<=# OF RACEWAYS, CONTINUE
4170 PRINT 'YOU DON'T HAVE THAT MANY RACEWAYS. TRY AGAIN.'
4180 PRINT
4190 GO TO 4110

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```

4200
4210
4220 PRINT "HOW MANY FISH DO YOU WISH TO LOAD IN RACEWAY "I1"
4230 INPUT B6
4240 PRINT
4250
4260 IF B6<=N1 THEN 4320                                'CHECK IF CAP EXCEEDED
4270 PRINT "YOU HAVE EXCEEDED RACEWAY CAPACITY. TRY AGAIN."
4280 PRINT "REMEMBER, POND CAPACITY ="I1"
4290 PRINT
4300 GO TO 4220
4310
4320 LET A(R,1+I7)=B6                                    '# OF FISH STOCKED
4330 LET A(R,2+I7)=B6/O1                                'LBS OF FISH STOCKED
4340
4350 GO TO 4110
4360 PRINT
4362 PRINT "Please note that in each of the months below the HARVEST and"
4364 PRINT "TRANSFER of fish both take place at the END of the month."
4370 FOR R=1 TO K
4380 LET A(R,3+I7)=F1                                    'FISH SIZE (") AT STOCKING
4390 NEXT R
4400
4410 ' INITIAL BOOKKEEPING
4420
4430 IF S=2 THEN 4490
4440 IF O=2 THEN 4470
4450 LET D$="NO SHADE CONTROL, NO AERATION"
4460 GO TO 4530
4470 LET D$="NO SHADE CONTROL, AERATION"
4480 GO TO 4530
4490 IF O=2 THEN 4520
4500 LET D$="SHADE CONTROL, NO AERATION"
4510 GO TO 4530
4520 LET D$="SHADE CONTROL, AERATION"
4530
4540 LET B(1)=A1                                          'POND SURFACE AREA
4550 LET B(2)=C3                                          'RACEWAY CAP (IN LBS)
4560 LET B(3)=N1                                          'RACEWAY CAP (# OF FISH)
4570 LET B(4)=F1                                          'FISH SIZE (") AT STOCKING
4580 LET B(5)=T(1)                                        'INITIAL WATER TEMP (F)
4590
4600 PRINT
4610
4620
4630
4640 ' START CYCLE
4650 ' -----
4660
4670
4680 FOR I=1 TO 12

```

'MONTH LOOP


```

5070      LET A(R,5+I7)=A(R,4+I7)
5080
5090
5100
5110 / FISH GROWTH (IN INCHES)
5120 / -----
5130
5140
5150      IF H7=10 THEN 5210          'IF NO FISH IN ANY RACEWAY, SKIP AHEAD
5160
5170      CALL 'GROWTH' I7,F2          'F2=GROWTH (")
5180
5190      LET A(R,8+I7)=F2            'FISH GROWTH (")
5200
5210      LET A(R,9+I7)=A(R,3+I7)+A(R,8+I7)    'NEW FISH SIZE
5220
5230      IF A(R,9+I7)>=9.0 GO TO 5260    'TEST FOR UNDERSIZE FISH
5240      LET S(I)=0                    'SET HARVEST FLAG =0 (TOO SMALL)
5250      GO TO 5310
5260      IF A(R,9+I7)>10.5 GO TO 5290    'TEST FOR SMALL HARVESTABLE FISH
5270      LET S(I)=1                    'SET HARVEST FLAG =1 (9-10.5 IN HARVESTABLE FISH)
5280      GO TO 5310
5290      LET S(I)=2                    'SET HARVEST FLAG =2 (OVER 10.5 IN HARVESTABLE FISH)
5300
5310      IF H7=10 THEN 5380          'IF NO FISH IN RACEWAYS, SKIP AHEAD
5320
5330      IF A(R,9+I7)<=15 THEN 5380    'IF FISH NOT TOO LARGE, CONTINUE
5340      PRINT
5350      PRINT 'WARNING!!! FISH SIZE NEXT MONTH TOO LARGE. THE PROGRAM WILL AUTOMATICALLY HARVEST ALL.'
5360      PRINT
5370
5380      IF I7=0 THEN 5420
5390      LET A(R,10+I7)=A(R,10+I7-25)+A(R,8+I7)    'GROWTH TO DATE
5400      IF A(R,1+I7)=0 THEN 5690    'IF NO FISH IN RACEWAY R, SKIP AHEAD
5410      GO TO 5440
5420      LET A(R,10+I7)=A(R,8+I7)
5430      IF A(R,1+I7)=0 THEN 5670
5440
5450
5460
5470 / FISH MORTALITY
5480 / -----
5490
5500
5510      CALL 'RANDOM' I7              'GENERATE RANDOM NUMBER FOR MORTAL CALC
5520
5530      LET A(R,11+I7)=INT(A(R,1+I7)*R7*D1*.01+.5)    '% OF MORTALITIES
5540
5550      IF R4=2 THEN 5590            'IF RAINDOWS, CONTINUE
5560
5570      LET A(R,11+I7)=INT(1.3*A(R,11+I7))    'BROOK MORTALITIES 1.3X RAINDOWS

```

```

5580
5590 IF A(R,11+I7)=INT(A(R,11+I7)) THEN 5620
5600 LET A(R,11+I7)=INT(A(R,11+I7))+1
5610
5620 PRINT
5630 PRINT '# OF MORTALITIES IN RACEWAY'#R; '*=';A(R,11+I7)
5640 PRINT
5650
5660
5670 LET A(R,12+I7)=A(R,1+I7)-A(R,11+I7) '# FISH AFTER MORTALITIES
5680
5690 IF I7=0 THEN 5730
5700 LET A(R,13+I7)=A(R,13+I7-25)+A(R,11+I7) 'MORTALITIES TO DATE
5710 IF A(R,1+I7)=0 THEN 6490 'IF NO FISH IN RACEWAY R, SKIP AHEAD
5720 GO TO 5740
5730 LET A(R,13+I7)=A(R,11+I7)
5740
5750
5760
5770 ' HARVEST
5780 ' -----
5790
5800 IF R9=2 THEN 6000 'IF BUSSEY THEN
5810
5820
5830 ' WILLOUGHBY POND CAPACITY (IN LBS) CALCULATION FOR NEXT MONTH
5840
5850
5860 CALL 'OXYGEN'#U8,D1 'O1=OXYGEN CONTENT (PPM) OF INCOMING WATER
5870
5880 LET G8=(D1-D2)*.0545*F7 'G8=FOOD/DAY (IN LBS) TO FEED FISH
5890
5900 CALL 'FEED'#F1,U8,D1 'D1=% BODYWGHT TO FEED FISH
5910
5920 LET C6=G8/(D1*.01) 'C6=NEXT MO CAPACITY (IN LBS)
5930
5940 GO TO 6080
5950
5960
5970 ' BUSSEY POND CAPACITY (IN LBS) CALCULATION FOR NEXT MONTH
5980
5990
6000 CALL 'LABRAT1'#U8,P3 'P3=NEXT MO POUNDAGE RATIO
6010
6020 LET C5=C1*P3 'NEXT MO POND CAP AT USER TEMP
6030
6040 LET L2=9/(A(R,9+I7)) 'NEXT MO LOADING FACTOR
6050 LET C6=C5/L2 'C6=NEXT MO POND CAPACITY AT USER
6060 'TEMP, USER FISH SIZE
6070
6080 LET F1=A(R,9+I7) 'F1=FISH SIZE(%) AT BEG OF NEXT MO

```

6090 CALL 'FISHLB' IF I, G1
 6100
 6110 LET N3=INT(C6*G1) 'N3=NEXT MO CAPACITY (# OF FISH)
 6120
 6130
 6140 IF A(R,1+I7)=0 THEN 6300 'IF NO FISH, CAN 'T HARVEST
 6150 IF A(R,9+I7)>15 THEN 6440 'HARVEST ALL IF FISH TOO LARGE
 6160 IF I=12 THEN 6190 'IF END OF YEAR, DON'T CALCULATE NEXT MO CAPAC
 6170
 6180 PRINT 'RACEWAY # 'I7' CAPACITY (# FISH) FOR NEXT MONTH IS 'N3';
 6190 PRINT 'YOU NOW HAVE 'A(R,12+I7); 'IN THE RACEWAY.'
 6200 PRINT 'DO YOU WISH TO HARVEST? (TYPE YES OR NO)'
 6210 INPUT C6
 6220 PRINT
 6230
 6240 IF C6='YES' THEN 6330
 6250 IF C6='NO' THEN 6300
 6260 PRINT 'PLEASE TYPE YES OR NO.'
 6270 PRINT
 6280 GO TO 6200
 6290
 6300 LET H1=0
 6310 GO TO 6430 'IF NO FISH IN RACEWAY, HARVEST =0
 6320
 6330 PRINT 'HOW MANY FISH DO YOU WISH TO HARVEST?'
 6340 INPUT H1
 6350 PRINT
 6360
 6370 IF H1<=A(R,12+I7) THEN 6430 'CHECK IF HARVEST LEGIT
 6380 PRINT
 6390 PRINT 'YOU DONT HAVE THAT MANY FISH. TRY AGAIN.'
 6400 PRINT
 6410 GO TO 6330
 6420
 6430 IF A(R,9+I7)<=15 THEN 6460 'IF FISH SIZE <= THAN LIMIT, CONTINUE
 6440 LET H1=A(R,12+I7) 'IF FISH SIZE > LIMIT, HARVEST ALL
 6450
 6460 LET A(R,14+I7)=H1
 6470 LET A(R,15+I7)=H1/G1 'FISH HARVESTED
 6480 'LBS OF FISH HARVESTED
 6490
 6500 IF I7=0 THEN 6520
 6510 LET A(R,16+I7)=A(R,16+I7-25)+A(R,14+I7) 'TOTAL HARVEST TO DATE
 6520 GO TO 6530
 6530 LET A(R,16+I7)=A(R,14+I7)
 6540
 6550 IF I7=0 THEN 6590
 6560 LET A(R,17+I7)=A(R,17+I7-25)+A(R,14+I7)/G1 'FOUNDAE HARVESTED TO DATE
 6570 IF A(R,1+I7)=0 THEN 7360 'IF NO FISH IN RACEWAY R, SKIP AHEAD
 6580 GO TO 6600
 6590 LET A(R,17+I7)=A(R,14+I7)/G1

```

6600.
6610      LET A(R,18+I7)=A(R,12+I7)-A(R,14+I7)          '* FISH AFTER HARVEST
6620
6630      IF A(R,9+I7)>15 THEN 6850                      'IF FISH LARGER THAN LIMIT, SKIP AHEAD
6640
6650
6660
6670      FISH TRANSFER
6680      -----
6690
6700
6710      IF K=1 THEN 6850                                'IF ONLY ONE RACEWAY, CAN'T TRANSFER FISH, CONTINUE
6720      IF A(R,18+I7)=0 THEN 6850                      'IF NO FISH IN RACEWAY R, SKIP AHEAD
6730
6740      PRINT "YOU NOW HAVE "A(R,18+I7)"FISH IN RACEWAY "R;"
6750      PRINT "DO YOU WISH TO TRANSFER FISH TO ANOTHER RACEWAY? (YES OR NO)"
6760      INPUT D$
6770      PRINT
6780
6790      IF D$="YES" THEN 6890
6800      IF D$="NO" THEN 6850
6810          PRINT "PLEASE TYPE YES OR NO."
6820          PRINT
6830          GO TO 6750
6840
6850      LET I9=0                                         'NO TRANSFER, TOTAL TRANSFER =0
6860      GO TO 7090
6870
6880      PRINT
6890      PRINT "INPUT THE RACEWAY # WHERE THE FISH WILL BE TRANSFERRED"
6900      INPUT I8
6910      PRINT
6920
6930      IF I8<>R THEN 6980                                'CHECK TO SEE IF TRANSFER TO SAME RACEWAY
6940          PRINT "YOU CAN'T TRANSFER FISH TO THEIR OWN RACEWAY."
6950          PRINT
6960          GO TO 6740
6970
6980      IF I8<=K THEN 7030                                'CHECK IF TRANSFER TO LEGIT RACEWAY
6990          PRINT "YOU DON'T HAVE THAT MANY RACEWAYS."
7000          PRINT
7010          GO TO 6740
7020
7030      PRINT "HOW MANY FISH DO YOU WISH TO TRANSFER"
7040      INPUT I9
7050      PRINT
7060
7070      LET A(I8,19+I7)=A(I8,19+I7)+I9                  'TOT FISH TRANSFERRED TO I8
7080
7090      LET A(R,20+I7)=A(R,20+I7)+I9                  'TOT FISH TRANS FR RACEWAY R
7100

```

```

7110 IF A(R,20+I7)<=A(R,18+I7) THEN 7180 'CHECK IF TRANSFER LEGIT
7120 PRINT 'YOU HAVE TRANSFERRED MORE THAN THE RACEWAY HOLDS. START'
7130 PRINT 'THE MONTH OVER AGAIN.'
7140 PRINT
7150 GO TO 7610
7160
7170
7180 IF A(R,18+I7)=0 THEN 7360 'IF NO FISH IN RACEWAY R, SKIP AHEAD
7190
7200 IF D$="NO" THEN 7360
7210 IF K=1 THEN 7360 'IF ONLY ONE RACEWAY, SKIP AHEAD
7220
7230
7240 PRINT 'DO YOU WISH TO TRANSFER MORE FISH? (YES OR NO)';
7250 INPUT E$
7260 PRINT
7270
7280 IF E$="YES" THEN 6880
7290 IF E$="NO" THEN 7360
7300 PRINT 'PLEASE TYPE YES OR NO.'
7310 PRINT
7320 GO TO 7240
7330
7340
7350
7360 NEXT R 'NEXT RACEWAY
7370
7380
7390
7400 MONTHLY FISH TOTALS
7410 -----
7420
7430 IF H7=10 THEN 7500
7440 PRINT
7450 PRINT
7460 PRINT 'RACEWAY SUMMARY (# OF FISH) FOR 'I$(I)
7470 PRINT '-----'
7480 PRINT
7490
7500 FOR R=1 TO K 'LOOP TO CALCULATE MO TOTALS
7510 LET A(R,21+I7)=A(R,18+I7)-A(R,20+I7)+A(R,19+I7) '# FISH IN RACEWAY R AT MO'S END
7520 LET A(R,22+I7)=A(R,21+I7)/Q1 'LBS FISH IN RACEWAY R AT MO'S END
7530 IF H7=10 THEN 7570
7540 PRINT 'RACEWAY' I$ 'HAS' I$ A(R,21+I7) 'FISH'
7550
7560
7570 IF A(R,22+I7)<=C6 THEN 7680 'IF LBS FISH IN RACEWAY R <= CAPACITY, CONTINUE
7580
7590 PRINT 'YOU MADE A MISTAKE WITH RACEWAY 'I$'. START THE MONTH AGAIN.'
7600 PRINT
7610 FOR R1=1 TO K 'LOOP TO CLEAR ENTRIES IF WRONG

```



```

7620          FOR R2=4 TO 25
7630          LET A(R1,R2+I7)=0
7640          NEXT R2
7650          NEXT R1
7660          GO TO 4810
7670
7680      NEXT R
7690
7700      PRINT
7710
7720      LET I7=I7+25
7730
7740
7750      IF I7=300 THEN 7880
7760
7770      FOR R=1 TO K
7780          LET A(R,1+I7)=A(R,21+I7-25)
7790          LET A(R,2+I7)=A(R,22+I7-25)
7800          LET A(R,3+I7)=A(R,9+I7-25)
7810
7820          LET H0=H0+A(R,1+I7)
7830
7840      NEXT R
7850
7860      IF H0<>0 THEN 7880
7870          LET H7=10
7880          LET H8=0
7890
7900      NEXT I
7910
7920
7930
7940      PRINT OUT MONTHLY AND YEARLY TOTALS
7950
7960      PRINT
7970      PRINT
7980      PRINT "RESULTS"
7990      PRINT "=====
8000      PRINT "DO YOU WISH TO HAVE THE RESULTS PRINTED OUT BY MONTH BY RACEWAY,"
8010      PRINT "BY RACEWAY BY MONTH, A SUMMARY OF ALL RACEWAYS BY MONTH, OR JUST"
8020      PRINT "A YEARLY SUMMARY? (1=MONTH BY RACEWAY, 2=RACEWAY BY MONTH, 3=SUM-"
8030      PRINT "MARY BY MONTH OF ALL RACEWAYS TOTALED, AND 4=YEARLY SUMMARY)";
8040      INPUT G5
8050          IF G5=1 THEN 8130
8060          IF G5=2 THEN 8150
8070          IF G5=3 THEN 8170
8080          IF G5=4 THEN 8130
8090      PRINT
8100      PRINT "PLEASE INPUT A 1, 2, 3, OR 4. TRY AGAIN."
8110      GO TO 8000
8120

```

'SET COUNTER

'END OF YEAR, SKIP AHEAD

'LOOP TO INPUT NEXT MO'S INITIAL VALUES

'# FISH NEXT MO

'LBS FISH NEXT MO

'SIZE NEXT MO

'COUNTER TO ADD FISH IN RACEWAYS NEXT MO

'IF SUM OF FISH IN ALL RACEWAYS >0, CONTINUE

'FLAG TO SKIP SPECIFIED CALCULATIONS IF FISH SUM = 0

'RESET H8

'NEXT MONTH

'CHECK IF ANSWER ALLOWABLE

