POLLUTION
PREVENTION

REDUCTION IN WASTE LOAD FROM A SEAFOOD PROCESSING PLANT

POLLUTION PREVENTION PROGRAM
NORTH CAROLINA DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES

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REDUCTION IN WASTE LOAD FROM
A SEAFOOD PROCESSING PLANT

Submitted by

Beaufort Fisheries Incorporated

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October 31, 1986

EXECUTIVE SUMMARY

Beaufort Fisheries Incorporated, a manufacturer of traditional menhaden fish products (meal, oil, solubles), is currently diversifying its product line into other seafood areas. The acquisition and installation of a spiral freezer with a capacity of processing in excess of 6000 lbs/hr and a freezer with storage of more than 1,000,000 lbs of finished product are major steps in this endeavor. This project is a feasibility study for reduction of waste load and water use in current processing operations: it also explores future business uses for the new processing/freezer facility.

The plant was initially surveyed to identify sources of solids loss as well as water use patterns. Methods were suggested to reduce or recover and reuse process water and solids from the plant. A conceptual design was proposed for the recovery system and integrated into the existing meal and oil operations. Costs and payback for the pollution prevention system were evaluated.

Waste streams from a whole frozen fish factory are primarily associated with washing of whole fish prior to sorting and inspection operations. Considerable waste loads can result from improper handling of fish aboard ship, in offloading fish to the dock, and from poor handling procedures in the processing plant. Current industrial handling methods were being replaced with a containerized (iced) handling procedure upon the research team’s recommendation.

Offloading practices were redesigned to reduce and recycle wash water from fish rinsing operations. This would significantly lower solids losses due to improper handling of whole fish and reduce water use under current processing design. By integrating the spent rinse water stream and recovered solids with existing meal and oil operations, significant savings could be realized in terms of both solid and liquid waste streams.

The adoption of four of the five process changes could result in preventing as much as 250,000 lb BOD5/yr, the need for 15 million gallons of potable water annually and result in a net savings of $900,000/yr. Both initial arid annual costs would be about $300,000.

The operation of a modern fish processing/freezer facility adjacent to an existing fish rendering operation can provide tremendous benefits in terms of waste handling systems. However, traditional industrial practices for handling fish cannot be expected to provide for good product quality or efficient plant operations in bait fish production or food grade types of production.

Beaufort Fisheries Incorporated realizes its potential for diversifying current processing operations to supply such items as bait fish and food-grade commodities. They are currently implementing the primary suggestions made within this study to upgrade handling;, processing and waste disposal practices.

ACKNOWLEDGMENTS

The authors wish to express appreciation to the many individuals who provided consultation, information and guidance throughout this study. Special gratitude is expressed to Mr. Jule Wheatly, President of Beaufort Fisheries Incorporated for his interest, concern and encouragement in this project.

The authors are deeply indebted to the North Carolina Agricultural Extension Service, UNC Sea Grant College Program and the Department of Food Science at N.C. State University for their support toward these activities and for allowing the subcontract to help implement this project. Special thanks is expressed to Mr. David Green who facilitated this work through the NCSU Seafood Laboratory Morehead City, NC.

The foresight of Mr. Roger Schecter and Mr. Gary Hunt of the N.C. "Pollution Prevention Pays" program allows for such projects to be instituted. Their help, concern and patience throughout this study is especially appreciated. They should be commended for their unique approach to helping industry find ways to prevent pollution. Funds for this project were provided through Agreement C-1538 of the Pollution Prevention Pays Program of the North Carolina Department of Natural Resources and Community Development.

The authors extend their appreciation to Ms. Lisa Nance for her invaluable assistance in typing this report. The editorial assistance of Ms. Susan Borowski is gratefully acknowledged.

LIST OF TABLES

LIST OF FIGURES

SCOPE OF WORK

Beaufort Fisheries Incorporated, under the direction of Mr. Sam Thomas, submitted the project entitled "Reduction in the Waste Load from a Seafood Processing Plant" to the North Carolina Pollution Prevention Pays" program on December 15, 1986. An agreement (No. (C-1538) was completed and signed on April 25, 1986 to authorize the project. A Memorandum of Agreement was entered into by Beaufort Fisheries and NC State University, who would assist in the project. Drs. Carawan and Thomas of the Food Science Department and Mr. Green of the NCSU Seafood Laboratory and the North Carolina Agricultural Extension Service cooperated in the study.

The project included a feasibility study for reduction of waste load by the recovery/reuse of process waste water. Following is the Scope of Work:

1. Perform a plant survey to identify sources, quantity and composition of wastewater generated.

2. Identify methods which can be used to reduce or recover/reuse the wastewater and solids.

3. Develop a conceptual design for a waste reduction system.

4. Evaluate the costs and pay-back period for the identified pollution reduction system with recommendation for implementation.

5. Present findings of this study in a final report to include technical and economic evaluations of the waste reduction options:

    - Introduction to the problem

    - Technical evaluation of technology(ies)

    - Economic assessment of costs, pay-back period and annual cost

    - Summary

Because of the new industry thrust by Beaufort Fisheries to develop products for human consumption from menhaden, the project team focused its efforts on this developing technology.

INTRODUCTION

Economic pressures on traditional menhaden rendering plants have left the industry scrambling for alternatives to reduce operating expenses and upgrade their products in market value. Management realizes that current industrial practices need to be reevaluated in order to successfully diversify an industry mired in competition with low-priced agricultural products.

Beaufort Fisheries, Incorporated has taken the first step towards diversification by investing in a spiral freezer and freezer holding facilities. They also realize that improved operation and management practices will effectively reduce product losses, conserve water use and efficiently control waste loads. Such efforts will help to insure future diversification possibilities presently being researched at both university and government levels.

Wastewaters from fish processing plants are usually high in proteinaceous compounds and oils. These waste streams can have extremely high biochemical oxygen demand (BOD) and represent sizable discharge to the surrounding receiving waters. The primary waste load in operating a frozen fish factory is directly related to handling considerations aboard ship and to process practices once fish are brought to shore.

This project emphasizes the handling and processing of fish for purposes other than industrial application. The approach taken is to manage problems connected with all operations from transport and processing through storage.

Two proven ways for reducing water use, product losses, large waste loads and wastewater discharge are improving plant efficiency and instituting process changes. The seafood industry has traditionally been slow to change due to economic restraints and seasonality of its catch. By responsibly making improvements in current processing practice, Beaufort Fisheries hopes to not only diversify its current production but also to maintain a favorable community status.