```

0130 CALL "RESULT":K,A(,),B(,),B$,T$(,),T(,),R9,R4,Q5      'RESULTS FOR CHOICES 1 AND 3
0140 GO TO 0200
0150 CALL "RESULT1":K,A(,),B(,),B$,T$(,),T(,),R9,R4        'RESULTS FOR CHOICE 2
0160 GO TO 0200
0170 CALL "RESULT2":K,A(,),B(,),B$,T$(,),T(,),R9,R4
0180
0190
0200 / COST ANALYSIS
0210
0220 LET W7 = 0
0230 LET W8 = 0
0240 CALL "REVENUE":A(,),T(,),S(,),K,K8,W7,W8,Z7
0245 PRINT "*****"
0246 PRINT
0250 PRINT "          PROFIT OR LOSS STATEMENT"
0252 PRINT
0255 PRINT "*****"
0260 GO TO 0720
0262 PRINT
0263 PRINT
0264 PRINT
0265 PRINT "***** COST ANALYSIS *****"
0266 PRINT
0267 PRINT
0270 CALL "INTEREST":Q2,Q3,T2,Q5,Q7
0280 PRINT
0290 PRINT
0300 PRINT
0310 PRINT "CAPITAL COSTS"
0320 PRINT "-----"
0325 PRINT
0330 PRINT "    Equipment and Buildings"
0350 PRINT "    $:Q2: million at $:(Q3*100): percent for $:T2: years."
0370 PRINT "    Annual cost = " "Q5
0380 PRINT
0390 PRINT "    Land"
0400 PRINT "    $:Q4: at $:(Q3*100): percent over $:T2: years."
0410 CALL "INTEREST":Q4,Q3,T2,Q6,Q7
0420 PRINT "    Annual cost = " "Q6
0425 PRINT
0426 PRINT "    TOTAL ANNUAL CAPITAL COST = " "(Q5+Q6)
0430 PRINT
0440 PRINT "OPERATING COSTS"
0445 PRINT "-----"
0447 PRINT
0450 LET W1 = (INT(B(11)*S1*100+.5))/100
0460 PRINT "    Cost of fingerlings " "W1
0470 LET W2 = B(6)*N
0480 PRINT "    Cost of feed " "W2
0490 LET W3 = ((K/B)*(N2/.015)*(F7/718))*37500
0500 LET W3 = (INT(W3*100+.5))/100

```

```

0510 PRINT '          Cost of pumping          ',W3
0530 'DATA ON WAGES COMES HERE
0540 ' 13000 FOR THE MANAGER, 8000 FOR EACH REGULAR WORKER, 900 FOR EACH TEMP.WORKER
0550 LET W9 = W7 +W8          'W9 = WEIGHT OF SMALL AND REGULAR SALEABLE FISH
0580 LET Z1 = 1 + INT (W9/33001)          'Z1 = TOTAL NO. OF WORKERS
0590 IF (W9/Z1)>25001 THEN 0620
0600 LET Z2 = 0          ' Z2 = NO.OF TEMP.WORKERS
0610 GO TO 0630
0620 LET Z2 = 1
0630 LET W4 = L7 + ((Z1-1)*L8) + (Z2*L9)
0640 PRINT '          Cost of labor          ',W4
0650 LET W5 = 8000
0660 PRINT '          Cost of operation and maintenance ',W5
0661 PRINT
0662 PRINT '          TOTAL ANNUAL OPERATING COST =          '+(W1+W2+W3+W4+W5)
0663 PRINT '          -----'
0664 PRINT
0670 LET W6 = 05+W8+W1+W2+W3+W4+W5
0680 PRINT '          TOTAL ANNUAL COST =          'W6
0690 GO TO 9161
0700 ' REVENUE ANALYSIS
0710
0720 PRINT
0730 PRINT
0740 PRINT '***** REVENUE ANALYSIS *****'
0750
0760 PRINT
0770 PRINT 'THE WHOLESALE SELLING PRICE OF BOTH BROOK AND RAINBOW TROUT WAS $1.75 PER POUND'
0780 PRINT 'DURING SEPTEMBER 1977. DO YOU WANT TO INPUT A NEW LATER SELLING PRICE?'
0790 PRINT ' (1=NO; 2=YES)'
0800 INPUT K7
0810 IF K7=1 THEN 0890
0820 IF K7=2 THEN 0920
0830 PRINT
0840 PRINT 'PLEASE TYPE 1 OR 2. TRY AGAIN.'
0850 GO TO 0800
0860
0870 ' SAMPLE TROUT SELLING PRICE
0880
0890 LET K8=1.75          ' DATA FROM : CARL HAMPE,SR. N.H. FISHERIES INC. SEPT. 1977
0900 GO TO 0980
0910
0920 ' USER INPUT TROUT SELLING PRICE
0930
0940 PRINT
0950 PRINT 'THE SELLING PRICE $/LB FOR TROUT ='
0960 INPUT K8
0970
0980 ' CALL REVENUE SUBPROGRAM
0990
9000

```

```

9010 LET W7=W7*.87                                'WEIGHT OF BUTTED COLD PACK TROUT = .87 OF LIVE TROUT
9020 LET W8=W8*.87
9030 PRINT
9040 PRINT 'TOTAL WEIGHT OF COLD PACKED TROUT 9 TO 10.5 INCHES LONG SHIPPED =' ,W7
9050 LET V1=W7*.8*K8
9060 PRINT 'GIVEN A 20% DISCOUNT FOR SMALL TROUT, THEIR TOTAL SELLING PRICE IS =' ,V1
9070 PRINT
9080 LET V2=W8*K8
9090 PRINT
9100 PRINT 'TOTAL WEIGHT OF COLD PACKED TROUT OVER 10.5 INCHES LONG SHIPPED =' ,W8
9110 PRINT 'THEIR TOTAL SELLING PRICE IS = ' ,V2
9120 PRINT
9130 PRINT
9140 PRINT 'TOTAL ANNUAL REVENUE (CURRENT PRICES) = ' (V1+V2)
9150 PRINT
9160 GO TO B262
9161 PRINT
9162 PRINT
9163 PRINT '##### NET PROFIT OR LOSS #####'
9164 PRINT
9165 PRINT
9166 LET F1$ = ' <##### $-#####'
9170 PRINT USING F1$,'TOTAL ANNUAL REVENUE',(V1+V2)
9180 PRINT USING F1$,'TOTAL ANNUAL COST',W6
9190 PRINT '-----'
9200 PRINT ' TOTAL ANNUAL NET'
9201 PRINT USING F1$,'PROFIT OR LOSS',((V1+V2)-W6)
9202 PRINT
9203 PRINT
9215 END
9220
9225 '***** END OF MAIN PROGRAM *****
9226 '*****
9227
9228
9230 SUB 'OXYGEN' U7,01
9240
9250 ' THIS SUBPROGRAM CALCULATES THE AMOUNT OF OXYGEN IN PPM (VARIABLE O1)
9260 ' ASSUMING THE WATER IS SATURATED, GIVEN THE WATER TEMPERATURE (VARIABLE U7),
9270 ' THE INFORMATION IN THE TABLE IS INTERPOLATED FROM DATA IN 'THE SOLUBILITY
9280 ' OF GASES IN LIQUIDS' BY RUBIN BATTINO AND H. LAWRENCE CLEVER, FROM
9290 ' 'CHEMICAL REVIEWS', VOL. 66, NO. 4, JULY 1966, PP. 395-463.
9300
9310
9320 DIM E(50)                                'DIMENSION VECTOR
9330
9340 FOR I=1 TO 42                            'LOOP TO READ IN SATURATION DATA
9350 READ E(I)
9360 NEXT I
9370
9380 LET K=U7-33                                'CONVERT TEMP TO VECTOR UNITS

```

```

9390
9400 LET O1=E(K)                                'CALCULATE OXYGEN SATURATION POINT
9410
9420 DATA 14.22,14.01,13.81,13.61,13.41,13.20,13.00,12.80,12.64,12.47,12.31
9430 DATA 12.15,11.98,11.82,11.66,11.49,11.33,11.20,11.07,10.94,10.81,10.67
9440 DATA 10.54,10.41,10.28,10.15,10.04,9.93,9.82,9.71,9.61,9.50,9.39,9.28
9450 DATA 9.17,9.08,8.99,8.91,8.82,8.73,8.64,8.55
9460
9470 SUBEND
9480
9490 '*****
9500
9510 SUB 'SUPPORT':S,O,L1
9520
9530 '   THIS SUBPROGRAM CALCULATES THE SQUARE FEET OF SURFACE AREA REQUIRED
9540 '   TO SUPPORT ONE POUND OF 9" TROUT AT 50 DEGREES F WATER TEMPERATURE AT
9550 '   5000 FT ELEVATION (VARIABLE L1), USING SHADE CONTROL (VARIABLE S) AND
9560 '   AERATION (VARIABLE O) OPTIONS. DATA COMES FROM TABLE 2, P. 15, FROM
9570 '   "HOW TO GROW TROUT IN YOUR BACK YARD", GENE R. BUSSEY. (LIFE SUPPORT
9580 '   SYSTEMS, INC.; ALBUQUERQUE, NM). 1972.
9590
9600
9610 IF S=2 THEN 9700
9620 IF O=2 THEN 9670
9630
9640 LET L1=16
9650 GO TO 9770
9660
9670 LET L1=4
9680 GO TO 9770
9690
9700 IF O=2 THEN 9750
9710
9720 LET L1=4
9730 GO TO 9770
9740
9750 LET L1=2
9760
9770 SUBEND
9780
9790 '*****
9800
9810 SUB 'LABRAT1':U7,P1
9820
9830 '   THIS SUBPROGRAM CALCULATES THE POUNDAGE RATIO (VARIABLE P1) FOR 9"
9840 '   TROUT SUPPORTED BY A 50 GPM, FULLY AERATED FLOW, WITHOUT AUXILIARY AER-
9850 '   ATION, GIVEN THE WATER TEMPERATURE (F) (VARIABLE U7). IT IS A MODIFI-
9860 '   CATION OF TABLE 2, P. 22, FROM "HOW TO GROW TROUT IN YOUR BACK YARD",
9870 '   GENE R. BUSSEY. (LIFE SUPPORT SYSTEMS, INC.; ALBUQUERQUE, NM). 1972.
9880 '   ADAPTED FOR VERMONT YANKEE NUCLEAR POWER PLANT.
9890

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```

9900
9910 LET Y7=-.072*U7+10.71
9920 LET Y8=EXP(Y7)
9930 LET P1=Y8/800
9940
9950 SUBEND
9960
9970 *****
9980
9990 SUB "FISHLB":F1,G1
10000
10010 ' THIS SUBPROGRAM CALCULATES THE # FISH/LB (VARIABLE G1), GIVEN THE
10020 ' FISH SIZE (VARIABLE F1). IT IS A MODIFICATION OF TABLE 11, P. 50, FROM
10030 ' "HOW TO GROW TROUT IN YOUR BACK YARD", GENE R. BUSSEY. (LIFE SUPPORT
10040 ' SYSTEMS, INC.: ALBUQUERQUE, NM). 1972.
10050
10060
10070 LET G1=2513/(F1^3.00228)
10080
10090 SUBEND
10100
10110 *****
10120
10130 SUB "FEED":F1,U7,D1
10140
10150 ' THIS SUBPROGRAM CALCULATES THE PERCENTAGE OF BODYWEIGHT TO FEED THE
10160 ' FISH (VARIABLE D1), GIVEN THE FISH SIZE (VARIABLE F1) AND THE WATER
10170 ' TEMPERATURE (VARIABLE U7). IT IS A MODIFICATION OF TABLE 12, P. 51,
10180 ' FROM "HOW TO GROW TROUT IN YOUR BACK YARD", GENE R. BUSSEY. (LIFE
10190 ' SUPPORT SYSTEMS, INC.: ALBUQUERQUE, NM). 1972.
10200
10210
10220 DIM B(22,16)
10230
10240 LET Z8=F1-INT(F1)
10250 LET Z9=INT(F1)
10260
10270 FOR I=1 TO 21
10280 FOR J=1 TO 16
10290 READ K
10300 LET B(I,J)=K
10310 NEXT J
10320 NEXT I
10330
10340 LET K1=(U7-32)/2
10350
10360 IF K1<> INT(K1) THEN 10450
10370 IF F1<> INT(F1) THEN 10400
10380 LET D1=B(K1,Z9)
10390 GO TO 10580
10400 LET D2=B(K1,Z9)

```

'DIFFERENCE BETWEEN FISH SIZE AND INT(FISH SIZE)
'INTEGER OF FISH SIZE
'READ IN DATA TABLE
'CONVERT TEMP TO # READ BY TABLE, K1
'SIZE AND TEMPERATURE ARE INTEGERS
'TEMPERATURE AN INTERGER, SIZE NOT

```

10410 LET D3=B(K1,Z9+1)
10420 LET D1=D3+Z8*(D2-D3)
10430 GO TO 10580
10440
10450 LET K2=INT(K1)
10460 IF F1<> INT(F1) THEN 10510
10470 LET D2=B(K2,F1)
10480 LET D3=B(K2+1,F1)
10490 LET D1=(D2+D3)/2
10500 GO TO 10580
10510 LET D2=B(K2,F1)
10520 LET D3=B(K2+1,F1)
10530 LET D4=(D2+D3)/2
10540 LET D5=B(K2+1,F1)
10550 LET D6=B(K2+1,F1+1)
10560 LET D7=(D5+D6)/2
10570 LET D1=D7+Z8*(D4-D7)
10580 LET D1=D1*1.2
10590

```

'SIZE AN INTEGER, TEMPERATURE NOT

'NEITHER SIZE NOR TEMPERATURE INTEGERS

```

10600 DATA 2.82,1.88,1.41,1.13,.94,.81,.71,.63,.56,.51,.47,.43,.4,.37,.35,.35
10610 DATA 3.01,2.01,1.51,1.2,1.1,.86,.75,.67,.6,.55,.5,.46,.43,.4,.38,.38
10620 DATA 3.22,2.15,1.61,1.29,1.07,.92,.81,.71,.64,.59,.54,.5,.46,.43,.41,.41
10630 DATA 3.46,2.31,1.73,1.38,1.15,.99,.87,.77,.69,.63,.58,.53,.49,.46,.43,.43
10640 DATA 3.72,2.48,1.86,1.49,1.24,1.06,.93,.83,.74,.68,.62,.57,.53,.50,.47,.47
10650 DATA 4.01,2.67,2.01,1.6,1.34,1.15,1.09,.89,.8,.73,.67,.62,.57,.53,.50,.50
10660 DATA 4.33,2.89,2.17,1.73,1.44,1.24,1.08,.96,.87,.79,.72,.67,.62,.58,.55,.55
10670 DATA 4.69,3.13,2.35,1.88,1.56,1.34,1.17,1.04,.94,.85,.78,.72,.67,.63,.59,.59
10680 DATA 5.1,3.4,2.55,2.04,1.7,1.46,1.28,1.13,1.02,.93,.85,.78,.73,.68,.64,.64
10690 DATA 5.46,3.64,2.73,2.18,1.82,1.56,1.37,1.21,1.09,.99,.91,.84,.78,.73,.69,.69
10700 DATA 6.01,4.01,3.01,2.4,2.1,1.72,1.5,1.33,1.2,1.09,1.92,.86,.81,.76,.76
10710 DATA 6.49,4.33,3.25,2.6,2.16,1.86,1.62,1.44,1.30,1.18,1.08,.99,.93,.87,.82,.82
10720 DATA 7.4,6.7,3.5,2.8,2.33,2.1,1.75,1.55,1.4,1.27,1.17,1.08,.99,.94,.87,.87
10730 DATA 7.52,5.02,3.76,3.01,2.5,2.15,1.88,1.67,1.5,1.37,1.25,1.16,1.07,1.94,.94
10740 DATA 8.07,5.38,4.04,3.23,2.69,2.31,2.02,1.79,1.61,1.47,1.34,1.24,1.15,1.08,1.01,1.01
10750 DATA 8.63,5.76,4.32,3.45,2.87,2.47,2.16,1.92,1.73,1.57,1.44,1.33,1.23,1.15,1.08,1.08
10760 DATA 9.22,6.15,4.61,3.69,3.07,2.64,2.31,2.05,1.84,1.68,1.54,1.42,1.32,1.23,1.16,1.16
10770 DATA 9.82,6.55,4.91,3.93,3.27,2.81,2.46,2.18,1.96,1.78,1.64,1.51,1.4,1.31,1.23,1.23
10780 DATA 10.44,6.96,5.22,4.18,3.48,2.99,2.61,2.32,2.09,1.9,1.74,1.61,1.49,1.4,1.31,1.31
10790 DATA 11.09,7.4,5.55,4.44,3.69,3.17,2.77,2.46,2.22,2.02,1.85,1.71,1.58,1.48,1.39,1.39
10800 DATA 11.77,7.85,5.89,4.71,3.92,3.37,2.94,2.61,2.35,2.14,1.96,1.81,1.68,1.58,1.48,1.48
10810 DATA 12.47,8.31,6.24,4.99,4.16,3.58,3.12,2.76,2.48,2.26,2.08,1.91,1.78,1.68,1.57,1.57
10820

```

10830 SUBEND

10840

10850 '*****

10860

10870 SUB 'GROWTH' U7,F2

10880

10890 ' THIS SUBPROGRAM CALCULATES THE FISH GROWTH IN INCHES (VARIABLE F2)

10900 ' GIVEN THE WATER TEMPERATURE IN DEGREES F (VARIABLE U7). IT IS A MOD-

10910 ' IFICATION OF TABLE 13. P. 50. FROM 'HOW TO GROW TROUT IN YOUR BACK.

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10920 ' YARD*, GENE R. BUSSEY. (LIFE SUPPORT SYSTEMS, INC.: ALBUQUERQUE, NH). 1972.
10930
10940
10950
10960 DIM A(42)
10970
10980 LET K=U7-33
10990
11000 FOR I=1 TO 42
11010   READ M
11020   LET A(I)=M
11030 NEXT I
11040
11050 DATA .06,.1
11060 DATA .14,.18,.22,.26,.3,.34,.38,.42,.46,.5,.54,.58,.62,.66,.7,.74
11070 DATA .78,.82,.86,.9,.94,.98,1.02,1.06,1.1,1.08,1.06,1.04,1.02,1
11080 DATA .98,.96,.94,.92,.9,.88,.86,.84,.82,.8
11090
11100 LET F2=A(K)
11110
11120 SUDEND
11130
11140 '*****
11150
11160 SUB 'RANDOM':R7
11170
11180 ' THIS SUBPROGRAM DELIVERS A RANDOM NUMBER BETWEEN .9 AND 1.1 FOR USE
11190 ' IN THE CALCULATION OF FISH MORTALITY RATES.
11200
11210
11220 RANDOMIZE
11230
11240 LET R7=.1*RND
11250
11260 IF RND<.5 THEN 11290
11270   LET R7=1-R7
11280   GO TO 11310
11290   LET R7=1+R7
11300
11310 SUREND
11320
11330 '*****
11340
11350 SUB 'RESULT':K,A(,),B(,),B$,T$,T(),R9,R4,G5
11360
11370 ' THIS SUBPROGRAM PRINTS OUT THE YEARLY RESULTS FOR THE FISH FARM. IT LISTS
11380 ' THE RESULTS FOR ALL RACEWAYS IN A GIVEN MONTH, PROCEEDING THROUGH THE SEASON.
11390
11400
11410 PRINT
11420 PRINT