THE MENHADEN FISHERY

Early Development

Menhaden have figured into the history of this country from its beginning. Legend has it that the Indian Squanto saved the Pilgrims from starvation that first winter by showing them how to plant menhaden along with their crops to fertilize the soil. Since that time, the menhaden has never been without a mission.

During the early 1800s, fishermen discovered the value of menhaden oil as a substitute for the more costly whale oil in lamps, paints and tanning solutions. After the Civil War, a greater demand for menhaden oil spurred the fishery to expand.

The introduction of the purse seine allowed fishermen to net large quantities of fish. A purse seine is a large "curtain-type" net, hung between surface floats and weights along its base. Two boats, called purse boats, drop the net in a circle. When a school of fish is enclosed, a heavy weight is attached to the purse line and dropped overboard. The purse line is then pulled in, causing the bottom of the seine to close like a purse.

The Fishery Today

In 1985, menhaden landings totaled over 1.2 million metric tons or 2.7 billion pounds and constituted over 44 percent of all finfish landed by U.S. commercial fishermen. These abundant fish inhabit virtually every bay and cove from the rocky coast of Maine down the Atlantic seaboard to Palm Beach, FL, and in the Gulf of Mexico from Cape Sable, FL, to the Yucatan Peninsula.

Although four species of the genus Brevoortia occur along the Atlantic coast of North America, the resource and fishery are dependent upon two species of menhaden. The Atlantic menhaden supports the older Atlantic Coast fishery and the younger, but currently larger, fishery in the Gulf of Mexico is supported by the Gulf menhaden. These fish are known by no less than 30 common names, including bunker, pogy, moss bunder and shad.

Research programs provide information on safe harvest levels and on the effects of man on the abundance of the resource. Results of these studies show that menhaden distribute themselves by size and age along the coast as the seasons change. Thus the resource provides unusual opportunities for fishermen to select menhaden of specific size ranges, oil content and other properties which are most desirable for their intended use.

The list of products made from menhaden is large and varied--from fertilizer to lamp oil, rust-resistant paints to animal feeds, and from cosmetics to medicines. But new ideas and products have developed over the years since man first caught menhaden and began searching for ways the protein-rich menhaden could directly benefit the diet of the nation and the world.

The menhaden resource base potentially available to North Carolina processors like Beaufort Fisheries has remained strong over the years. In 1981, commercial landings of menhaden in North Carolina exceeded 300 million pounds

(Table 1) which accounted for nearly 80 percent of total finfish landings (Table 2). In 1985, menhaden landings in North Carolina dropped to 100 million pounds with an ex-vessel value of only 2.33 million dollars. This decline in catch is attributed to reduced fishing effort on the part of processors due to low meal and oil prices. Menhaden landings can be expected to vary both in availability of the resource and the price that can be received for its products.

The menhaden catch varies with the effort expanded by fishermen to catch fish. This effort closely follows both the availability of fish and the price for industrial products such as meal and oil.

New Products from Menhaden

Depressed meal prices and the search for new and innovative sources of food-grade proteins have lead researchers and entrepreneurs to consider traditionally industrial species of fish for direct process into food-grade products. Interest in high tech processing to produce surimi manufacture is leading the way for research into food applications for menhaden. Traditional food processing techniques also may provide additional product forms such as fillets, roe, and mince which can support product development in areas like sausages and purees. The menhaden industry has made the initial step in providing food grade products through its efforts to supply bait fish to the crab and crayfish industries.

Table 1. Industrial Finfish Landings and Ex-Vessel Value for North Carolina

Year	Million Pounds	$ Million
1976	134.9	4.53
1977	158.1	4.37
1978	192.3	7.50
1979	254.3	8.06
1980	196.9	7.14
1981	309.4	10.04
1982	187.0	5.77
1983	178.0	6.17
1984	157.7	4.75
1985	97.7	2.33

Table 2. Current Catch and Value.

Year	Industrial Finfish	Total Finfish Landings	Percent of Total	Market Value Percent
1981	309.4	388.5	79.6	27.7
1985	97.7	170.4	57.3	8.0

SEAFOOD WASTEWATER CHARACTERISTICS

Introduction

Authors of EPA documents (1970, 1973a. 1973b and 1975) have presented wastewater flow diagrams for representative seafood processing operations. Liquid and solid waste point sources are identified. A summary of the raw wastewater characteristics for the canned and preserved seafood processing industry is presented in Table 3.

Major types of wastes found in seafood processing wastewaters are blood, offal products, viscera, fins, fish heads, shells, skins and meat "fines." These wastes contribute significantly to the suspended solids concentration of the waste stream. However, much of the solids can be removed from the wastewater and collected for animal food.

Seafood Processing

Several seafood processing operations were selected as being representative of North Carolina fisheries and most applicable to this study.

<u>Water Use.</u> Tuna processing plants were reported to have wastewater discharge as high as 3,600,000 GPD (Table 3). Bottom fish wastewater discharge ranged from 6,000 – 400,000 GPD. Fish meal plants ranged from 10.000 – 92,000 GPD in the survey.

<u>Wastewater Characteristics.</u> Carawan et al (1979) reported on an EPA survey with BOD, COD, TSS and oil and grease (FOG) parameters. Bottom fish were found to have a BOD5 of 200 – 1000 mg/l. COD of 400 – 2000 mg/l, TSS of 100 – 800 mg/l and FOG of 40 – 300 mg/l (Table 3). Fish meal plants were reported to have a BOD5 of 100 – 24,000 mg/l, COD of 150 – 42,000 mg/l, TSS of 70 – 20,000 mg/l, and FOG of 20 – 5,000 mg/l. The higher numbers were representative of bailwater only. Tuna plants were reported to have a BOD5 of 700 mg/l, COD of 1600 mg/l, TSS of 500 mg/l and FOG of 250 mg/l. Seafood processing wastewater was noted to sometimes contain high concentrations of chlorides from processing water and brine solutions, and organic nitrogen (0 – 300 mg/1) from processing water.

Fish Processing

<u>Tuna.</u> In an EPA report (1973), the authors noted that the annual tuna catch averages about 400 million pounds, almost all of which is canned. They concluded that as much as 65 percent of the tuna is wasted in the canning process. The degree of wastage depends somewhat on the species being processed so variations will occur. They reported on a study that examined the waste from a tuna canning and by-product rendering plant in detail for a five-day period. The following observations were made:

- The average waste flow was 6,800 gal/t of fish.
- Wastewater varied from 500 – 1,550 mg/l BOD5.
- The average daily COD ranged from 1,300 – 3.250 mg/l.
- The total solids averaged 17,900 mg/l of which 40 percent was organic

Table 3. Raw Wastewater Characteristics - Canned and Preserved Seafood Processing Industries

Subcategory	Flow	BOD	COD	TSS	FOG
	(GPD)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Farm-Raised Catfish	21M-45M	340	700	400	200
Conventional Blue Crab	700	4400	6300	620	220
Mechanized Blue Crab	20M-73M	600	1000	330	150
West Coast Shrimp	90M-160M	2000	3300	900	700
Southern Non-Breaded Shrimp	180M-240M	1000	2300	800	250
Breaded Shrimp	150M-200M	720	1200	800	---
Tuna Processing	65M-3.6MM	700	1600	500	250
Fish Meal	92M-10M[a]	100-24M[a]	150-42M[a]	70-20M[a]	20-5M[a]
All Salmon	58M-500M	253-2600	300-5500	120-1400	20-550
Bottom & Finfish (all)	6M-400M	200-1000	400-2000	100-800	40-300
All Herring	29M	1200-6000	3000-10,000	600-5000	600-800
Hand Shucked Clams	86M-170M	800-2500	1000-4000	600-6000	16-50
Mechanical Clams	300M-3MM	500-1200	700-1500	200-400	20-25
All Oysters	14M-320M	250-800	500-2000	200-2000	10-30
All Scallops	1M-115M	200-10,000	300-11,000	27-4000	15-25

- Higher range is for bailwater only
- 1,000
M - 1,000,000

Finfish Handling

Carawan and Thomas (1981) surveyed the North Carolina seafood industry. They examined finfish handling practices in North Carolina as related to wastewater. Finfish primarily include flounder, croaker, trout, spot and bluefish. Unloading, washing and separating ice, sorting, grading and re-icing before shipping all constitute finfish handling. Most of the wastes were generated from the debris and ice removal in the washing tank.

Results of the survey (Table 4) found that total solids averaged 2.4, ash 1.11, organic solids 1.30 and BOD5 0.23 lb/1000 lb while water use was 110 ga1/1000 lb of fish handled. Table 5 illustrates the species difference found during handling of fish.

Scales may drop off during unloading, contributing large amounts of settleable solids to the waste load. Slime, blood and sand were also found to be part of the wastewater. Fish were strenuously washed, and removed materials were measured to gain an idea of maximum waste load.

Average BOD5 of rinse tank wastewaters was 251 mg/l. Scales seemed to constitute the bulk of the solids in the effluent from the wash tanks surveyed. The scales and other solids were removed during screening with a 20 mesh screen Results of screening tests are tabulated in Table 6. Some 74-90 percent of the settleable solids were removed with the screen.

Finfish Processing

North Carolina finfish processors use hand labor in processing flounder, trout and croaker. Carawan and Thomas (1981) examined three finfish processing plants. These three plants were processing 715 -1000 lb/hr of flounder, trout and croakers in the round or fillet. Raw effluent from these plants had the average characteristics as listed in Table 7. The average water use was 1.34 gal/lb and the wastewater BOD5 was 190 mg/l.

Plant review confirmed that controlling waste solids greatly influenced the wastewater characteristics. Of 29 plants surveyed by Carawan and Thomas, 9 sent their solids for dehydration, 12 used their solids for bait and 8 plants disposed of all the material overboard.

One processor cooperated in an experiment where raw fish frame composting was tried as a disposal method. Grass cuttings, pine straw, horse manure and soil were mixed and composted for six weeks. Raw fish frames were added and completely decomposed within 4 weeks.

Japanese Food Fish Factories

The Japanese have an extensive background in processing fish into various food products. Japanese fish factories have wastewater with characteristics as reported in Table 8. The units and characteristics do not necessarily coincide with the units reported in other publications. The authors calculated water use at 1800 gal/1000 lb) to 6,000 ga1/1000 lb for the various types of plants. If the highest waste load and lowest volume are used for calculations of wastewater strength, the BOD5 could exceed 7,000 mg/l for surimi processing. However,

Table 4. Water Use and Wastewater in Finfish Handling

Parameter	Waste Load	
	(lb/1000 lb)	
	Average	Range
Total Solids	2.40	.87-4.60
Ash	1.11	.53-2.15
Organic Solids	1.30	.34-2.44
BOD_5	.23	.01-1.00
	(gal/1000 lb)	
Wastewater	110	60-180

Table 5. Waste from Fish Handling

	Trout	Croaker	Flounder
		(lbs/1000 lbs)	
Total Solids	6.56	4.08	3.20
Organic Solids	4.06	1.98	1.36
Ash	2.50	2.10	1.34

Table 6. Effect of Screening on Fish Handling Wastewater

	Settleable solids			
	Plant 1	Plant 2	Plant 3	Average
	(ml/l)			
Effluent				
Raw	3.8	20.0	100	41
Screened	1.0	2.0	14	5.7
Removal (%)	74	90	86	86

Table 7. Water and Wastewater for North Carolina Finfish Processors

	Rinse Tank	Mechanical Scaling	Fillet & Rinse	Cleanup	Total
- - - - - - - - - - - - - - - - -			(lb/1000 lb raw fish)	- - - - - - - - - - - - -	
TS	2.08	4.74	3.44	0.27	10.53
Ash	0.37	2.03	1.37	0.12	3.89
OS	1.71	2.60	2.08	0.15	6.54
TSS	0.38	2.59	0.86	0.09	1.96
DS	0.71	1.85	2.96	0.13	5.65
BOD	0.59	0.56	0.86	0.10	2.11
FOG	0.10	0.30	0.71	0.03	1.14
- - - - - - - - - - - - - - - - - -			(gal/1000 lb)	- - - - - - - - - - - - - - -	
Flow	544	318	457	16	1335

Table 8. Wastewater and Waste from Japanese Fish Factories

Factory	Wastewater	Waste
	(m^3/ton)	BOD kg[a]
Canned Tuna	15-20	10-15
Frozen Fish	42	10
Kamaboko	10-50	0.5-4
Surimi	5-40	10-35

[a] Where BOD kg = BOD (mg/l) x $\frac{\text{water volume } (m^3)}{1,000}$

average values calculated by these authors indicated BOD's of 750 mg/l for tuna, 240 mg/l for frozen fish, 205 mg/l for kamaboko and 3,625 mg/l for surimi.