```



```

11430 PRINT
11440 PRINT
11450 PRINT
11460 PRINT 'VERMONT YANKEE TROUT FARM'
11470 PRINT '=====
11480 PRINT
11490 IF G5=4 THEN 12320
11500 PRINT 'IF JUST WANT YEARLY SUMMARY, SKIP AHEAD
11510 PRINT
11520 PRINT 'INITIAL CONDITIONS'
11530 PRINT '-----
11540 PRINT
11550 IF R4=2 THEN 11580
11560 PRINT 'FISH STOCKED = BROOK TROUT'
11570 GO TO 11590
11580 PRINT 'FISH STOCKED = RAINBOW TROUT'
11590 PRINT '# OF RACEWAYS ='I'K
11600 IF R9=1 THEN 11630
11610 PRINT 'IF WILLOUGHBY, SKIP AHEAD
11620 PRINT 'RACEWAYS' SURFACE AREA ='I'B(1)
11630 PRINT 'RACEWAYS' INITIAL CAPACITY (# OF FISH) ='I'B(3)
11640 PRINT 'RACEWAYS' INITIAL CAPACITY (LBS) ='I'B(2)
11650 IF R9=1 THEN 11670
11660 PRINT B$
11670 PRINT 'INITIAL MONTH'S WATER TEMPERATURE (F) ='I'B(5)
11680 PRINT 'FISH SIZE (IN INCHES) AT LOADING ='I'B(4)
11690 PRINT
11700 PRINT
11710 FOR I=1 TO 12
11720 PRINT '**** 'I'T$(I)';' ****'
11730 PRINT
11740 PRINT 'MONTHLY TEMPERATURE HIGH ='I'T(I)
11750 PRINT
11760 FOR R=1 TO K
11770 PRINT 'RACEWAY'IR
11780 IF R>9 THEN 11810
11790 PRINT '-----
11800 GO TO 11820
11810 PRINT '-----
11820 PRINT
11830 PRINT 'INITIAL CONDITIONS'
11840 PRINT
11850 PRINT '# OF FISH ='I'A(R,1+I7)
11860 PRINT 'LBS OF FISH ='I'A(R,2+I7)
11870 PRINT 'FISH SIZE (IN INCHES) ='I'A(R,3+I7)
11880 PRINT
11890 PRINT 'FEED INFORMATION'
11900 PRINT
11910 PRINT 'MONTHLY FEED (IN LBS) ='I'A(R,4+I7)
11920 PRINT 'FEED SUM (IN LBS) TO DATE ='I'A(R,5+I7)
11930 PRINT

```

```

11940      PRINT "FISH GROWTH"
11950      PRINT
11960      PRINT "MONTHLY GROWTH (IN INCHES) ="&A(R,8+I7)
11970      PRINT "SUM OF GROWTH TO DATE ="&A(R,10+I7)
11980      PRINT "FISH SIZE AT MONTH'S END ="&A(R,9+I7)
11990      PRINT
12000      PRINT "MORTALITY INFORMATION"
12010      PRINT
12020      PRINT "# OF MONTHLY MORTALITIES ="&A(R,11+I7)
12030      PRINT "MORTALITIES TO DATE ="&A(R,13+I7)
12040      PRINT "# FISH AFTER MORTALITIES ="&A(R,12+I7)
12050      PRINT
12060      PRINT "HARVEST AND TRANSFER INFORMATION"
12070      PRINT
12080      PRINT "# FISH HARVESTED ="&A(R,14+I7)
12090      PRINT "LBS OF FISH HARVESTED ="&A(R,15+I7)
12100      PRINT "SUM OF FISH (#) HARVESTED TO DATE ="&A(R,16+I7)
12110      PRINT "SUM OF FISH (LBS) HARVESTED TO DATE ="&A(R,17+I7)
12120      PRINT "# FISH AFTER MORTALITIES AND HARVEST ="&A(R,18+I7)
12130      PRINT
12140      PRINT "# OF FISH TRANSFERRED TO RACEWAY ="&A(R,19+I7)
12150      PRINT "# OF FISH TRANSFERRED FROM RACEWAY ="&A(R,20+I7)
12160      PRINT
12170      PRINT "FINAL CONDITIONS"
12180      PRINT
12190      PRINT "# FISH IN RACEWAY ="&A(R,21+I7)
12200      PRINT "LBS OF FISH IN RACEWAY ="&A(R,22+I7)
12210      PRINT
12220      PRINT
12230      PRINT
12240      LET H9=H9+A(R,21+I7)
12250      NEXT R
12260      IF H9=0 THEN 12320
12270      LET H9=0
12280      LET I7=I7+25
12290      PRINT
12300      NEXT I
12310
12320      PRINT
12330      PRINT
12340      PRINT
12350      PRINT "YEARLY SUMMARY"
12360      PRINT "===== "
12370      PRINT
12380      PRINT
12390      FOR R=1 TO K
12400          PRINT "RACEWAY"&R
12410          IF R>9 THEN 12440
12420          PRINT "-----"
12430          GO TO 12450
12440          PRINT "-----"

```

'CHECK TOTAL, RACEWAYS EMPTY, END

```

12450 PRINT
12460 PRINT "YEARLY FEED =" ; A(R,280)
12470 LET B(6)=B(6)+A(R,280)
12480 PRINT "YEARLY GROWTH (IN INCHES) =" ; A(R,285)
12490 PRINT "YEARLY MORTALITIES (#) =" ; A(R,288)
12500 LET B(7)=B(7)+A(R,288)
12510 PRINT "YEARLY SUM OF FISH HARVESTED (#) =" ; A(R,291)
12520 LET B(8)=B(8)+A(R,291)
12530 PRINT "YEARLY SUM OF FISH HARVESTED (LBS) =" ; A(R,292)
12540 LET B(9)=B(9)+A(R,292)
12550 LET B(10)=B(10)+A(R,2)
12560 LET B(11)=B(11)+A(R,1)
12570 PRINT
12580 PRINT
12590 NEXT R
12600 PRINT
12610 PRINT "SEASON TOTALS"
12620 PRINT "===== "
12630 PRINT
12640 PRINT "TOTAL FEED (LBS) =" ; B(6)
12650 PRINT "TOTAL MORTALITIES =" ; B(7)
12660 PRINT "TOTAL FISH LOADED =" ; B(11)
12670 PRINT "TOTAL FISH LOADED (LBS) =" ; B(10)
12680 PRINT "TOTAL FISH (#) HARVESTED =" ; B(8)
12690 PRINT "TOTAL FISH (LBS) HARVESTED =" ; B(9)
12700 PRINT "FEED CONVERSION RATIO =" ; B(6)/(B(9)-B(10))
12710 SUDEND
12720
12730 "*****
12740
12750 SUB "RESULT1":K,A(,),B(,),B$,T$,T(,),R9,R4
12760
12770 ' THIS SUBPROGRAM PRINTS OUT THE YEARLY RESULTS FOR THE FISH FARM. IT LISTS
12780 ' THE RESULTS BY RACEWAY, GIVING MONTHLY AND YEARLY SUMMARIES.
12790
12800 PRINT
12810 PRINT
12820 PRINT
12830 PRINT
12840 PRINT
12850 PRINT "VERMONT YANKEE TROUT FARM"
12860 PRINT "===== "
12870 PRINT
12880 PRINT
12890 PRINT
12900 PRINT "INITIAL CONDITIONS"
12910 PRINT "-----"
12920 PRINT
12930 IF R4=2 THEN 12960
12940 PRINT "FISH STOCKED = BROOK TROUT"
12950 GO TO 12970

```

'IF RAINBOWS THEN 22735

```

12960 PRINT 'FISH STOCKED = RAINBOW TROUT'
12970 PRINT '# OF RACEWAYS ='#K
12980 IF R9=1 THEN 13000
12990 PRINT 'RACEWAYS' SURFACE AREA ='#B(1)
13000 PRINT 'RACEWAYS' INITIAL CAPACITY (# OF FISH) ='#B(3)
13010 PRINT 'RACEWAYS' INITIAL CAPACITY (LBS) ='#B(2)
13020 IF R9=1 THEN 13040
13030 PRINT B$
13040 PRINT 'INITIAL MONTH'S WATER TEMPERATURE (F) ='#B(5)
13050 PRINT 'FISH SIZE (IN INCHES) AT LOADING ='#B(4)
13060 PRINT
13070 PRINT
13080
13090 ' TEST TO FIND OUT DURING WHICH MONTH ALL RACEWAYS ARE EMPTY
13100
13110 FOR I=1 TO 12
13120     FOR R=1 TO K
13130         LET H9=H9+A(R,1+I7)
13140     NEXT R
13150
13160     IF H9<>0 THEN 13190
13170         LET G7=I-1
13180         GO TO 13230
13190         LET H9=0
13200         LET I7=I7+25
13210 NEXT I
13220
13230 LET I7=0
13240
13250
13260 'PRINT OUT INITIAL CONDITIONS
13270
13280 PRINT
13290 PRINT
13300 PRINT '# AND LBS OF FISH'
13310 PRINT '-----'
13320
13330 FOR R=1 TO K
13340 PRINT
13350 PRINT 'RACEWAY'#R
13360 PRINT
13370     FOR I=1 TO G7
13380         PRINT I$(I)
13390         PRINT '# OF FISH ='#A(R,1+I7)
13400         PRINT 'LBS OF FISH ='#A(R,2+I7)
13410         PRINT
13420         LET I7=I7+25
13430     NEXT I
13440
13450     LET I7=0
13460

```

'MONTH LOOP

'RACEWAY LOOP

'H9=SUM OF FISH IN ALL RACEWAYS

'IF ALL RACEWAYS NOT EMPTY, CONTINUE

'RESET H9

'ADJUST COUNTER

'RESET TABLE COUNTER

'RACEWAY CYCLE

'MONTH LOOP

'ADJUST TABLE COUNTER

'RESET TABLE COUNTER

13470 NEXT R
 13480
 13490 ' FEED INFORMATION
 13500
 13510 PRINT
 13520 PRINT
 13530 PRINT 'FEED INFORMATION'
 13540 PRINT '-----'
 13550
 13560 FOR R=1 TO K
 13570 PRINT
 13580 PRINT 'RACEWAY' R
 13590 PRINT
 13600 FOR I=1 TO 67
 13610 PRINT T\$(I), 'MONTHLY FEED (IN LBS) =' A(R,4+I7)
 13620 LET I7=I7+25
 13630 NEXT I
 13640
 13650 LET I7=0
 13660
 13670 NEXT R
 13680
 13690
 13700 ' FISH GROWTH INFORMATION
 13710
 13720 PRINT
 13730 PRINT
 13740 PRINT 'FISH GROWTH'
 13750 PRINT '-----'
 13760
 13770 LET R=1
 13780 PRINT
 13790 PRINT 'ALL RACEWAYS'
 13800 PRINT
 13810 FOR I=1 TO 67
 13820 PRINT T\$(I)
 13830 PRINT 'MONTHLY GROWTH (IN INCHES) =' A(R,8+I7)
 13840 PRINT 'FISH SIZE AT MONTH'S END =' A(R,9+I7)
 13850 PRINT
 13860 LET I7=I7+25
 13870 NEXT I
 13880
 13890 LET I7=0
 13900
 13910
 13920
 13930 ' MORTALITY INFORMATION
 13940
 13950 PRINT
 13960 PRINT
 13970 PRINT 'MORTALITY'

'RACEWAY CYCLE

'MONTH LOOP

'ADJUST TABLE COUNTER TO NEXT MONTH

'RESET TABLE COUNTER

'MONTH LOOP

'ADJUST TABLE COUNTER TO NEXT MONTH

'RESET TABLE COUNTER

```

13980 PRINT "-----"
13990
14000 FOR R=1 TO K 'RACEWAY CYCLE
14010 PRINT
14020 PRINT "RACEWAY" ; R
14030 PRINT
14040 FOR I=1 TO 67 'MONTH LOOP
14050 PRINT T$(I), " OF MONTHLY MORTALITIES =" ; A(R,11+I7)
14060 LET I7=I7+25 'ADJUST TABLE COUNTER TO NEXT MONTH
14070
14080 NEXT I
14090
14100 LET I7=0 'RESET TABLE COUNTER
14110
14120 NEXT R
14130
14140
14150 ' HARVEST AND TRANSFER INFORMATION
14160
14170 PRINT
14180 PRINT
14190 PRINT "HARVEST AND TRANSFER"
14200 PRINT "-----"
14210
14220 FOR R=1 TO K 'RACEWAY CYCLE
14230 PRINT
14240 PRINT "RACEWAY" ; R
14250 PRINT
14260 FOR I=1 TO 67
14270 PRINT T$(I)
14280 PRINT " FISH HARVESTED =" ; A(R,14+I7)
14290 PRINT "LBS OF FISH HARVESTED =" ; A(R,15+I7)
14300 PRINT " OF FISH TRANSFERRED TO RACEWAY =" ; A(R,19+I7)
14310 PRINT " OF FISH TRANSFERRED FROM RACEWAY =" ; A(R,20+I7)
14320 PRINT
14330 LET I7=I7+25 'ADJUST TABLE COUNTER TO NEXT MONTH
14340 NEXT I
14350
14360 LET I7=0 'RESET TABLE COUNTER
14370
14380 NEXT R
14390
14400
14410 'YEARLY SUMMARY
14420
14430 PRINT
14440 PRINT
14450 PRINT
14460 PRINT "YEARLY SUMMARY"
14470 PRINT "=====
14480 PRINT

```

```

14490 PRINT
14500   FOR R=1 TO K
14510     PRINT "RACEWAY";R
14520     IF R>9 THEN 14550
14530     PRINT "-----"
14540     GO TO 14560
14550     PRINT "-----"
14560     PRINT
14570     PRINT "YEARLY FEED =" ;A(R,280)
14580     LET B(6)=B(6)+A(R,280)
14590     PRINT "YEARLY GROWTH (IN INCHES) =" ;A(R,285)
14600     PRINT "YEARLY MORTALITIES (#) =" ;A(R,288)
14610     LET B(7)=B(7)+A(R,288)
14620     PRINT "YEARLY SUM OF FISH HARVESTED (#) =" ;A(R,291)
14630     LET B(8)=B(8)+A(R,291)
14640     PRINT "YEARLY SUM OF FISH HARVESTED (LBS) =" ;A(R,292)
14650     LET B(9)=B(9)+A(R,292)
14660     LET B(10)=B(10)+A(R,2)
14670     LET B(11)=B(11)+A(R,1)
14680     PRINT
14690     PRINT
14700   NEXT R
14710   PRINT
14720   PRINT "SEASON TOTALS"
14730   PRINT "===== "
14740   PRINT
14750   PRINT "TOTAL FEED (LBS) =" ;B(6)
14760   PRINT "TOTAL MORTALITIES =" ;B(7)
14770   PRINT "TOTAL FISH LOADED =" ;B(11)
14780   PRINT "TOTAL FISH LOADED (LBS) =" ;B(10)
14790   PRINT "TOTAL FISH (#) HARVESTED =" ;B(8)
14800   PRINT "TOTAL FISH (LBS) HARVESTED =" ;B(9)
14810   PRINT "FEED CONVERSION RATIO =" ;B(6)/(B(9)-B(10))
14820 SUBEND
14830
14840 *****
14850 *****
14860   THIS SUBPROGRAM CALCULATES AND PRINTS OUT RESULTS OF SUMMARIES FOR ALL RACEWAYS BY MONTH.
14870
14880 SUB "RESULT2" IK,A(,),B(,),B$,T$(,),T(,),R9,R4
14890
14900 PRINT
14910 PRINT
14920   PRINT
14930   PRINT
14940   PRINT "VERMONT YANKEE TROUT FARM"
14950   PRINT "===== "
14960   PRINT
14970   PRINT
14980   PRINT
14990   PRINT "INITIAL CONDITIONS"

```

```

15000 PRINT "-----"
15010 PRINT
15020 IF R4=2 THEN 15050 'IF RAINBOWS THEN
15030 PRINT "FISH STOCKED = BROOK TROUT"
15040 GO TO 15060
15050 PRINT "FISH STOCKED = RAINBOW TROUT"
15060 PRINT "# OF RACEWAYS =" ; K
15070 IF R9=1 THEN 15090 'IF WILLOUGHBY, SKIP AHEAD
15080 PRINT "RACEWAYS' SURFACE AREA =" ; B(1)
15090 PRINT "RACEWAYS' INITIAL CAPACITY (# OF FISH) =" ; B(3)
15100 PRINT "RACEWAYS' INITIAL CAPACITY (LBS) =" ; B(2)
15110 IF R9=1 THEN 15130
15120 PRINT B$
15130 PRINT "INITIAL MONTH'S WATER TEMPERATURE (F) =" ; B(5)
15140 PRINT "FISH SIZE (IN INCHES) AT LOADING =" ; B(4)
15150 PRINT
15160 PRINT
15170
15180 ' TEST TO FIND OUT WHICH MONTH ALL RACEWAYS ARE EMPTY
15190
15200 FOR I=1 TO 12 'MONTH LOOP
15210 FOR R=1 TO K 'RACEWAY LOOP
15220 LET H9=H9+A(R,1+I7) 'H9=SUM OF FISH IN ALL RACEWAYS
15230 NEXT R
15240
15250 IF H9<>0 THEN 15280 'IF ALL RACEWAYS NOT EMPTY, CONTINUE
15260 LET G7=I-1
15270 GO TO 15320
15280 LET H9=0 'RESET H9
15290 LET I7=I7+25 'ADJUST COUNTER
15300 NEXT I
15310
15320 LET I7=0
15330
15340 ' CALCULATE AND PRINT OUT RESULTS
15350
15360 FOR I=1 TO G7 'MONTH LOOP
15370 FOR R=1 TO K 'RACEWAY LOOP
15380 LET B1=B1+A(R,1+I7) '# FISH BEGINNING OF MO
15390 LET B2=B2+A(R,2+I7) 'LBS OF FISH BEGINNING OF MO
15400 LET B3=B3+A(R,4+I7) 'FEED (LBS)
15410 LET B4=B4+A(R,11+I7) 'MORTALITIES
15420 LET B5=B5+A(R,14+I7) 'HARVEST (#)
15430 LET B6=B6+A(R,15+I7) 'HARVEST (LBS)
15440 LET B7=B7+A(R,21+I7) '# FISH AT MO END
15450 LET B8=B8+A(R,22+I7) 'LBS OF FISH AT MO END
15460 NEXT R
15470
15480 PRINT "**** " ; I$ (I) ; " ****"
15490 PRINT
15500 PRINT

```



```

15510 PRINT '# OF FISH IN ALL RACEWAYS AT BEGINNING OF MONTH ='#B1
15520 PRINT 'LBS OF FISH IN ALL RACEWAYS AT BEGINNING OF MONTH ='#B2
15530 PRINT
15540 PRINT 'TOTAL MONTHLY FEED (IN LBS) ='#B3
15550 PRINT
15560 PRINT 'MONTHLY FISH GROWTH (IN INCHES) ='#A(R,8+I7)
15570 PRINT 'FISH SIZE AT MONTH'S END ='#A(R,9+I7)
15580 PRINT
15590 PRINT '# OF MORTALITIES ='#B4
15600 PRINT
15610 PRINT '# OF FISH HARVESTED ='#B5
15620 PRINT 'LBS OF FISH HARVESTED ='#B6
15630 PRINT
15640 PRINT '# OF FISH IN ALL RACEWAYS AT END OF MONTH ='#B7
15650 PRINT 'LBS OF FISH IN ALL RACEWAYS AT END OF MONTH ='#B8
15660 PRINT
15670 PRINT
15680 LET B1=B2=B3=B4=B5=B6=B7=B8=B9=0 'RESET B'S
15690
15700 LET I7=I7+25
15710 NEXT I
15720
15730 PRINT
15740 PRINT
15750 PRINT
15760 PRINT 'YEARLY SUMMARY'
15770 PRINT '=====
15780 PRINT
15790 PRINT
15800 FOR R=1 TO K
15810 PRINT 'RACEWAY'#R
15820 IF R>9 THEN 15050
15830 PRINT '-----'
15840 GO TO 15860
15850 PRINT '-----'
15860 PRINT 'YEARLY FEED ='#A(R,280)
15870 LET B(6)=B(6)+A(R,280)
15880 PRINT 'YEARLY GROWTH (IN INCHES) ='#A(R,285)
15890 PRINT 'YEARLY MORTALITIES (#) ='#A(R,288)
15900 LET B(7)=B(7)+A(R,288)
15910 PRINT 'YEARLY SUM OF FISH HARVESTED (#) ='#A(R,291)
15920 LET B(8)=B(8)+A(R,291)
15930 PRINT 'YEARLY SUM OF FISH HARVESTED (LBS) ='#A(R,292)
15940 LET B(9)=B(9)+A(R,292)
15950 LET B(10)=B(10)+A(R,2)
15960 LET B(11)=B(11)+A(R,1)
15970 PRINT
15980 PRINT
15990 NEXT R
16000
16010 PRINT

```

```

16020 PRINT "SEASON TOTALS"
16030 PRINT "=====
16040
16050 PRINT "TOTAL FEED (LBS) =" ; B(6)
16060 PRINT "TOTAL MORTALITIES =" ; B(7)
16070 PRINT "TOTAL FISH LOADED (#) =" ; B(11)
16080 PRINT "TOTAL FISH LOADED (LBS) =" ; B(10)
16090 PRINT "TOTAL FISH (#) HARVESTED =" ; B(8)
16100 PRINT "TOTAL FISH (LBS) HARVESTED =" ; B(9)
16110 PRINT "FEED CONVERSION RATIO =" ; B(6)/(B(9)-B(10))
16120
16130 SUBEND
16140
16150 "*****
16160
16170 SUB "REVENUE" ; A(,), T(,), S(,), K, K8, W7, W8, Z7
16180
16190
16200 ' THIS SUBPROGRAM CALCULATES THE WEIGHT DERIVED FROM THE SEASON'S TROUT HARVEST.
16210
16220 LET I7=0
16230 LET Z7=0.0
16240 LET W7=0.0
16250 LET W8=0.0
16260
16270 FOR I=1 TO 12
16280
16290 IF S(I)>0 GO TO 16340 'TEST FOR FISH UNDER 9"
16300 FOR R=1 TO K
16310 LET Z7=Z7+A(R,15+I7) 'CUMULATE UNDERSIZE FISH OVER RACEWAYS
16320 NEXT R
16330 GO TO 16440
16340
16350 IF S(I)>1 GO TO 16400 'TEST FOR FISH 9" TO 10.5"
16360 FOR R=1 TO K
16370 LET W7=W7+A(R,15+I7) 'CUMULATE FISH 9" TO 10.5"
16380 NEXT R
16390 GO TO 16440
16400
16410 FOR R=1 TO K
16420 LET W8=W8+A(R,15+I7) 'CUMULATE FISH OVER 10.5"
16430 NEXT R
16440 LET I7=I7+25
16450 NEXT I
16460
16470 ' CALCULATION OF TOTAL LBS OF FISH HARVESTED
16480
16490 LET T1=0.0
16500 FOR R=1 TO K
16510 LET T1=T1+A(R,292)
16520 NEXT R

```

```

16530
16540
16550 PRINT
16560 PRINT "YIELD INFORMATION"
16570 PRINT "=====
16580 PRINT
16590 PRINT "LIVE WEIGHT (LBS) HARVEST OF UNMARKETABLE FISH ="I27
16600 PRINT "LIVE WEIGHT (LBS) HARVEST OF MARKETABLE FISH 9 TO 10.5 in. ="IW7
16610 PRINT "LIVE WEIGHT (LBS) HARVEST OF MARKETABLE FISH OVER 10.5 in. ="IWB
16620 PRINT "TOTAL WEIGHT OF ALL HARVESTED FISH ="IT1
16630 PRINT
16640 PRINT
16650
16660
16670 SUBEND
16680 "*****
16690
16700 SUB "INTEREST":Q2,Q3;T2,Q5,Q7
16710 "CALCULATES TOTAL INTEREST AND YEARLY REPAYMENT GIVEN PRINCIPAL, INTEREST, AND TIME IN YEARS
16720
16730 LET Q3=Q3/100.
16740
16750 LET I1=1.0/(1.0+Q3)
16760 FOR I=1 TO T2
16770     LET Q7=Q7+(I1*I)
16780 NEXT I
16790 LET Q5=Q2/Q7
16800 LET Q7=Q5*T2
16810 LET Q7=Q7*1000000
16820 LET Q5=Q5*1000000
16830 SUBEND
READY

```

APPENDIX E'
VERMONT YANKEE FISH FARMING SIMULATION
COST RE-EVALUATION

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Cost Modifications

Several additional runs of the Vermont Yankee Fish Farming Simulation program were produced using minimum capital cost estimates. In Case I the operation was expanded to a level three times the design level. This simulation utilized 24 runways each measuring 12 feet by 80 feet and with a water depth of 3 feet. Each runway was operated at a flow level of 715 gals. per minute or sufficient to allow a complete change of water twice an hour. At this massive level of operation, the facility used about 2-1/2 percent of the Connecticut River's absolute minimum flow at Vernon and used less than 1 percent of the 3.605 billion B.T.U.'s exhausted from the Vernon plant each hour. However, an operation at this level, without a generating plant shutdown, was shown to be capable of producing almost 1/2 million pounds of dressed trout all of which reach the market over a four-month period. This is perhaps too large a volume for the New England market to absorb without a deleterious impact on the market price.

Cost assumptions, for minimum capital investment, Case I, are shown in the following table:

TABLE I
Modified Construction

Support Systems:

	Total	<u>Portion to Aquaculture</u>
Sitework	107,110	36,000
Utilities	43,500	14,500
Pump Station	224,000	112,000
Heat Exchange Bldg.		eliminate and mechanically mix water
Support Systems	258,300	129,150
Wastewater Treatment	140,000	140,000
		\$ 431,650

Commercial Fish Hatchery:

Building shell: 18,000 SF @ \$25./SF	450,000
Mechanical	123,000
All other costs	\$ 776,000

First Unit - Grand Total \$1,207,650

Scaling Factors

Unit #1 (unit price)	\$ 1,207,650
Unit #2 (unit #1 x .80)	966,120
Unit #3 (unit #1 x .68)	<u>826,230</u>
	\$ 3,000,000

In addition, the heat exchange building was eliminated, the object being to see if the unit, scaled up to 3 times its design size, could be made to operate at a profit if the heat exchangers were eliminated and certain other cost reductions were made.

Extensive trials with the model in this mode lead us to conclude that given cost structures as they exist in 1977 and as they are likely to exist for the next few years, there is no profit to be made raising trout in even this facility for it still appears that the capital investment and operating costs exceed the market value of the product.

In a final effort to realize a profitable program, we investigated additional cost modifications to determine what the cost parameters might be for a successful commercial endeavor. This work led to the cost modifications of Case II shown in Table II which include the cost modifications of Case I.

TABLE II

New Costs

Support Systems:	(from Table I)	\$ 431,650
Commercial Hatchery:		
Building Shell - re: Wm. Patterson, Leb.		98,750
Mechanical		133,000
Raceways - re: Precision Concrete Woodstock		31,500
Electrical		10,500
Furnishings		30,000
Vehicles		12,500
HVAC (heating of offices involved in bldg. bid.)		
Ventilation only		<u>3,000</u>
		\$ 319,250
subtotal		750,900
Mobilization - 5%		37,550
Contingency - 10%		<u>75,900</u>
Grand Total:		\$ 864,350

These capital costs allow the unit at its original design size (eight 12' x 80 x 3' raceways) to operate at a break-even point (Run #3), or, with one slight modification (Run #4), to make a modest profit. Run #3 assumes that the entire capital cost of \$864,350 is borrowed on a 25-year pay back program at 8 percent interest. If there is no shutdown of several days duration at the generating plant, the first unit can produce a revenue slightly in excess of \$290,000 the first year at a break-even annual net.

Using a portion of the facilities for the production of bait fish during the September-December period may provide additional income. During that period, it is never necessary to use more than 5 of the 8 raceways to achieve full production of trout. The underutilized raceways could be used to raise roughly 200,000 bait fish each. The required extra pumping would cost roughly \$10,800. Additional labor would be no more than \$4,000 and feed perhaps \$2,000. Bait fish at a size range of from 3 to 4 inches bring about five cents each on the wholesale market and an average of one dollar a dozen at retail.

Thus, for an additional \$17,000 in annual operating costs, an extra \$30,000 in income might well be realized if the product were to be sold at wholesale. If this were done, the operation would show a net profit of roughly \$13,000 for the year.

One additional modification is shown in Run #4. Here fingerlings were stocked at 5.5 inches rather than at 4 inches. A major local supplier has agreed that for the number we are contemplating purchasing from him, this can be done at the cost as in the program. In this case, our feed conversion ratio suffers somewhat, but, even with the new higher cost for feed, the operation results in a profit of somewhat over \$6,000 before any bait fish are produced.

While it is true that fingerlings could be raised at this facility, it is our considered opinion that no additional financial benefit would be derived from such an operation. Additional capital investment would be required for the specialized eyeing-hatching containers, incubators, rearing, sorting and holding tanks, agitators and refrigeration units that would be essential if the Vernon site were to be used.

It is also possible to start the cycle with fingerlings at 5.5 inches (or there about) rather than 4 inches, which may provide some economic advantages. First, the large raceways in the Vernon model are designed to allow fish of modest size to gain weight rapidly - they operate more efficiently at the upper end of the growth cycle than at the lower. Second, by purchasing 5.5-inch fish, a significantly larger portion can be brought to market size thus effecting some savings in the cost of stock. Third, stocking of 5.5-inch fingerlings allows the harvest and thus the marketing to start as early as the end of December and to extend through a full five-month period. This is a distinct advantage as compared to the alternative which is to stock 4-inch fish and harvest over four months. The 5.5-inch fingerlings also provide for a significantly lower harvest of undersize fish which can be marked only at a 20 percent discount.

Conclusion - Case II Model and Original Design

If an eight raceway unit producing on the order of 160,000 pounds of trout a year can be built and operated as indicated in our Case II model, the operation would at least break-even in today's market. In the years ahead, the situation should be come more favorable.

In the case of the original KCM design the operations would lose more than \$100,000 per year under today's market conditions.

The conclusions for the Case II model and the original design concept are summarized in Table III.

TABLE III
SUMMARY OF FISH FARMING SIMULATION PROGRAMS
(Cost Summaries Based Upon Stated Assumptions)
SINGLE UNIT WITH 8 RACEWAYS

	<u>An Original investment (Appendix E)</u>	<u>At revised investment and modified operation</u>
Cost of hatchery and support systems	\$ 1,880,000.00	\$ 864,350.00
Interest rate	9.0	8.25
Years for repayment	20	25
Fingerlings:		
Type	Rainbow	Rainbow
Cost	\$250/1000	\$250/1000
Size	4 inches	5.5 inches
No. of raceways	8	8
O ₂ level at discharge	6 PPM	6 PPM
Pumping rate/raceway	715 GPM	715 GPM
Cost of electricity	\$ 0.0155/kwh	\$0.0155/kwh
Cost of labor:		
Manager	\$ 13,000.00	\$ 13,000.00
Assistant	8,000.00	8,000.00
Temp. help	450./month	450./month
Minimum water temperature	60°F.	60°F.
Cost of feed	\$ 5.26/100 lbs.	\$15.50/100 lbs.
Time of harvest	Feb. - June	Feb. - June
No. of fish harvested	162,705	144,869
Live weight harvested:		
Under 10.5 inches	15,478.2	-0-
10.5 inches or over	93,751.8	163,544
Cold pack weight sold:		
Under 10.5 inches	13,466.1	-0-
10.5 inches or over	81,564.1	142,284.0
Price for fish:		
Under 10.5 inches	1.40	1.40
10.5 inches and above	1.75	1.75
 Total Revenue	 161,589.66	 248,996.15
Annual capital cost	205,947.00	92,708.40
Annual operating cost	<u>135,614.00</u>	<u>153,832.45</u>
 ANNUAL PROFIT (LOSS)	 (179,971.61)	 12,456.30

F
APPENDIX

APPENDIX F

COMMERCIAL APPLICATION OF WASTE HEAT FROM
YANKEE NUCLEAR POWER STATION

By John H. Ryther

Marine Environmental Services
Hanover, N.H.

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Marine Environmental Services
Hanover, New Hampshire

December, 1976

Commercial Application of Waste Heat from the Vermont
Yankee Nuclear Power Station

- I. Vermont Yankee operating and environmental conditions that would affect operation of an aquaculture facility.

Species suitable for aquaculture in Vermont utilizing the heated cooling water of the Vermont Yankee Nuclear Power Plant should have the following characteristics:

A. Assuming that the only large and readily available source of water for an aquaculture project of significant size is the Connecticut River, the organisms must be able to tolerate and grow well in Connecticut River water with respect to all water quality parameters except temperature.