The wastewater parameters reported in Table 9 are also for Japanese fish products factories. Surimi plants would have a BOD5 of 8,204 mg/l. Kamaboko plants would have a BOD5 of 6,776 mg/l while fish meal plants would have a BOD5 of 18,400 mg/l.

Another Japanese scientist reported that water use in surimi processing was twenty-five times the throughput. Thus, water use is 3,000 gal/1000 lb fish or 27,300 gal/1000 lb surimi. This can be contrasted with the volume reported in Table 8 of 4,800 gal/1000 lb fish.

The Industrial Fisheries

In a properly managed menhaden rendering plant, wastewater quantities are small. The only inherently troublesome wastewater source is the fish pumping water. The other wastes result from spills and leakages, both of which can be minimized.

The menhaden is a small, oily fish of the herring family. This fishery, largest in the United States, is located mainly in the Middle Atlantic and Gulf states including North Carolina. Menhaden have been used primarily for the manufacture of fish meal, fish solubles and oil. The manufacturing process is (in most cases) highly mechanized.

The fish are caught in purse seines and pumped into the fish holds for transport to the plants. Then the fish are pumped from the holds, washed, automatically weighed and conveyed into the plant. Continuous steam cooking is normally employed. The cooked fish are then pressed to remove the oil and most of the water. This press water is screened to remove solids and centrifuged to separate the oil. The remaining water, called stickwater, is discharged or evaporated to produce condensed fish solubles. The solid residual from which the water and oil have been pressed is known as "pressed cake." The pressed cake is dried to about 10 percent moisture and then ground €or fish meal.

The wastewaters from the production of fish meal, solubles, and oil from herring, menhaden and alewives can be divided into two categories: high volume. low-strength wastes and low-volume, high-strength wastes. The high-volume, low-strength wastes consist of the water used for unloading, fluming, transporting, and handling the fish plus the washdown water. The fluming flow has been estimated to be 200 gal/t of fish with suspended solids of 5,000 mg/l. The solids consist of blood, flesh, oil and fat. The above figures vary widely Other estimates listed herring pump water flows of 250 gpm with total solids concentrations of 30,000 mg/l and oil concentrations of 4,000 mg/l. The boat's bilge water has been estimated to be 400 gal/t of fish with a suspended solids level of 10,000 mg/l.

The stickwaters comprise the strongest wastewater flows. The average BOD5 value for stickwater ranges from 56,000-112,000 mg/l, with average solids concentrations, mainly proteinaceous, ranging up to 6 percent. The fish processing industry has found the recovery of fish solubles from stickwater to be at least marginally profitable. In most instances, stickwater is now evaporated

Table 9. Wastewater Parameters in Japanese Fish Product Factories

Parameter	Surimi	Fish Meal	Kamaboko
	Wastewater Concentration		
	(mg/l)		
BOD_5	8,204	18,400	6,776
COD	1,210	5,032	606
SS	757	1,683	578
Fat	541	1,743	149
NH_3-N	15	86	5
TkN	305	912	199

to produce condensed fish solubles. Volumes have been estimated to be about 120 gal/t of fish processed.

Dried scrap and meal are the most highly valued products from menhaden, although oil production was the initial reason for processing. Most of the scrap and meal is used as an animal feed supplement.

Menhaden Wastewater Characteristics. A simplified flow sheet for a traditional menhaden processing operation is given in Figure 1. The industrial wastes generated are summarized by sampling stations in Table 10. Though waste from the frozen fish factory is quite different from the rendering plant, the location of both facilities in the same facility makes for easier handling of both solid and liquid waste streams. Spent wash water streams can be incorporated into bail water requirements once solids have been screened out.

Bloodwater waste characteristics were reviewed by Parin et. a1 (1982). The results of their investigation are presented in Table 11.

Summary

Wastewater from fish processing and industrial fisheries is very diverse and varies with management and process practices. Each plant is unique so generalizations about water use and wastewater characteristics are difficult. However, average numbers for water use and waste load appear to have value for each industrial category.

Figure 1. Simplified Flow Diagram for Typical Menhaden Processing Operation

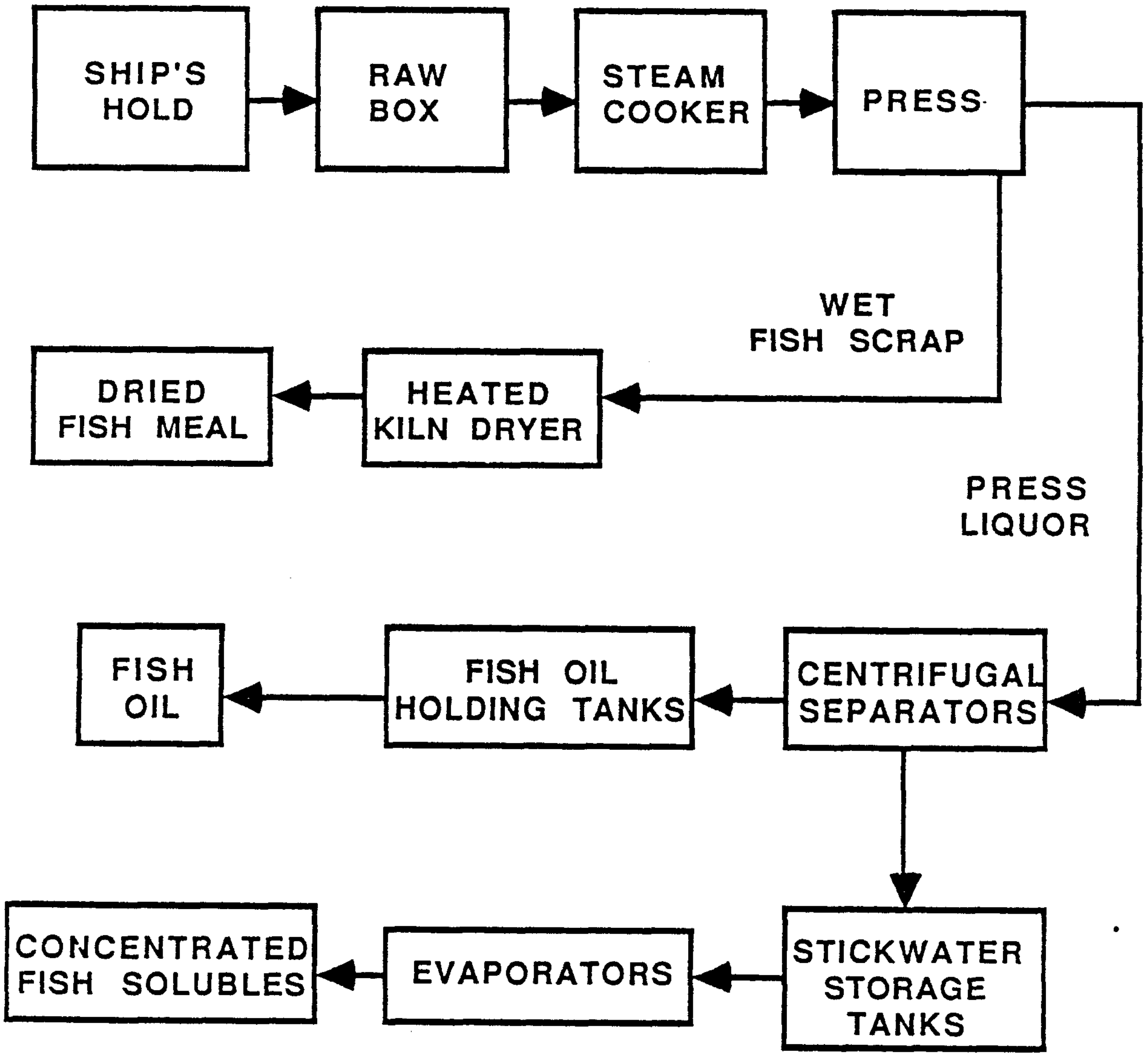


Table 10. Average Wastewater Analyses from Various Sources at Menhaden Plants

Sampling Stations	BOD	TSS	FOG
	(mg/l)	(mg/l)	(mg/l)
Boat Storage Compartment Wastes	154	1,800	------
Make up Tank Waste	23,400	35,400	6300
Rawbox Leakage Wastes	31,500	53,700	10,700
Kiln Spray Drier	207	16,100	45
Stickwater from Centrifugal Separators	74,500	59,300	15,300
Stickwater Storage Tank Wastes	47,000	53,000	18,200
Evaporator (cooling water wastes)	2,260	14,600	130

Source: Praessler and Davis (1956)

Table 11. Basic Characteristics of Fish Bloodwater from Fish Meal Factories

Characteristic	Fourie (1959)	Tornes et al (1965)	Parin et al (1979)	Parin et al (1982)
Total Solids (%)	8.00	8.70	4.64	7.25
Total Nitrogen (kjeldahl) (%)	----	----	2.21	4.41
Total Lipids (%)	----	0.61	0.77	1.17
pH	----	6.3	6.90	6.90
COD (mg/l)	----	----	----	93,000
Chloride (%)	2.00	1.95	0.18	----
MPN (%)	----	----	----	0.75

PROCESSING MENHADEN FOR USES OTHER THAN MEAL AND OIL

Introduction

Menhaden have been used for food, animal feed and fertilizer for centuries. However, the last century has seen a consumer reluctance to eat menhaden - a "poor man's" fish. Salted menhaden and menhaden roe have been enjoyed by coastal families throughout the years. The abundance and low cost of menhaden offer exciting opportunities to develop new uses and markets for what has been largely an industrial fish - processed into oil and fish meal to feed animals. Potential uses for menhaden include bait, fish oil, fish products and surimi.

Bait Fishery

A sideline to finfish processing has always been supplying scrap fish as bait to crab and lobster fishermen. Steady increases in the numbers of crab pot fishermen have made this sideline into a fairly profitable business. Small-scale menhaden purse seining operations developed during the mid-1920's along the Chesapeake Bay. Today, the activity has grown into a full-fledged fishery as demand for fresh fish as bait continues to be strong in the seafood industry.

Fish Oil

Fatty Acids

During the 18th and 19th centuries, menhaden were salted and eaten very much like herring is consumed today. In John Lawson's History of North Carolina, written in 1714, he called menhaden an "excellent sweet food." Today, developmental research into food grade processing of menhaden is hoping to prove medical benefits of consuming the highly unsaturated fatty acids present in fish flesh. Menhaden is known to be a very good source of these omega-3-fatty acids. An example of current. efforts includes the following from research (Miller, 1987) supported by the Gulf and South Atlantic Fisheries Development. Foundation, Incorporated:

> "To demonstrate systems needed to preserve and use fresh-caught menhaden through a number of unit operations needed to produce a palatable fish oil, a canned menhaden product with relatively high fat content (fish lipid), and a tasty pickled menhaden product with relatively high natural fat content, the three products to he used for determining nutritional profiles, taste panel evaluations and other information needed to prove a basis for marketing.
>
> An issue raised by reviewers of the proposal had to do with the opinion that relatively poor domestic market outlook exists for canned and pickled fish products. Our reply to this objection was that our preservation experiments, in employing a systems approach, must necessarily include protective measures through all of the handling and processing steps, from sea to final product. Such demonstrations require the formulation and evaluation of final products, as explained in the proposal, the most. important of which is a palatable, unrefined fish lipid suitable for addiction to other food products. The need for this product and its relevance to the April 30, 1984 report to G&SAFDFI (Fatty Fish and Human Nutrition -

Resource Notebook), and worldwide interest in the long chain omega-3 fatty acids. appears to justify including this or a similar approach in the work plan."

Menhaden for Direct Human Consumption - Including Surimi

The present uses for menhaden are comparable (Lanier, 1985) to the utilization of domestic soybeans at the turn of the century; the oil is not approved for food use domestically, and the protein is used almost entirely for animal feeds. Just as the people of the Far East first utilized the soybean, the Japanuse have manufactured many food products from fish protein.

The Japanese manufacture this fish protein into a food ingredient --a product they have termed "surimi." Development of a high quality surimi from menhaden, coupled with current efforts to gain approval from the U.S. Food and Drug Administration for domestic food use of menhaden oil, would reach another milestone in the long and fruitful history of these abundant fish.

The word surimi translates from Japanese as "minced fish." The Japanese found that mechanically deboned, or minced, fish can be transformed by a simple water-leaching process to yield the light, bland and functional protein material known as surimi.