B. If the species is to be cultured through the summer, it must be able to survive annual peak temperatures for short periods of time and grow well at mean summer temperatures. For 1975 these were, respectively, 80° and 77°F. To provide a reasonable safety factor, the species should be able to tolerate 85° for as much as 10 days and to grow normally at 80°F for sustained periods of one month or more.

C. If the species is to be grown throughout the winter, it should be capable of good growth at some selected and controlled temperature between that of ambient Connecticut River water and

Connecticut Yankee cooling water. The latter will depend upon the mode of operation of the plant during winter (i.e., once-through, closed, or hybrid cooling water system). However, even with an open, once-through system, it is understood that an intake temperature of 60° is maintained through recirculation to provide optimum back pressure. With a normal Δt of 20°F, the minimum cooling water temperature in winter for any type of operation is therefore 80°.

If, however, a heat exchanger is used to raise the ambient river water temperature with the heated cooling water, a loss of efficiency will result that will depend upon flow rates, size of the heat exchanger, and other factors. Use of a heat exchanger is recommended because of both legal and technical problems in using cooling water directly, particularly in a closed cycle mode of operation with cooling towers. Thus maximum water temperatures that could be attained in an aquaculture system in winter cannot be determined without engineering specifications of the heating system to be employed for the aquaculture unit and the mode of operation of the power plant cooling system.

D. The cultured species must be able to survive sudden decreases from normal winter operating temperatures to ambient Connecticut River water temperatures of approximately 33°F within 1-2 hours, at times of unscheduled shutdowns. The cultured organisms must also be able to survive the same ambient winter temperatures for sustained periods of a month or more in the event of either scheduled or unscheduled prolonged shutdowns.

Figure 1 shows the ambient Connecticut River water temperature at environmental study Station 7 (4.5 miles North of Vermont Yankee and therefore not influenced by the plant). Also shown is the ambient temperature plus a constant Δt of 20°F . If the latter were a constant characteristic of the Vermont Yankee cooling water throughout the year, the water temperature available for aquaculture would be represented by the envelope between the two solid lines. If a heat exchanger were used with a 50% transfer efficiency from the cooling water to the ambient river water, the resulting temperature of the heated water may be represented by the broken line, and the water available for aquaculture by the envelope between the broken line and the lower solid line. In both cases, the water available for aquaculture is considered to be any mixture desired of ambient and heated water.

The various candidate species for aquaculture to be reviewed below have optimal temperatures for growth of $60\text{-}80^{\circ}\text{F}$. As Figure 1 shows, no temperature within that range can be maintained for more than about four months out of the year with mixtures of ambient river water and cooling water or for more than about two months a year if a heat exchanger with 50% transfer efficiency were used.

If, on the other hand, the intake temperature is maintained at 60°F and the cooling water temperature at 80°F for the entire period when ambient temperature is less than 60°F by recirculation of whatever fraction may be needed of the cooling water, as discussed

above, the available temperature for aquaculture is much more flexible (Figure 2). In this case, straight mixtures of ambient and cooling water would provide optimal growing conditions throughout the year for organisms with an optimum at 80°F, ten months for those with a 70°F optimum and about 8 months for those with a 60° optimum, the reduction, of course, being due in each case to the increase of ambient temperature above growth optima.

Mixtures of ambient river water and water heated with an exchanger will provide optimal temperatures for shorter periods of time, depending upon transfer efficiency of the heat exchanger. In the case shown in Figure 2, optimal growing temperatures of 60°-80°F could still only be obtained for two to three months out of the year.

Figure 1. Effect of Heat Exchanger - Routine Operations

Figure 2. Effect of Heat Exchanger with Input held at 80°F Minimum.

II. A Review of Candidate Species for Aquaculture using Heated Cooling Water from Vermont Yankee Nuclear Power Corp.

A. American eel (Anguilla rostrata)

The American eel is a catadromous fish, living most of its life in fresh or brackish water and returning to the open ocean to spawn and complete its life cycle. The exact time and place of spawning and the length of time required to pass through the leaf-shaped (leptocephalus) larval stage are not well understood, but the latter metamorphose into tiny transparent elvers, sometimes referred to as "glass eels", in late winter to early spring at which time they begin to migrate up estuaries and salt rivers towards their freshwater homes.

The eel has not been spawned or reared through its complete life cycle in captivity. Culture of the species is therefore dependent upon the collection of elvers or glass eels from nature as they begin their upstream migration.

After an initial period of acclimatization and early growth in indoor tanks or outdoor nursery ponds, the young eels are transferred to running-water raceways or semi-stagnant ponds. In Japan, eels are usually fed ground up trash-fish or invertebrates (i.e., molluscs, worms, etc.). In experimental eel culture in the United States, food consists of a mixture of ground manhaden

(75%), cornmeal (25%), vitamin premix, and antibiotics for disease control. Normal food conversion is poor, 5-10:1, and both uneaten food and unassimilated wastes create problems in water quality that may necessitate aeration and would require effluent treatment in the United States to meet discharge standards. Somewhat better conversion efficiencies may be achieved with prepared pelletized food, but the eels do not readily accept such feeds.

Growth is optimal at 80°F and feeding stops at 55°F. At 50°F, the eels bury in the substrate and remain inactive. Thus growth in temperate climates is seasonal and two years is required to reach a marketable size of 1/4 to 1/2 lb.

Eel culture had its origin in Japan over 150 years ago. Today over two million kilograms are reared annually in both Japan and Taiwan, where the practice is more recent. Most of the eels raised in these countries are consumed domestically, but some are shipped to Europe, particularly Italy. The preferred size for the oriental eel market is relatively small, 1/4 to 1/2 lb, which may bring a price as high as \$6.00/lb. The Europeans prefer a larger fish, 1 lb or more in size, which sells for \$1.50-\$2.00/lb.

The present eel culture industry in Japan and Taiwan, and to a much less extent in Europe, is not able to satisfy the world demand for the species, part of which is also met by conventional commercial fishing. Some 18 dealers in the United States along

the Eastern seaboard purchase eels from commercial fishermen for export to Europe and Japan. Price to the fishermen is approximately \$0.50/lb for whole fish which are shipped alive or live-frozen. However, the demand for the price of eels on the foreign market, although often high, is seasonal, strongly dependent upon quality of the product, and is generally unpredictable. There is no significant market for eels in the United States.

There is also no commercial eel culture practiced in the United States. A small Sea Grant research project in North Carolina and an embryonic NSF-sponsored project in Trenton, N. J., the latter utilizing the heated water from the P.S.E&G Mercer fossil fuel power plant, represent the only attempts to rear eels experimentally in this country.

The American eel occurs naturally in the Connecticut River in the vicinity of Vermont Yankee. Thus it can tolerate the natural water quality conditions as well as the normal seasonal temperature extremes. The species is also believed to be able to withstand sudden temperature drops of 40°-50°F such as might occur with an unscheduled shutdown in winter. However, due to the remote and unpredictable market, the poor food conversion efficiency and attendant pollution problems, uncertainty concerning the supply and availability of the juvenile animals collected from the wild, the high cost and limited availability of natural food, the

relatively high temperature required for optimal growth, and the fact that growth of the species in heated cooling water effluent is already being studied at another utility, eel culture is not recommended for Vermont Yankee.

B. Yellow perch (Perca flavescens)

There is, at present, no commercial aquaculture of yellow perch, nor has it yet been attempted. Research on cultivation of the species, primarily at the University of Wisconsin, is in its infancy and is still in the preliminary stage.

Juvenile (ca. 1 gram) fish have been grown to a marketable size of 150 grams (1/3 lb) in 9 to 11 months on a diet of prepared pelletized food and at a constant temperature of 72°F and a constant photoperiod of 16 hours light alternating with 8 hours dark. Growth drops off sharply as both temperature and photoperiod depart from these optima. Food conversion efficiency is 1.5:1 (dry weight of food to wet weight of fish).

The estimated cost of rearing yellow perch ranges from \$0.50 to \$0.65 per pound. The value of the fish in the round (i.e., whole fish) ranges from \$0.55 to \$0.77 per pound. Thus the margin of profit is at best small and at worst negative.

There are, at present, no commercial hatcheries that produce juvenile (fingerling) yellow perch. Spawning the species artificially and rearing to the fingerling size has been done

successfully and presents no special problem, but cannot be done on demand. The fish spawn in the early spring and it takes about six weeks for the fingerlings to reach a size that can be used in a grow-out operation. It is not possible at present to maintain a constant supply of the juvenile fish that could be introduced into a grow-out facility at any time of year, and it is estimated that several years of research will be needed to achieve such reproductive control.

The commercial market for yellow perch is almost exclusively the Great Lakes region of the United States and Canada, with 75% of the annual production consumed in Wisconsin alone. The commercial fishing yield from the Great Lakes has been steadily declining, which makes aquaculture for the species attractive. Several commercial operations for growing yellow perch are presently in the planning or construction phase, at least one of which projects a five million pound per year facility. How expandable the market may be and how much the new production from these sources will affect the already precarious cost-effectiveness of yellow perch culture remains to be seen.

Yellow perch grow naturally in the Connecticut River and can withstand its normal temperature range throughout the year. Whether the species can survive sudden drops in temperature that might occur with an unscheduled shut-down is not known.

In conclusion, the technical constraints to yellow perch aquaculture are the seasonal availability of fingerlings and the sensitivity of growth to temperature and day length. The economic constraints are the value of the species, which barely exceeds its cost of production, and a geographically and hence quantitatively limited market. Since other species such as trout, for example, do not have these problems and limitations, it is not recommended that yellow perch aquaculture be pursued at Vermont Yankee at this time, but progress with the species elsewhere should be followed, the size of its potential market should be investigated, and the cost of its production in a culture system using waste heat and a flow-through water system should be determined independently.

C. Walleye pike (Stizostedion vitreum)

This larger cousin of the yellow perch has also never been grown in culture for food, although the species has long been reared in captivity for stocking natural waters for recreational purposes. As with the perch, the spawning and rearing to fingerling size is not difficult, although it also cannot be done out of season and there is now no commercial source of juveniles.

Walleye culture is also being studied experimentally at the University of Wisconsin and a few other places, but it is not as far along as the yellow perch in that regard and for that

reason alone does not merit consideration here in any detail. There are, however, a few aspects of its biology and culture potential that appear to differ from the yellow perch and these points deserve brief mention.

First, although optimal growth of the walleye occurs at 72°F, as with the perch, the pike is relatively insensitive to day-length or photoperiod. That factor appears to be very important in controlling growth of perch and could represent a costly problem to control in any large-scale yellow perch culture system.

Second, the walleye pike appears to be less adaptable to an exclusive diet of pelletized, artificial feeds and the very young require live food such as water fleas (Daphnia) be mixed with the feed before it is accepted. Once the fish are accustomed to an artificial diet, the larger fish appear to accept it readily with conversion efficiencies comparable to that of yellow perch. Thus, nutrition may not be a real problem, but it is likely that further research is needed on the subject.

Also like the yellow perch, the commercial market for walleyes is largely confined to the Great Lakes region and is centered in Wisconsin. However, it is much smaller than that for yellow perch, which is a problem that should be thoroughly investigated before its cultivation is seriously considered. A

closely related problem is the marketable size of the species, which may be considerably larger than that of yellow perch and could require two years or more in culture.

It is likely, however, that the small commercial market and larger commercial size of walleye pike merely reflect their size and availability in the commercial fishing catch and their relative abundance in nature. Those familiar with the two species usually prefer the walleye as a food and its price, when available, is significantly higher than that of perch. With those advantages, it would appear that walleye pike should be evaluated together with yellow perch, though the state-of-the-art of their cultivation may put both species out of the picture for the immediate future.

D. The giant freshwater prawn (Macrobrachium rosenbergi)

Macrobrachium is included in this species evaluation because it is the freshwater organism that is currently commanding the most interest in the United States. This large crustacean is native to Southeast Asia where it was initially cultured. There are now innumerable attempts being made to grow Macrobrachium in the United States, principally in Hawaii, Florida, Puerto Rico, and other semi-tropical parts of the country, as well as elsewhere in the tropical Western Hemisphere. To the author's knowledge, none of these attempts has yet succeeded economically

with the possible exception of Hawaii, where the operation has been at least partially state subsidized.

Macrobrachium rosenbergi is a truly tropical organism whose growth is most rapid at temperatures of 80°-85°F and whose lower lethal temperature is 59°F. Even in Florida, the species seldom survives the winter. However, the animals grow very rapidly and, if stocked as postlarvae early in the southern spring, can reach a marketable size of 100 grams by fall. This type of culture is now being attempted experimentally at the P.S.E.&G. Mercer Station, a fossil-fuel power generating plant in Trenton, New Jersey, where Macrobrachium are grown in the heated cooling water discharge in summer and rainbow trout are grown in winter.

Although there are several other species of Macrobrachium including at least two that are indigenous to Southern United States and can tolerate lower temperatures than M. rosenbergi, they have other disadvantages that out-weigh that advantage. Chief among these is their strongly cannibalistic habit, which is shared by M. rosenbergi only to a very minor extent and which is so severe in the others as to virtually preclude their intensive cultivation.

Another problem in Macrobrachium culture at inland locations is that the larvae require brackish water of 10-20‰.

(30-60% seawater) for their development. This means that the culturist must have a second marine site or a large supply of seawater at his freshwater site if he wishes to rear his own animals through their entire life cycle and produce his own supply of post-larvae for grow-out operations in freshwater. Alternatively, he may purchase post-larvae from another specialist, but the price is usually high, \$0.075 per animal from one dealer in Florida in 1976, and may add significantly to operating costs.

Other aspects of Macrobrachium culture need not be discussed here because the organism is unsuitable for aquaculture at Vermont Yankee due to its temperature requirement alone. Even the cooling water itself would be marginal for the best growth of the species during much of the year. If a heat exchanger were used providing water at a somewhat lower temperature, the latter would be suboptimal for Macrobrachium most of the time. Most important, however, is the fact that a shut-down, planned or otherwise, resulting in a drop to ambient water temperature at any rate of decrease, would be lethal to the giant prawns in all but the three warmest months of the year. This would represent a risk that could not be accepted.

E. Channel catfish (Ictalurus punctatus)

Catfish farming is by far the most successful form of aquaculture practiced today and to date in the United States. The industry rose from virtual obscurity in 1963 to an annual production of 30 million kilograms in 1969, six times the yield of its closest competitor, rainbow trout. For that reason alone channel catfish deserves to be included in any review of candidate species for freshwater aquaculture in the United States.

However, it is for the same reasons that catfish are not recommended for use at Vermont Yankee. The industry is so well established and has worked out its own problems so successfully that the use of Federal research funds to further investigate cultivation of the species cannot be justified. Furthermore, the fact that such funds have already during the past decade been used to study catfish culture in the heated cooling water discharges of power plants in Texas, Oklahoma, Nebraska, Colorado, Tennessee, and perhaps elsewhere give further weight to this argument.

In addition, the catfish industry, which reached a production peak in 1969, has since leveled off if not actually declined. It was estimated that not more than 25% of the catfish farmers in business in 1969 were operating at a profit. It is likely that that percentage has since decreased as the industry

becomes more and more dominated by a few larger, efficient operators and as it becomes increasingly threatened by competition from Central and South America, where cheap labor and a longer growing season provide special advantages.

To these social and economic factors must be added the fact that the demand for catfish is virtually non-existent in Northeastern United States and that catfish grown in Vermont would have to be shipped to the South and compete there with those grown in the region.

For all of the above reasons, catfish culture is not recommended for Vermont Yankee irrespective of the technical aspects of its culture there.

F. Striped bass (Morone saxitalis)

The striped bass is the most popular and sought-after saltwater game fish in the Northeastern United States. Although protected in those states from commercial fishing, sportsmen are usually allowed to sell their catch and the species also enjoys the reputation of a fine eating fish. Further to the South, in the mid-Atlantic States and particularly in Chesapeake Bay, commercial fishing for the species is allowed and small (1-2 lb) rockfish, as they are called there, are a common menu item. The present market for bass is small and restricted but this is due primarily to the limited source and supply. Price

also tends to fluctuate widely, from as little as \$0.20 to over \$1.00/lb in the round, as the supply of this migratory fish rises and falls with the season and abundance. There seems little doubt, however, that the market could be expanded very considerably and the price stabilized at a reasonably high level if a larger and more consistent supply of this fish were made available, for it has excellent food quality and enjoys an enviable reputation in the better seafood restaurants.

The striped bass is an anadromous fish that ascends the estuaries of the Chesapeake and Delaware Bays, the Hudson River, and similar bodies of water south as far as the St. Johns River of Northern Florida, where the fish spawn. The center of their spawning area is believed to be the Chesapeake Bay estuary. Juvenile bass descend from their freshwater source soon after larval development and spend the rest of their lives migrating up and down the coast seasonally.

During the past several years, the new year classes of striped bass have apparently failed and few individuals have been recruited into the population. The reasons for this sudden decline are not well understood, but are believed by many to have been caused by pollution (e.g., kepone, PCB) in the spawning areas and the resulting failure of eggs to hatch or larvae to develop normally. The alternative explanation is that the population is currently undergoing one of its natural, periodic declines

in abundance, the causes of which are not known but the occurrences well documented in the past. Whatever the reason, there has been a drastic decline in the numbers of small striped bass all along the Eastern seaboard over the past two seasons, and the small pan-sized rockfish, formerly so common in restaurants in the Baltimore-Washington area, have all but disappeared.