For centuries, water-washing of minced fish had been but one step in the process of converting fresh, whole fish into the highly prized kamaboko fish cakes, popular during Japanese celebrations. Later, as the popularity of these products grew and the local supply of fresh fish diminished, Japanese technologists were forced to develop a stable intermediate product in order to tap distant sources of fish such as the Alaska pollock.

This intermediate product was termed "surimi." It was the same mechanically deboned, washed and pressed material made on the premises by kamaboko manufacturers. But now. it was stabilized with the addition of sugars and sugar alcohols so it could endure the long months of frozen storage needed to ship it back to Japan. By 1980, Japanese and other foreign fishing fleets dominated the American pollock fishery.

As the market for kamaboko leveled out in the late seventies, several new surimi-based shellfish analog products such as "kanibo," translated as "kamaboko crab." were developed. This effort was in response to a dramatic decline in the American king crab fishery. Sharp cost increases of natural crab persuaded American seafood wholesalers to explore kanibo as a perfect substitute for the scarce natural crab.

Imports of the surimi product began in earnest. In 1982 and 1983, the United States imported more surimi-based simulated crabmeat from Japan than it actually produced real king crab meat. The domestic market for such simulated products skyrocketed to an estimated 70 million pounds in 1984. Japanese entrepreneurs have exploited the American market.

Besides being an essential ingredient in the manufacture of these popular seafood analogs, surimi may prove to be as widely used in other food products as vegetable proteins. Its superior heat-gelling properties make it a potentially useful "glue" in many types of engineered foods and a prime candidate for use in popular processed meat items such as hot dogs and bologna. Its flavor can he blander than soy protein and, like other meats, it is more nutritious than vegetable proteins.

Should surimi be manufactured from menhaden? Menhaden is low in cost (about 2 cents per pound) and very abundant. Menhaden contain very functional proteins which American researchers have discovered can be refined into a surimi of . comparable quality to surimi prepared from Alaska pollock. Conversion of menhaden into quality surimi could be the initiation of a new era in this largest of American fisheries. The increasing market for domestic surimi-based products could transform a sluggish fishery into an expanding giant.

BEAUFORT FISHERIES - NOW AND THE FUTURE

Introduction

Beaufort Fisheries has been a fish oil and fish meal plant. for approximately 50 years. Low fish meal prices over the last several years have forced management to reconsider the future of Beaufort Fisheries.

This project studied the possibilities of utilizing the current facilities for new products and processes. In 1986, a new belt freezer and freezer storage facility were instituted. Currently, these facilities have only been used for bait fish operations. Planned expansion into other lines has been slowed by the low prices currently paid for fish meal and oil which have depleted cash reserves.

The plant is located on the waterfront in Beaufort, N.C. - a historical town prized for its beauty and recreation. Beaufort has been a fishing community for centuries. The management at Beaufort Fisheries is dedicated to maintaining the livelihood of the fisherman and protecting the delicate ecological balance that provides the food web which supplies the plant. Because of the location of the plant on the waterfront, with limited land for many wastewater treatment options, water use and wastewater control become limiting factors in expansion or new ventures.

Survey for Product Losses and Wastes

The research team surveyed Beaufort Fisheries utilizing the following format:

1. Drawings of product lines and equipment for menhaden processing into food were conceptualized and studied.

2. Literature was surveyed for known water use reduction measures, and product and byproduct recovery methods.

3. Researchers, processors and equipment manufacturers were contacted for ideas and suggestions.

4. The team visited the plant to review their independent. and joint, findings.

3. The research team prepared a list and mutually reviewed the sources of waste and product losses. Safety and feasibility of recovery were discussed. Notes were made on how management might prevent the loss and/or waste and blend food processing operations into an industrial waste facility.

Alternative Operations

The research team concluded that several alternative uses €or menhaden were worthy of consideration. The operations examined include:

1. Phase I - Frozen Fish -- Bait Fish Operation
2. Phase II - Frozen Fish - Direct Food Uses
3. Phase III - Surimi Processing

Figure 2 gives a layout of areas examined in Beaufort Fisheries as it existed during this study. The spiral freezer and holding freezer are the two new additions added prior to this study. They are adjacent to the fish meal and oil process room. The fish conveyor system was also examined.

Phase I - Frozen Fish - Bait Fish Operations

Phase I of utilizing menhaden for other than meal production was initiated early in 1986. Menhaden were to be transported quickly to the plant, flash-frozen and stored in the freezer until shipped to fishermen or distributors.

The spiral freezer and holding freezer were built adjacent to the fish meal operations as shown in Figure 2. The sequence of processes for the bait fish operation is shown in Figure 3. Since menhaden arrive by boat, the operation was located near the dock, and a vacuum pump system (Figure 4) and a fish conveyor system were added to transfer raw fish from the vacuum pump system to the process room. Road access with loading dock facilities for truck transport of frozen bait fish was essential.

In the bait fish operation, menhaden arrive in the conventional manner as for meal and oil processing. They are transported from the ship's hold using a vacuum pump system (Figure 3). They are discharged into the wash tank and then onto the belt conveyor. The fish are conveyed to the process room where they are sorted and inspected on a belt conveyor. Then the fish are discharged onto the spiral freezer belt where they are exposed to high velocity air at -40°F. They exit the spiral freezer and are placed in waxed fish boxes holding approximately 60 lb. The boxes are palletized and the pallets are transported into the holding freezer by fork lift trucks. As product is sold, pallets are brought from the freezer and transported by truck.

Water use and waste generation are minimal when proper practices are observed. Accurate data measurements were hampered during the course of this study because of the abnormal weather experienced during the summer of 1986, i.e., it was so hot that the menhaden would spoil before they could be processed.

Phase I of the operation was originally planned to utilize conventional blast freezer capabilities to individually quick freeze (IQF) whole menhaden for bait purposes. Difficulties arose in this endeavor due to:

1. Failure to convince crabbers to use IQF menhaden, i.e. directly frozen fish (IQF) can be put in pots instead of thawing a 60 lb box overnight for use the next morning.

2. Price of bait dropped to low level so that running the IQF tunnel was not economically profitable.

3. Quality of whole fish supplied during summer months was extremely poor due to manner of handling on-hoard and high temperature during July and August.

Because of the above problems, Beaufort Fisheries is currently using the 0°F holding freezer for storage purposes of menhaden and other food grade fish caught in the local area. There is no processing at the present time.