During construction of the Cooper-Santee Dam in South Carolina, bass that had migrated upstream to spawn became landlocked. This isolated population flourished in its freshwater environment, the fish growing to a large size (up to 50 lbs or more) and creating a popular sports fishery. This event stimulated the construction of numerous striped bass hatcheries throughout the South to provide juveniles both for stocking large freshwater lakes and impoundments and for replenishing stocks in Southern estuaries (e.g., in the Gulf of Mexico) where the species was formerly established. The current decline of the species in the Central Atlantic and the Northeastern States, discussed above, has led to increasing interest in hatchery production for that area as well. Most of these developments are quite recent, having started about 1970 or later, so evaluation of the broad stocking program is premature. But the state-of-the-art of producing fingerling striped bass in hatcheries is apparently now well advanced, although the

species cannot yet be routinely spawned and the young reared on demand and out-of season.

The striped bass is an unusually hardy species that can tolerate a wide range of environmental conditions, including salinities from freshwater to full seawater, temperatures from freezing to above 90°F, sudden temperature drops of 25°F or more within a few minutes, and rough handling. The species is relatively free from major disease problems, even under crowded hatchery conditions.

The nutrition of the striped bass has not yet been thoroughly studied and no artificial diet specifically for the species has yet been developed. Newly hatched larvae grow well on a diet of brine shrimp nauplii or other small crustacea (e.g., zooplankton collected from the wild). The larger animals grow very well on ground menhaden or squid. Although it is somewhat difficult to acclimate the fish to a diet of prepared feed, they will eventually accept commercial trout pellets and, once adjusted to such food, appear to thrive on it.

Striped bass grow well within a wide temperature range, from about 65° to 80°F. In Florida, the species has been grown to a size of one kilogram (2.2 lbs) in one year. However, fish grown in freshwater at a high temperature (75°-80°F) were found to have soft flesh and to be of inferior market quality.

The above-mentioned research in Florida represents the only known attempt by a commercial firm to produce striped bass for food. The project was relatively short-lived and the effort discontinued. Since that time, the cost of fish in general has increased very significantly and the availability of striped bass on the market in particular has declined sharply, as discussed above. Also since that time, considerably more knowledge of the species and its culture has been obtained through the extensive hatchery and stocking programs being carried out across the country. For those reasons, the time would appear to be ripe for another attempt at rearing small (ca. 1 lb) striped bass for the food market. It should not be difficult to rear fish of that size in one year or less if they can be maintained at a temperature of 65°-70°F. However, the economics of such an undertaking with respect to cost of production and market value of the product remain to be determined and would require a research effort of considerable magnitude and perhaps several years duration.

Because Vermont Yankee is not primarily a research organization and is not equipped to undertake a research program that could be both basic and prolonged in nature, culture of striped bass is not recommended for the Vermont Yankee aquaculture project.

G. Bait minnows: Golden shiner (Notemigonus crysoleucas) and Fathead or Blackhead minnow (Phimephales promelas).

The bait fish industry of the United States is second only to catfish with respect to the area of ponds in cultivation and the weight, number, and value of fish produced per year. This large industry is centered in Arkansas with minor activity in a few other surrounding states. The species cultivated, in order of their importance, are golden shiners, fathead minnows, carp, and goldfish. Only the first two will be considered here. All, however, are easy to grow, hardy, omnivorous, fast growing, and prolific - all of the attributes desired in aquaculture.

Baitfish farming involves the culture of vast numbers of very small organisms through their entire life cycle. Mature fish (2-2 1/2 inches long) are placed in breeding ponds, where they spawn in the spring, when temperatures reach 65°-70°F. Shiners spawn on natural vegetation or on artificial beds of Spanish moss or similar material. The fathead minnows spawn on the underside of almost any surface; wooden boards are often used. Eggs of the golden shiner are moved to special nursery ponds to prevent their being eaten by the adults. The male fathead minnow, on the other hand, guards the nest and agitates the water around the eggs and the young of that species are grown together with the adults, many of which, however, die after

spawning. In no case have any species of bait minnow been brought to sexual maturity and spawning condition out of season through hormonal control or environmental manipulation, so the supply of young is restricted to one time of year.

Rearing of the minnows is usually done by extensive culture methods utilizing large areas of standing-water ponds, with little or no exchange of water. The ponds may be fertilized to enhance the supply of natural food, but supplementary feeding is done sparingly. This method of culture would appear to have no application for an aquaculture system utilizing waste heat.

The other, less common technique in minnow farming is the intensive method whereby the water is continually exchanged and the fish are dependent entirely upon artificial, prepared food. The very young fish at first require flour-fine mash, after three weeks powdered mash, and later commercial catfish pellets or other feeds specially made for the industry. The fish are normally fed 2-3% of their body weight per day which, on an average, is equivalent to 10-20 lbs/acre/day.

Minnows hatched in the spring will reach a size of one to three inches by late summer or early fall, the larger golden shiner growing somewhat faster than the fathead minnow. Some of the stock can therefore be harvested and sold by the end of

the first growing season. However, a greater fraction of both species is usually not large enough by the end of the first year and must be held over for harvest the following spring or summer. In this regard, much depends of course on the use of the bait. For bass and other large sports fish, minnows of 2-3 inches are required, while minnows 1-2 inches are used for pan fishing.

Most of the information available on baitfish culture is empirical in nature and based on commercial farming experience. Few controlled experiments that relate directly to aquaculture have been done with any of the species in question. Unfortunately, virtually nothing is known about the optimum temperature for growth or the effects of temperature on the length of time required for the minnows to reach a marketable size.

Yields depend upon the culture method and the amount of feeding, but average about 1000 lbs/acre/year in ponds intensively managed and heavily fed. The fish weigh 6-20 lbs/1000 depending upon their size at harvest and bring a wholesale price to the grower of \$1.50-2.50/lb. This is equivalent to a gross income of about \$2000/acre/year, of which one-third to one-half is consumed by the price of feed. This is not a spectacular income compared to that potentially to be had from intensive farming of luxury food species, but is made profitable

in the large minnow farms of Arkansas by the fact that hundreds of acres are maintained in production.

Such land is presumably not readily available at Vermont Yankee but, in any event, it would not prove feasible to circulate heated water through a large area of ponds and maintain its elevated temperature. Furthermore, the advantage of using heated water in baitfish culture is not immediately obvious. As mentioned above, the effect of temperature on the growth of bait species is not known in the first place. But it seems unlikely that fish spawned in the spring could have their growth accelerated to the extent that they would be marketable before late fall of the same year, too late in the New England season to be of use. By the following fishing season (late spring in Vermont and vicinity) the minnows would probably be large enough to be sold without use of heated water. Acceleration of their growth in winter could very well result in fish too large for the local market by the following summer.

Added to these uncertainties is that of the market for bait minnows in Vermont and other New England States, where trout and salmon are the most popular freshwater sports fish and minnow-fishing is not the common form of angling that it is throughout the South.

Because of these uncertainties, bait fish culture is not recommended as a primary crop in the Vermont Yankee.

Aquaculture project. If space and facilities were available, however, it could prove interesting to investigate on a small scale the possible advantages of heated water to bait culture in such a climate as that of Vermont. But if such an experiment were to be attempted, it should probably be preceded by a market analyses of the demand for bait minnows in Northern New England.

Both golden shiners and fathead minnows occupy a natural temperature range from freezing to about 80°F. The fathead minnow is generally considered to be more of a cold-water species than the golden shiner and is native to the North-Central States. However, it is not common in the Eastern United States and has not been reported in the Connecticut River, as has the ubiquitous golden shiner. For that reason, it is recommended that any research on bait minnows be restricted to the golden shiner.

H. Rainbow trout (Salmo gairdneri)

Besides catfish, rainbow trout is the only freshwater organism and the only other finfish that has been successfully grown for food in an aquaculture operation in the United States. The species is grown in many other countries as well and its production in at least two of these, Denmark and Japan, is considerably greater than that in this country. The relatively low price of imported, frozen rainbow trout from those countries has, in fact, severely affected the price and the entire field of trout culture in the United States.

If one were to add to the trout grown for food those produced by the many private, state, and federal hatcheries for stocking natural waters for sports fishing, the United States would undoubtedly be the world leaders in this field. Rearing trout for the latter purpose also predated the food aquaculture industry by many years, and the state-of-the-art of trout culture was well advanced by the time interest in aquaculture was born in this country.

Many books have been written about trout culture and there is no need to review that extensive literature here. It is sufficient to say that the fish can be conditioned and spawned routinely in captivity and that both fertilized eggs and fingerling trout of several varieties may be purchased in any desired quantity for aquaculture. The nutrition of the species has been

studied intensively and several commercial feeds are now available that provide a complete diet, high conversion efficiency, and rapid growth. Aquaculture of the species has usually involved the production of "portion-size" fish of about 9" length and 1/3-1/2 lb weight. Fish of this size can be grown in six months to one year from hatching, depending upon water temperature and food.

Most of the trout culture for food in the United States has, until very recently, been concentrated in the Snake River Valley of Idaho and its environs. Several of the trout farmers of this area have the advantage of access to spring water at nearly optimum temperatures throughout the year and at no cost for pumping water. It is important to the present discussion to emphasize here that even with such natural endowments, the trout farmers in question have had difficulty in operating at a profit.

The industry has, in the past few years, begun to expand to other parts of the United States, particularly in the South where sites can be found with cold spring or well water available throughout the year.

The optimum temperature for rainbow trout, as for most salmonid fishes, is relatively low compared to most finfishes, ranging from about 59° to 64°F. Some species of salmonids,

including rainbow trout, can survive temperatures as high as 80°F for short periods of no more than a few hours. However, the fish grow poorly and are in obviously stressed condition above 70°F.

Salmonids are more susceptible to disease than most other fishes, their intensive culture being always threatened by the spectre of mass mortalities from any of several recognized but hard to control diseases. When stressed by high temperatures, the animals are much more likely to succumb to such causes.

Because of the temperatures available at Vermont Yankee from both ambient and heated sources (see Figures 1,2) salmonid fishes cannot be reared there from about mid-June to mid-September. Normally, rainbow trout spawn in nature in late fall and the eggs hatch in early spring. Fry maintained at optimal temperatures and fed adequately can grow to marketable, portion-size fish by fall. This schedule would not, however, be possible at Vermont Yankee because even the ambient water temperature is too high in summer. The fish may, however, be held in a hatchery in cold (i.e., spring-fed) water and with light feeding throughout the summer at the end of which time they might be 3-6" in length. Such fish, stocked in a grow-out facility at Vermont Yankee in September with heated water provided as

needed throughout the winter to maintain a water temperature of 60°F, would reach a marketable size during the late fall, winter, and early spring (i.e., the larger and faster growing fish first and the slower growing individuals later). Trout marketed at that time, when fresh fish are scarce and prices are high, would find a better market than those harvested at the conventional time of summer and early fall.

There is little reason to believe that rainbow trout could not be successfully grown at Vermont Yankee. However, as pointed out above, the species is already being grown extensively in the United States and elsewhere and the industry is already in a marginal and precarious condition economically. Research is also already in progress at the P.S.E.&G. Mercer Station (Trenton, N.J.) on growing rainbow trout in heated cooling water, and there are several similar studies being carried out elsewhere in the world. For those reasons, it is not recommended that rainbow trout be the species selected for aquaculture at Vermont Yankee.

I. Brook trout (Salvelinus fontinalis)

In contrast to the rainbow trout and other introduced salmonid species, the brook trout (which is a char and not a true trout) is the native trout of New England. For that reason, it is held in special regard by sports fishermen and is believed by many to be superior to rainbow and other trout as a food. While the latter attribute would be difficult to document, the fact that it is generally believed to be true is probably sufficient to affect its relative market value.

Although brook trout are not now and have not been grown in culture for food, at least in any significant quantity, they have been reared for recreational stocking purposes for many years. The techniques of their cultivation are essentially the same as those for rainbow trout, with which they are often grown together in New England state hatcheries.

Brook trout reportedly grew a little more slowly than rainbow trout, normally reaching a size of 6"-9" in one year. Length may be misleading in this regard, however, because brook trout are deeper and more heavily bodied than rainbows, a fact that could be distinct advantage in the appearance and general appeal of a "portion-size" trout.

Brook trout may also require slightly lower temperatures for optimal growth and they may do somewhat better in natural bottom ponds than in artificial ponds or raceways, although none of these facts appear to be well documented.

Like rainbows, brook trout spawn in the fall and the eggs hatch the following spring. As proposed for rainbows, brook trout could be hatched and the fry reared in a commercial hatchery through the spring and summer. If indeed brook trout grow more slowly, the additional time spent in the hatchery could be an advantage. Stocked in a grow-out facility at Vermont Yankee in September, the brook trout would be ready for market during the winter and early spring.

Because of the special regard with which brook trout are held in New England, the fish could probably be marketed fresh in the better New England restaurants without their being confused with frozen, imported rainbow trout, a distinctly inferior and less appealing product, and at a significantly higher price. While a market analyses is needed to confirm this possibility, it is tentatively proposed here that an aquaculture project at Vermont Yankee for the purpose of producing food should give first consideration to rearing brook trout to be marketed fresh as a high-priced, speciality food.

J. Atlantic salmon (Salmo salar)

There is no species of fish that surpasses salmon as sports - or food-fish, particularly in New England. However, the Atlantic salmon has been in a serious decline for many years and for many reasons - pollution, destruction or daming off of spawning sites, overfishing of the ocean stocks, etc. Many rivers in New England and the Canadian Maritimes that formerly supported runs of Atlantic salmon no longer do so. Included among these is the Connecticut River.

Serious efforts are now being made to restore the Atlantic salmon to much of its former natural habitat in New England and Canada. In addition to control of the ocean fishery, habitat improvement, construction of fish ladders, etc., one of the major elements in the restoration program is the production and release of large numbers of Atlantic salmon smolts into the river systems in question. In the spring of 1975 the first Atlantic salmon in recent times were found in the Connecticut River below the Holyoke dam. Apparently, the environment of the river will now support the existence of the species. To establish a sizeable population of salmon in the Connecticut River will, however, require the release of a large number of seaward-migrating salmon smolt that were reared and imprinted in the Connecticut River, for salmon normally return only to the native river from which they went to sea.

In nature, salmon ascend freshwater rivers in the spring and summer, reaching their gravel-bottom spawning beds in the tributary streams by fall, when they spawn. The eggs hatch the following spring and the young alevins remain in the streams where they hatched, normally for at least two and often for as much as three or four years before they become smolts and migrate to sea. Smoltification is a specific physiological change in the young fish that accompanies their normal growth. Salmon smolt are thin and silvery in appearance and may range in size from 5 to almost 10 inches. However, even the larger smolt are not fleshy and the average weight is no more than about 0.1 lb.

In captivity, the newly hatched salmon alevins kept at ambient water temperatures normally require at least two and sometimes three years to become smolts. The reason for the long period of time needed for the development of these young fish, both in nature and in hatcheries supplied with water under natural conditions, is the long winters and low water temperatures that occur where salmon are found and the fact that little or no growth of the fish occurs under those conditions.

The holding of fish in a hatchery for long periods of time (i.e., years) is costly in terms of both money and space and severely limits the number of individuals that can be released in a year. However, it has been demonstrated in Iceland, where

hatcheries are supplied with warm water from natural hot springs, that smolts can be produced in one year from the time of hatching. Attempts have been made to heat the water in winter at one or more of the Federal salmon hatcheries in Northern New England to accelerate smoltification, but the cost of doing so was found to be excessive and the practice has been discontinued.

It is suggested here that juvenile salmon taken from hatcheries in New England during the fall (September) of their first year be grown in heated water from Vermont Yankee. Held at their optimal temperature of approximately 60°F, they would smoltify during or at the end of their first year and be ready for release as one-year smolt during their second spring. Such a project could contribute significantly to the Connecticut River salmon restoration program and would be looked upon favorably by sportsmen, conservationists, and the public. If a cooperative program could be worked out between Vermont Yankee and the various State, Federal, and private organizations involved in salmon restoration in New England, it is likely both that the juvenile fish would be made available from existing hatcheries and that funds would be made available that would defray the costs of the operation.

Summary

Of the ten species that have been considered here as candidates for an aquaculture project utilizing the heated wastewater at Vermont Yankee Nuclear Power Plant, only one (Macrobrachium) was found to be biologically unsuitable. Three others (eels, catfish, and rainbow trout) were eliminated on economic and/or social grounds (i.e., lack of sufficient need, demand, or price). A fourth (bait fish) probably fits into the same category, but could stand further examination with respect to both its market and its culture potential in warm water.

Three species (yellow perch, walleye pike, and striped bass) look interesting, particularly because they could be grown the year-round, in ambient Connecticut River water in summer and in water heated by Vermont Yankee in winter. The current state-of-the-art of growing these species and the lack of knowledge of their market potential made it appear that considerable time and effort would have to be spent on rather basic research with no guarantee that any of them would be found suitable at the end. They were therefore reluctantly eliminated.

The species that appeared most promising for aquaculture for food, particularly for application in an operation of modest size in Northern New England, was brook trout, a fish for which there is believed to be considerable demand and a potentially high price

if marketed fresh as a luxury food, and one for which the culture technology is well developed but is not presently being exploited in the food market.

Of even higher potential value to Vermont Yankee, however, could be the production of Atlantic salmon smolts for release into the Connecticut River as part of the New England salmon restoration program, an activity towards which the heated wastewater from the utility could make a unique contribution.

III. The effects of different modes of power plant and cooling system operation, including the effects of planned and unplanned shutdown, on the economic feasibility and design of the aquaculture system.

A. Water quality

The presence of radioactive nuclides, released purposefully or accidentally, in the cooling water, the presence of biocides such as chlorine, plant wastes of any kind including those from water deionization, wash-down, blow-down, etc., heavy metals from condensor tubes - all render the water unsuitable for aquaculture. The presence and/or concentration of such substances in the cooling water, during either open or closed (i.e., once-through vs. cooling tower) mode of operation, are not known. In the absence of such information, the worst case must be assumed requiring the use of a heat exchanger system to raise the temperature of Connecticut River water to the degree necessary for aquaculture. Capital and operating costs and design features will include the heat exchanger itself and a separate pumping and distribution system.

B. Water temperature

The species that can be grown in an aquaculture system, the rate of growth, and the quantity of organisms that can be grown depend upon the volume and temperature of the secondary

aquaculture system. The latter, in turn, will be determined by the mode of operation of the power plant and its cooling system, the resulting temperature of the cooling water, and the size and design of the heat exchanger used for the aquaculture system. Examples of the temperature ranges that can be expected at different seasons and under different operating conditions are shown in Figures 1 and 2 and discussed in Section I of this report.

In general, the higher the Δt of the cooling water, the smaller the heat exchanger needed and the lower the capital cost of the aquaculture system. Operation of the closed cycle (cooling tower) mode would presumably therefore be desirable for aquaculture, though specific details concerning the relative temperatures and Δt 's of the cooling water with different operating modes are not available.

C. Planned shutdowns

Presumably, the planned shutdowns may be done slowly with a gradual decrease in the temperature of the cooling water. The rate of temperature decrease to ambient levels under such conditions is not known, but is assumed to be 24-48 hours. Organisms that can live within the temperature range between that selected and controlled for their growth in an aquaculture system (60°-80°F, depending upon the species selected) and ambient

Connecticut River water in winter (approximately 33°F) normally can tolerate a decrease within that range over a period of 24 hours. Species that do not naturally live within that temperature range should not be selected.

D. Unplanned shutdowns.

Presumably, unplanned shutdowns are abrupt and complete and result in a rapid decrease in the cooling water Δt to ambient levels within 1-2 hours. Most organism that live within a seasonal range of temperature as large as the cooling water Δt can withstand a sudden drop of temperature of the entire Δt within one hour. However, all such species may not be so adaptable. Knowledge of the effects of such thermal shock is not available for all of the candidate species for aquaculture and should be determined experimentally, where not available, for any species seriously considered for such purposes.

E. Prolonged shutdowns

Although cultured organisms may withstand either planned (gradual) or unplanned (rapid) shutdowns with the resulting decrease in temperature to winter ambient conditions, no candidate species for aquaculture will grow at such temperatures. Shutdowns for a month or more in winter can therefore seriously disrupt production schedules. Failure of the organisms to grow

to the desired size within one growing season could present serious problems, particularly with those species such as trout and salmon that cannot withstand summer ambient temperatures.

Capital and operating costs of a standby water heating system with sufficient capacity to permit normal operation of the aquaculture system must be weighed against the expected incidence and duration of both planned and unplanned winter shutdowns to determine the need and desirability of such emergency equipment.

G
APPENDIX

APPENDIX G

VERMONT YANKEE
AQUACULTURE RESEARCH LABORATORY (AQUALAB)
FISH REARING FACILITY REPORT

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VERMONT YANKEE FISH REARING FACILITY REPORT

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VERMONT YANKEE FISH REARING FACILITY

CHAPTER 1: Introduction

In recent years, increasing attention has been paid to the feasibility of using waste heat of power generation for aquaculture. There are several reasons for this. Energy of all kinds has become an increasingly valuable commodity, and people have become aware to a high degree of the effects of dumping waste heat into the environment. Present-day fossil fuel plants reject about 50% of all heat generated through their condensers, and nuclear plants reject about 65%.

Increasingly, this heat has been utilized as a resource rather than as an environmentally degrading waste. Several species of finfish and shellfish exhibit greatly increased growth rates when held in warmed water. To date, species cultured in power plant waste heat include: lobster, trout, fresh-water prawn, catfish, pompano, yellowtail, oysters, carp, and tilapia, to name but a few. Even though there are problems, such as toxic antifouling chemicals added to the condenser water, and rapid temperature changes caused by sudden plant shutdowns, the concept shows considerable promise.

The Vermont Yankee facility described here is being considered both to use waste heat and to accelerate the stocking of the Connecticut River with what has become an all but extinct fish in America - the Atlantic salmon.

VERMONT YANKEE FISH REARING FACILITY

CHAPTER 2: Biological Considerations

A. General

Populations of the Atlantic salmon in the United States have been in a serious decline for many years, to the point where fish runs in rivers of the Northeastern states have virtually ceased to exist. No single reason exists for this; rather, it is a combination of over fishing, pollution, dams, destruction of spawning sites, and many other things.

A major component of present-day restoration efforts is the production and release of Atlantic salmon smolts into river systems which once supported spawning runs. A potentially important part of this production is a warm-water rearing facility such as that being considered for the Vermont Yankee Nuclear Site.

The Atlantic salmon is not an easy fish to culture. It is unique from other salmonids in its space, food and temperature requirements, and thus requires a unique facility design. There are still unknowns and problems to be solved at the present-day level of technology. Hopefully, a test facility such as the one envisioned here will aid in answering many of these questions.

B. Species Description and Cultural Requirements

The Atlantic salmon (Salmo salar) is an anadromous fish which may spend its adult years in the sea or in lakes, ascending streams to spawn. Its original distribution in North America was from the Delaware River up into the Hudson Bay area. However, by the early 19th century, most large runs had vanished.

Adult fish enter rivers and streams to spawn from April through October. Spawning occurs in late October and early November, and may be anywhere in the river from just upstream of the tidal zone to near the headwaters.

The eggs usually hatch in late April or early May. The larvae, or alevins remain in the gravel for approximately six weeks before emerging to feed. The parr, as they are then called, will remain in the streams from two to five years or more, depending on the water temperature, their growth rate and several other factors. Seaward migration, or smoltification, occurs in spring or early summer.

Several studies have been done examining factors affecting smoltification in Atlantic salmon (Saunders & Henderson, 1969; Saunders, 1970; Knutsson & Grav, 1976). It appears that size is the most important factor, and that temperature determines growth rate. Photoperiod is also important, but seems to be dependent on temperature. Gradually increasing day length throughout the late winter and spring enhances smoltification, whereas the opposite regime inhibits it.

The cultural requirements of underyearling Atlantic salmon fry are as follows:

	<u>SOURCE</u>
1) Space requirements: Up to 4" fish - 50 fish/ft. ² of tank bottom 4" to 10" fish - 10 fish/ft. ² of tank bottom	W.M. Carter, 1971 John Ryther, 1977
2) Flow requirements: 3-5 water turn-overs/hr.	Carter, 1971 Ryther, 1977
3) Temperature: Range: 10-18 degrees C. (50-65 degrees F.) (for growth) Optimum growth: 15 degrees C. (59 degrees F.)	Knutsson & Grav, 1976 Saunders & Henderson, 1969
4) Photoperiod: Increasing from winter through spring	Knutsson & Grav, 1976
5) Food: Silver Cup	Ryther, 1977
6) Conversion efficiency: 1.7:1	Ryther, 1977
7) Length-Weight relationship $L = 15.07 W^{.34}$	

C. Growth Acceleration by Temperature Control

In a controlled environment, salmon growth can be accelerated over that found in nature. Wild Atlantic salmon usually migrate to sea after from two to five years of fresh-water residence. In several instances, one-year smolts have been produced in a hatchery environment with the aid of heated water. However, Carter (1971) noticed a very poor return of adults from smolts stocked at a size of under eight inches. He knew of no reason for this. Knutsson and Grav (1976) held underyearling hatchery-reared fry in water at 7 degrees C., 11 degrees C., and 15 degrees C. over one winter at various photoperiod regimes, and found that the lowest mortalities in smoltification occurred in those fish reared at 15 degrees C. In addition, gradually increasing day length over the rearing period contributed to success of smoltification.

D. Effects of Sudden Temperature Changes

The Vermont Yankee Nuclear Power Plant is subject to shut-downs, both planned and unplanned, of various durations. At these times, there will be sudden drops in effluent water temperatures. Unless some form of back-up heating is supplied, the fish-rearing facility will be subject to the same rapid temperature fluctuations. This may lead to short-term stress problems as well as slowing growth.

In general, salmonid fish are tolerant of rapid decreases in temperature. A temperature decrease of 1 degree F. per minute, or a maximum of 15 degree F. in 30 minutes, is acceptable. However, temperature cannot be permitted to remain below that needed for growth for any period of time, as the fish must be large enough for smoltification in the spring. If the fish are undersize at release time, they may have to be held for an additional year, or large mortalities may result if released. A backup heating system should provide minimum 50 degree F. water to the rearing tanks during ambient river water temperatures of 32 to 50 degrees F.

E. Recovery of Power Plant Waste Heat

For purposes of this rearing program, it is desirable to recover the bulk of the waste heat by use of a heat exchanger. There are several reasons for this. First of all, the Delaney Amendment to the Federal Water Quality Act makes the rearing of fish used for food in water to which any radioactive substance has been added illegal. Second, the plant adds certain chemicals for slime control to its cooling water stream. Among these are sodium hypochlorite, sulfuric acid, and a demineralizer regenerant (Aquatec, 1976). Also, if a back-up boiler is to be used for standby heating, a heat exchanger will be required for the boiler in any case.

A limited number of fish should be held in pure discharge water as an experiment. If it is technically feasible to rear fish directly in discharge water, and any legal difficulties can be overcome, then an expanded scale facility could be built and operated at a considerable savings without the use of a heat exchanger.

VERMONT YANKEE FISH REARING FACILITY

CHAPTER 3: Fish Rearing Program

A. General

The primary objective of the fish-rearing program is to stock out 25,000 Atlantic salmon smolts in the spring. In order to accomplish this, approximately 31,000 underyearling fingerlings will have to be stocked into the facility each fall, assuming an overall 20% mortality.

Obtaining these fingerlings may represent a major difficulty. According to U.S.F.W.S. personnel, there will not be an "excess" of Atlantic salmon fingerlings in the foreseeable future, and 31,000 fish represents a large part of production for any hatchery now in existence. Therefore, securing a source for these fish is crucial to the feasibility of the program.

Since many elements of fish-rearing in nuclear power plant effluents are still experimental, the fish rearing program will contain several experiments to gain more information that may be used in later, scaled-up rearing programs.

Fish rearing and experimental programs will be carried out over a two or three year period in order to determine the feasibility of an expanded-scale, permanent, Atlantic salmon rearing station at the Vermont Yankee Nuclear Plant site. In addition, the rearing facility may be used to carry out other experiments during the summer, when water temperature is too high to hold salmon.

B. Smolt Production

Three-inch Atlantic salmon fingerlings will be stocked in September of each year. Thirty-one thousand fingerlings total will be required, of which 30,000 will be directly stocked into rearing tanks, and 1000 will be stocked into experimental aquaria. Initially, three circular rearing tanks will be stocked with 10,000 fish per tank, or a density of 40 fish per square foot of tank bottom. At the end of approximately six to seven weeks, the fish will be evenly distributed into all tanks. They will then be reared until time for release in April. A summary of the fish rearing program is shown in Table 1.

Feeding is assumed to be at about 5.7% of body weight per day with Silver Cup, at a conversion of 1.7:1. Assuming a feed cost of \$0.25/lb. delivered to the site, total cost of feed for the rearing program per year is \$5,917.50.

It is assumed that temperatures will be maintained at or near 60 degrees F. during the rearing period. This has been determined to be the most favorable temperature for growth of Atlantic salmon pre-smolts. In addition, natural photoperiod or constantly increasing day length through most of the rearing period has been shown to enhance survival at smoltification (Knutsson & Grav, 1976).

A growth rate of approximately 0.63 inches per month is assumed under these conditions. This is based on data obtained from the Powder Mill Hatchery, operated by the Maine Department of Inland Fisheries and Wildlife. This growth rate should yield a mean fish length of 8 inches at the end of April, when plant-out will occur.

C. Experimental Program

The basic objectives of the experimental program are:

- 1) To determine the increase in growth rate attributable to increased temperatures of the rearing water; and
- 2) To determine the feasibility of growing Atlantic salmon fingerlings in straight power plant effluent, with no heat exchanger and no back-up heating.

One thousand fingerlings will be used in the experimental study. These will be broken into two groups of five hundred, one to be held in ambient river water, and the other in straight condenser discharge water. Each group of five hundred will be broken further into four lots of 125 fish each. Four-foot diameter fiberglass tanks will be used as rearing units.

Half of the eight tanks will receive ambient river water. While it is recognized that these fish will in all probability not grow sufficiently fast to be released in the spring, they will provide some comparison for the accelerated growth fish.

The remaining experimental tanks will be supplied with plant discharge and ambient water. This group of fish will be subjected to exposure to any plant treatment chemicals, and to any sudden temperature changes caused by fluctuations in plant operation. Excessive temperature levels may be avoided by mixing in river ambient water as needed.

Parameters such as mortality, temperature and D.O. should be recorded on all groups of experimental fish at least daily. A sample should be taken weekly for weighing. In case of an unusually high mortality, an effort should be made to correlate this with temperature, chlorinity, etc. to determine the cause of mortality. Experimental fish should be fed the same ration as those in the smolt production ponds (Silver Cup), at a daily rate based on conversion and growth (Haskell, 1955).

Based on the results of the first year's experimental program, experiments may be continued, expanded, changed or dropped for the second year. For example, more research into variable photoperiod or feeding rates may be necessary, or excessive mortality may require that the experimental rearing in straight condenser water be discontinued.

D. Summer Programs

From the time of smolt release in late April until September first, when the facility will have to be readied for stocking, the site should be available as a warm-water aquaculture research lab. Possible users might be Vermont Fish and Game, U.S. F.W.S., or various universities.

Mean ambient Connecticut River water temperatures in the summer of 1975 were as high as 75 degrees F. The maximum condenser water temperature of 100.1 degrees F. during 1976 occurred in September. It would appear, therefore, that species such as catfish, yellow perch, or striped bass, which are able to tolerate and grow in these temperatures, might be candidates for a summer experimental rearing program at the Vermont Yankee site. While the circular ponds, considered best for Atlantic salmon, may not be ideal for other species, they should suffice on an experimental basis during the four summer months.

TABLE 1. FISH REARING PROGRAM, VERMONT YANKEE
Temperature - 60 Degrees F.

EVENT	Stock Tanks	Rear	Redis- tribute Rear	Rear	Release Summer Programs							
No. of Fish (Beg. Mo.) Assumes 2.5% mort./month	30,000	29,250	28,520	27,810	27,115	26,440	25,780	25,135	24,505			
Total Wt. (lbs) Beg. Mo.	265	440	730	1050	1450	2018	2580	3265	4015			
Tanks Req'd	3	3	9	9	9	9	9	9				
Flow Req'd GPM (As- sumes 1.5 ft. tank depth, 4 water changes per hour)	560	560	1680	1680	1680	1680	1680	1680				
Lbs. Feed Req'd. (As- sumes conv. ratio of 1.7:1)	630	1020	1530	2210	3060	3950	5020	6250				
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.

VERMONT YANKEE FISH REARING FACILITY

CHAPTER 4: Schematic Facility Design

A. Design Criteria

Criteria for facility design were as follows:

SITE - The site is in proximity to the Vernon Dam and future fish ladder, and is located so as not to interfere with any of the power-plant systems or operations. The area may be access-controlled for visitors without involving the entire plant security system.

WATER SUPPLY - Three separate sources of water are needed for the fish-rearing programs - river ambient, river heated, and discharge ambient. Reasons for this were discussed in Chapters 2 and 3. In addition, backup heating is needed for the rearing program in case of sudden shut-down, and a volume of water sufficient to provide four water turn-overs per hour per tank is required.

MECHANICAL SYSTEMS - A heat exchanger system to raise minimum temperature (32 degrees F.) river water to at least 60 degrees F. is needed (See Chapter 1 for explanation) at maximum design flow. In addition, the ability to heat minimum temperature river water to at least 50 degrees F. for prolonged periods by boiler is needed in case of plant shut-down.

REARING UNITS - Atlantic salmon need rearing space, not rearing volume, or they become aggressive and disease results. They also need relatively swift-flowing water. Several salmon culturists recommended circular tanks as being most efficient and easiest to maintain. A "permanent" facility was desired, therefore, concrete tanks are specified.

BUILDINGS - It is most cost-effective to have the heat exchangers and boilers near the pumps, at the discharge canal. Two buildings are therefore needed, one for the mechanical equipment, and one for the rearing facilities. Due to low winter temperatures, the rearing tanks should be covered. Therefore, the main hatchery building needs to house all tanks, visitor lobby, rest rooms, crew rooms, laboratory and storage.

WASTE DISPOSAL - Domestic waste will be piped to a septic tank on site. Since the circular tanks used throughout the rearing facility are essentially continuously self-cleaning, there should not be any build-up or concentration of pollutants in the fish-rearing effluent. According to the regulations of the Vermont Water Resources Board, no treatment should be needed for discharge into Class C, Type III waters.

B. Site Orientation

The hatchery rearing building is located near the existing Vernon Dam and is sited to provide visitors and hatchery personnel with views of both the river and dam. A future fish ladder and holding pond will be located south of the rearing building at the dam.

A nature trail leading through the existing stand of deciduous trees connecting the rearing building with the dam may be a desirable future addition.

The vehicular entry drive to the rearing building is sited to permit surveillance from the existing guard house. At the rearing building the service road separates from the main drive, thus limiting traffic interaction. Parking areas and drives are located to permit sun exposure thus minimizing snow accumulation.

C. Water Supply Systems

River ambient water will be lifted by three 640 gpm pumps located in a new river water intake structure. A small amount of river ambient water will be piped directly from the pumps to the main Rearing Building. This pipeline will not be insulated. The remainder of the water will be pumped to the Rearing Building via the heat exchangers in the Mechanical Building. Here, ambient river water is tempered normally by the plant discharge water or by the boiler water during plant shut-down. The 12" heated water line to the Rearing Building will be insulated.

The plant discharge water will be lifted from the existing plant discharge structure by three 3600 gpm pumps located on the top of the existing discharge structure. The plant discharge water for the experimental tanks will be pumped directly to the main Rearing Building. This pipeline will not be insulated. The 24" plant discharge water supply line to the heat exchangers will be insulated, but the return line to the river will not be.

D. Mechanical Systems

The mechanical system consists of pumps, boilers and heat exchangers to heat Connecticut River water to the desired rearing temperature and deliver it to the rearing facility. The following temperatures were used as part of the design criteria for this system.

1) Minimum River Water	32 degrees F.
2) Minimum Discharge from Power Plant	70 degrees F.
3) Optimum Rearing Water	60 degrees F.
4) Minimum Rearing Water (Boiler back-up)	50 degrees F.
5) Circulating Boiler Water	190 degrees F.

A maximum rearing facility water flow of 1920 gpm is assumed.

The rearing water temperature will be automatically regulated by the temperature controller and heating medium diverting valve as shown on the schematic diagram. Normally, the plant discharge water will be used as the heating medium. At plant shut-down, scheduled or unscheduled, the plant discharge water supply pumps will be automatically turned off after a pre-determined period of time-delay and the boiler water then will automatically replace the plant discharge water as the heating medium. The temperature control system can also be operated manually.

Two 250 hp boilers are provided to heat the maximum designed river water flow at 32 degrees F. to 50 degrees F. The boilers will be No. 2 fuel oil fired.

The heat exchangers shall have the heating medium in a cast iron shell and the river water in stainless steel tubes.

E. Rearing Units

Two types of rearing units will be used - 18 feet diameter concrete circular tanks and four feet diameter fiberglass tanks. There will be nine concrete tanks, each of approximately 250 square feet of bottom area, with outside standpipes. Provisions for use of a crowder screen should be incorporated into each tank. Immediately adjacent to these tanks will be the experimental rearing unit of eight four-foot diameter fiberglass tanks. Concrete tanks will be supplied with tempered river water through a spray bar, which insures both aeration and circulation. Fiberglass tanks may be supplied with any one or a combination of ambient river water, heated river water, or raw discharge water.

F. Buildings

MECHANICAL BUILDING

The building will be of approximately 1400 square feet and will house two boilers, five heat exchangers, and four boiler water pumps. Construction would consist of slab on grade with a masonry wainscot above which will be insulated metal curtainwall construction. This construction technique is compatible with existing structures and well suited to the Vermont climate. The life expectancy of this building is fifty years.

REARING BUILDING

A rearing building will be used to produce approximately 25,000 Atlantic salmon from September through April. An experimental rearing program is anticipated during the remainder of the year. To respond to this goal and its related design criteria, approximately 8100 square feet of rearing, support and visitor area would be required. Specifically, these would consist of:

Rearing Area - 6400 square feet. This would contain nine circular rearing tanks each with 250 square feet of surface area. In addition, eight 4 foot diameter experimental tanks provide a research area for 1000 fish. Access to each tank is provided to easily facilitate fish transfer. Controlled natural light would be permitted to enter the rearing area. Interior materials for this area would provide hard, nonpervious surfaces such as concrete or masonry with an epoxy paint. Supply and drain pipes to the large rearing tanks will be underground with piping to experimental stations overhead to facilitate flexibility. The winter design temperature of this room would be 50 degrees F.

Mechanical Storage - 600 square feet. This area will be used to house the headboxes and aerators for incoming water. In addition, sufficient space is allotted to store 11,000 pounds of dry feed (90 day shelf life) as well as a small shop area and repair or storage area for one hatchery vehicle. The winter design temperature of this room will be 50 degrees F.

Office - 200 square feet. An office area will be provided for the hatchery manager and one assistant. The location will be in close proximity to the rearing and visitor area thus providing security. In addition, view of the approach drive will permit observation of service vehicles. An electrical display panel would be located within this room so that it may be observed by not only hatchery personnel, but also visitors. Materials would be compatible with an office environment. Winter design temperature would be 68 degrees F.

Crew Area - 200 square feet. A lunch area, lavatory, locker area, and overnight dormitory for one man would comprise the crew area. In addition to providing a changing and clean-up area for the regular full-time winter crew, this area could be used by any visiting scientists or investigators, both in winter and summer. The overnight accommodation may be used in case any 24-hour experiments or monitoring are necessary. This area will be particularly useful in providing space for any occasional or outside researcher. Ready access to the rearing room and exterior with view windows both inside and out should be provided. In keeping with the "residential" character of this area, finishes would be gypsum drywall, and vinyl floor over slab. Winter design temperatures would be 68 degrees F.

Laboratory - 100 square feet. The laboratory will be used to monitor the experimental rearing tanks as well as facilitate simple fish rearing studies such as weight measurements, discharge monitoring, and bacteriology tests. Access will be from the rearing area with both interior and exterior view windows. Winter design temperatures would be 68 degrees F.

Visitor Display Area - 300 square feet. This area will be used for free-standing and wall hung graphics which explain the process of fish rearing. The room is sized for 20 to 25 people at one time which is equivalent to one gradeschool class. View of the hatchery operations by the visitors without their actually coming into contact with daily procedures is an important design criteria. Finish materials should be selected that will receive abuse. The winter design temperature would be 68 degrees F.

Rest Rooms - 260 square feet. The rest rooms were sized based on the anticipated visitor load. Handicap standards would be met in all cases. A janitor room would be located in this area. Materials which require little maintenance such as ceramic tile should be selected for this area. The winter design temperature would be 68 degrees F.

The general appearance of the building would be residential in character conforming to the environmental qualities of the surrounding area. Materials should be selected to provide a 50 year life with little maintenance such as brick or weathering steel. The landscape immediately adjacent to the building would be low maintenance such as wildflower mix and ground cover.

G. Waste Disposal

A 12" drain line, not insulated, is provided to gather all waste water from the rearing and experimental tanks and discharge it into the Connecticut river at a new discharge structure. Domestic waste will be piped into a septic tank system to be installed near the Rearing Building.

H. Operation

Full-time winter staff might consist of a manager and two assistants. Routine daily operation should include feeding, counting mortalities, checks of the mechanical system, cleaning as required, and monitoring of environmental parameters such as temperature and D.O. Temperature control, both routine and in case of shut-down, is automatic. Fish should be handled to the minimum extent possible, so it is anticipated that there will be only one fish transfer, during November. It is also anticipated that all fish will be tagged before release in April, which may require temporary extra crew.

It is difficult to anticipate mode of operation or staffing during the summer months, as these will vary depending on the agency using the facility and the experimental programs being carried out. However, the facilities should adequately accommodate either an academic research program involving student assistants, or a state or federal government-sponsored experimental warm-water rearing program during those months when it is not used for Atlantic salmon.

VERMONT YANKEE
FISH REARING FACILITY

CHAPTER 5: Cost Estimates

A. Capital Costs Including Construction

PURPOSE

The purpose of this preliminary cost estimate at the feasibility stage is to provide initial cost information for the construction program budget. It includes costs for all items needed to complete the full rearing program.

COST FACTORS AND ASSUMPTIONS

The prices used are for high quality, low maintenance construction. Fifty-year building life is assumed as a basis of this estimate.

OVERTIME

No allowance has been made for overtime work.

WEATHER CONDITIONS

Normal conditions are assumed. No consideration has been given to unusual weather extremes.

LABOR

Prices reflect the work being performed by one licensed and bonded general contractor.

OVERHEAD AND PROFIT

The unit prices used include all labor, material and equipment, and the overhead and profit of the general contractor and sub-contractors.

REMOTENESS

Due to the type of construction and proximity to urban areas, the remoteness factor would be less than one percent and is therefore negligible.

MOBILIZATION

This item consists of furnishing all bonding, licensing, plant, labor, materials and equipment necessary to mobilize the contractor's equipment to the project site and, upon completion of the work, to demobilize the equipment from the site. Based on past experience, seven percent of the construction cost will be used.

CONTINGENCY

A fifteen (15) percent contingency factor is used to account for changes during the remaining engineering phases and changes encountered during construction.

ESCALATION

This cost estimate is based upon Spring 1977 prices. To estimate the cost of construction, the cost estimate has been escalated to the mid-point of construction effort which is estimated to be the Fall of 1978. Escalation is estimated at nine (9) percent per year or a total of fourteen (14) percent.

The following items have not been included in the cost estimate:

- sales tax
- fees for building permits

TABLE 2
VERMONT YANKEE
CAPITAL COST ESTIMATE SUMMARY

A. Sitework	\$ 10,100
B. Paving	8,550
C. Utilities	5,700
D. Site Mechanical	212,100
E. Mechanical Building - Shell	31,500
F. Mechanical Building - Water Heating System	193,700
G. Mechanical Building - Electrical	26,000
H. Rearing Building - Shell	243,000
I. Rearing Building - Mechanical	21,600
J. Rearing Building - Electrical	18,500
K. Rearing building - Tanks	17,500
L. Furnishings and Special Equipment	9,500
M. Vehicles	<u>6,200</u>
Sub-Total	\$ 803,950
Mobilization - 7%	<u>56,280</u>
	\$ 860,230
Contingency - 15%	<u>129,030</u>
	\$ 989,260
Escalation* - 14%	<u>138,500</u>
	\$1,127,760
Fees & Special Services***	<u>112,240</u>
	\$1,240,000

* At 9% to Fall, 1978.

** Estimate for professional design services, contract administration, limited construction observation, limited field work and allowance for operations manual draft.

ITEM	QUALIFICATIONS	QTY.	UNIT	COST \$	COST \$
A. <u>Sitework</u>					
Erosion Control	Hydroseeding	33,000	SF	0.03	1,000
Grading			LS		550
Soil Treatment	Underpaving	0.50	AC	1,300	650
Landscape and Signs			LS		2,000
Fence	6' Chain Link	700	LF	8.40	5,900
					\$ 10,100
B. <u>Paving</u>					
Site Roads, Service & Parking Areas	Asphalt and 9" Base	1222	SY	7.00	\$ 8,550
C. <u>Electrical Utilities</u>					
Transformer			LS		2,000
Secondary Electric Service (underground)			LS		1,000
Site Lighting			LS		2,000
Communication System			LS		300
					\$ 5,700
D. <u>Site Mechanical</u>					
<u>Plant Discharge Water System</u>					
Modify existing disch. structure to house new pumps.			LS		\$ 1,500
Pumps	With 100 hp motor	3	EA	7,500	22,500
Valving	Pump discharge	3	EA	3,000	9,000
Piping to Mech. Bldg. & return to Discharge	With insulation one way, 24"	300	LF	30.00	9,000
Site piping to Rearing Facility	3" without insulation	1800	LF	6.00	10,800
Piping in Rearing Facility			LS		2,200

Vermont Yankee
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Cost Estimates

ITEM	QUALIFICATIONS	QTY.	UNIT	COST \$	COST \$
<u>River Water System</u> (cont'd)					
New Intake Structure with rotating screen			LS		80,000
Pumps	With 25 hp motor	2	EA	4,000	8,000
Pump	With 15 hp motor	1	EA	3,000	3,000
Pump Discharge Valving		3	EA	2,000	6,000
Piping from Intake to Mech. Bldg.			LS		3,000
Piping in Mech. Bldg.			LS		2,500
Site piping, Bldg. 12" with insulation to Rearing Facility		1800	LF	16.00	28,800
Site piping from Intake to Rearing Facility.	3" without insulation	1800	LF	6.00	10,800
Drain site piping			LS		4,400
Discharge Structure			LS		5,000
Drainfield and septic tank			LS		5,000
					<u>5,000</u>
					\$ 212,100
E. <u>Mechanical Building - Shell</u>					
Steel Insulated Building including foundation, insulation, finishes, utilities, etc. (for equipment and mechanical, see "water heating system")		1500	SF	21.00	\$ 31,500
F. <u>Mechanical Building - Water Heating Systems</u>					
<u>Water Heating:</u>					
Boilers	250 hp hot water	2	EA	25,000	\$ 50,000
Fuel System	Storage tanks, piping		LS		9,000

Vermont Yankee
KCM #015-3
Cost Estimates

ITEM		QUALIFICATIONS	QTY.	UNIT	COST \$	COST \$
<u>Water Heating: (cont'd)</u>						
Boiler Water Supply & Return Piping				LS		3,500
Heat Exchangers		St. Stl. Tubes, C.I. Shell	5	EA	22,500	112,500
Temp. Control Valve			5	EA	3,000	15,000
Boiler Water Treatment Equipment				LS		2,500
Boiler Water Pumps		With 10 hp motor	1	EA	1,200	1,200
						<u>\$ 193,700</u>
G.	<u>Mechanical Building - Electrical</u>					
Stand-by Power		100 kw	1	EA	20,000	\$ 20,000
Equipment Wiring				LS		1,000
Service & Distribution System				LS		4,000
Lighting-Interior				LS		500
Misc. Devices				LS		300
Fire Alarm System				LS		<u>200</u>
						\$ 26,000
H.	<u>Rearing Building - Shell</u>					
Including foundations, insulation, finishes, utilities, etc. - not including mech., elec., rearing tanks, furnishings and equipment.			8100	SF	30.00	\$ 243,000
I.	<u>Rearing Building - Mechanical</u>					
Piping in Rearing Facility				LS		\$ 2,500
Piping Each Tank (Rearing)			9	EA	1,000	9,000
Piping Each Test Tanks			8	EA	600	4,800

Vermont Yankee
KCM #015-3
Cost Estimates

ITEM		QUALIFICATIONS	QTY.	UNIT	COST \$	COST \$
I.	<u>Rearing Building - Mechanical (cont'd)</u>					
	Drains			LS		2,300
	Aerators			LS		<u>3,000</u>
						\$ 21,600
J.	<u>Rearing Building - Electrical</u>					
	Main Service			LS		\$ 2,000
	Lighting Fixtures			LS		3,000
	Misc. Devices	Receptacles, etc.		LS		1,500
	Heaters			LS		1,000
	Conduit & Wire			LS		3,500
	Monitor & Alarm			LS		5,000
	Fire Alarm System			LS		1,500
	Grounding System			LS		<u>1,000</u>
						\$ 18,500
K.	<u>Rearing Building - Tanks</u>					
	19' diameter	Concrete	9	EA	1,500	\$ 13,500
	4' diameter	Fiberglass	8	EA	500	<u>4,000</u>
						\$ 17,500
L.	<u>Furnishings and Special Equipment</u>					
	desks, chairs, lab equipment, shop equipment	hand tools				
	nets and screens					
	scales					
	miscellaneous	dock, blinds, files, etc.)				
M.	<u>Vehicles</u>					
	One Pick-Up	Four-wheel Drive	1	EA	6,200	\$ 6,20

B. Operation and Maintenance Costs

The cost of operating and maintaining this facility is estimated to serve as a basis for planning and decision-making. Following is a summary of estimated annual operation and maintenance expenses. These costs are based on an eight month per year facility operation (September through April).

Water pumping costs based on 0.015 per kwh	\$18,500
Boiler heating costs based on \$0.50 per gal.	
Stand-by	11,000
20-day scram	37,500
Building Utilities	1,000
Supplies (including feed)	7,000
Insurances (auto, fire, etc.)	1,000
Maintenance (vehicular, building)	1,000
Labor	
1 Manager @ \$12,500/year	8,500
2 Assistants @ 10,500/year	<u>7,000</u>
TOTAL:	\$92,500

SELECTED REFERENCES

- 1) Aquatec, 1976. Ecological studies of the Connecticut River, Vernon, Vermont. Report V, January - December 1975. Aquatec, Inc., Burlington, Vermont. 88 pp.
- 2) Carter, Wilfred M., 1971. Atlantic salmon culture. Unpublished, 11 pp.
- 3) Haskell, D.L. 1955. Weight of fish per cubic foot of water in hatchery troughs and ponds. Prog. Fish. Cult. 17(3):117.
- 4) Knutsson, S. and T. Grav, 1976. Seawater adaptation in Atlantic salmon (Salmo salar L.) at different experimental temperatures and photoperiods. Aquaculture (8) 169-187.
- 5) Muench, K.A., 1976. The role of the electric utilities industry in developing the use of thermal effluent in aquaculture. Proceedings of the World Mariculture Society, Seventh Annual Meeting, Avault, Ed. pp. 535-541.
- 6) Refstie, T. and A. Kittelsen, 1976. Effect of density on growth and survival of artificially reared Atlantic salmon. Aquaculture (8) 319-326.
- 7) Ryther, J.H., 1977. Personal Communication.
- 8) Saunders, R. L., 1970. Influence of photoperiod on smolt development and growth of Atlantic salmon (Salmo salar). J. Fish. Res. Bd. Canada (27) 1295-1311.
- 9) Saunders, R.L. and E.B. Henderson, 1969. Growth of Atlantic salmon smolts in relation to salinity, temperature and diet. Fish. Res. Bd. Can. Tech. Rep. (149)1-20.
- 10) Sylvester, J.R., 1975. Biological considerations on the use of thermal effluents for finfish aquaculture. Aquaculture (6)1-10.

Figure 1

Figure 2

Figure 3

Figure 4