Figure 2. Line Diagram of Freezer Facility Adjacent to Meal Plant at Beaufor Fisheries, Inc.

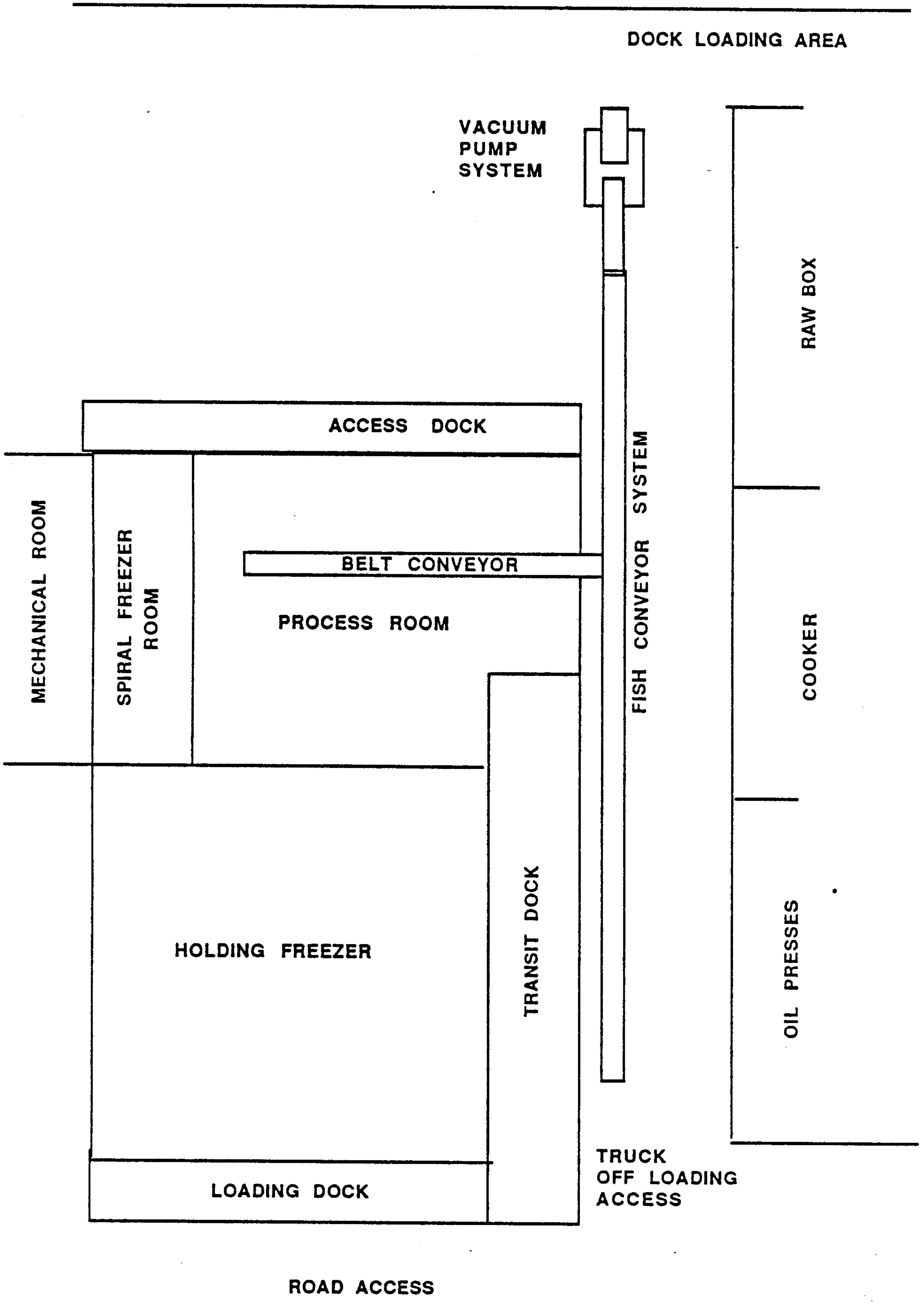


Figure 3. Schematic Diagram of Current Bait Fish Processing Operations

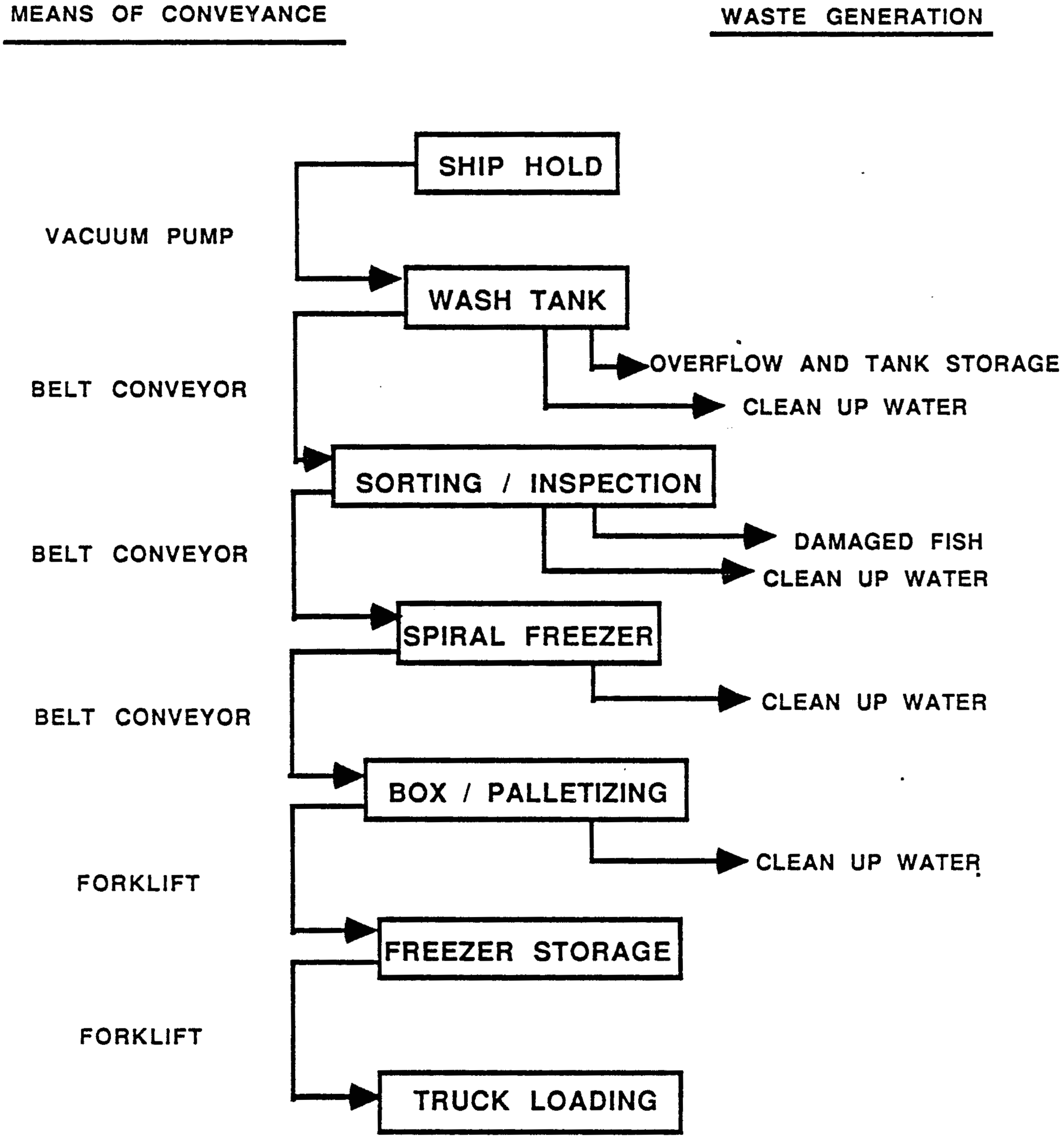
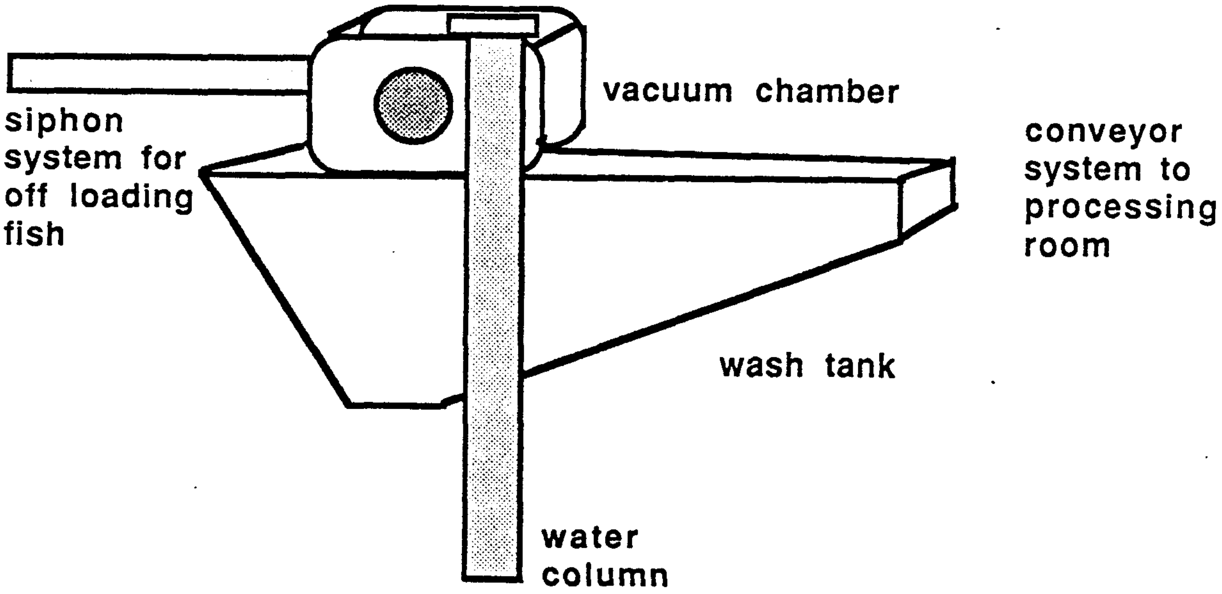


Figure 4. Vacuum Pump/Wash Tank System used in Fish Handling Operations



Phase II - Frozen Fish - Direct Food Uses

Phase II of utilizing menhaden for other than meal production is a conceptualized process currently under review by management. Menhaden would be transported to the plant either on boats in specialized containers or by truck where it would be handled as iced fish. The fish would be mechanically processed or cut by hand and then quick frozen.

Processing options for direct food uses for menhaden are schematically presented in Figure 5. Fish would be received iced either in containers on board ship or boxed from trucks. They would be received and inspected. Then the ice/fish mixture would be dumped into a tank and conveyor system for washing and ice separation. Following washing and deicing, the fish would be discharged onto a conveyor for inspection and sorting. Whole fish could be frozen without gutting. Fish could be gutted, gutted and headed or filleted by hand and then frozen. Another alternative is that fish could be mechanically processed (head and gutted or minced) and then frozen. Mechanical processors are available to head, gut and/or fillet the fish before freezing. Such equipment is expensive and difficult to maintain. Large volumes of fish would be necessary to justify such capital intensive equipment.

The primary "potable" water requirements would be related to washing of whole fish prior to sorting and inspection operations, to washing of headed and gutted fish or fillets and to cleanup. A prerequisite to this operation would be good handling practices aboard ship, i.e. containerized ice handling. The cost for these upgraded handling practices will be the same or higher than for other food fish.

Processing operations could possibly include the following:

1. Whole fish: sort; inspect (IQF); bag/box; palletize

2. Cut fish: mechanical operations, i.e. Baader 33 H&G machines

Depending on end-product uses (fillets, dressed, canned, smoked), the number of unit operations will differ. Water requirements, process yields and waste generated will also vary.

Such operations will require additional fresh water supply, operating expense, new facilities and extensive cleanup practices. Commitment to these potential diversified operations is tied to research development for the use of fish for products, fish oils and menhaden surimi.

Phase: III - Surimi Processing

The surimi process begins by either filleting or gutting the fish by machine (Figure 6). Experience has indicated that the primary source of pigments (which must be removed by washing) is the backbone, which can be removed by filleting but not by heading and gutting. However, filleting may result in lower meat yields and will likely incorporate more belly tissue, which is higher in fat.

Figure 5. Schematic Representation of Processing Menhaden into Direct Food Products

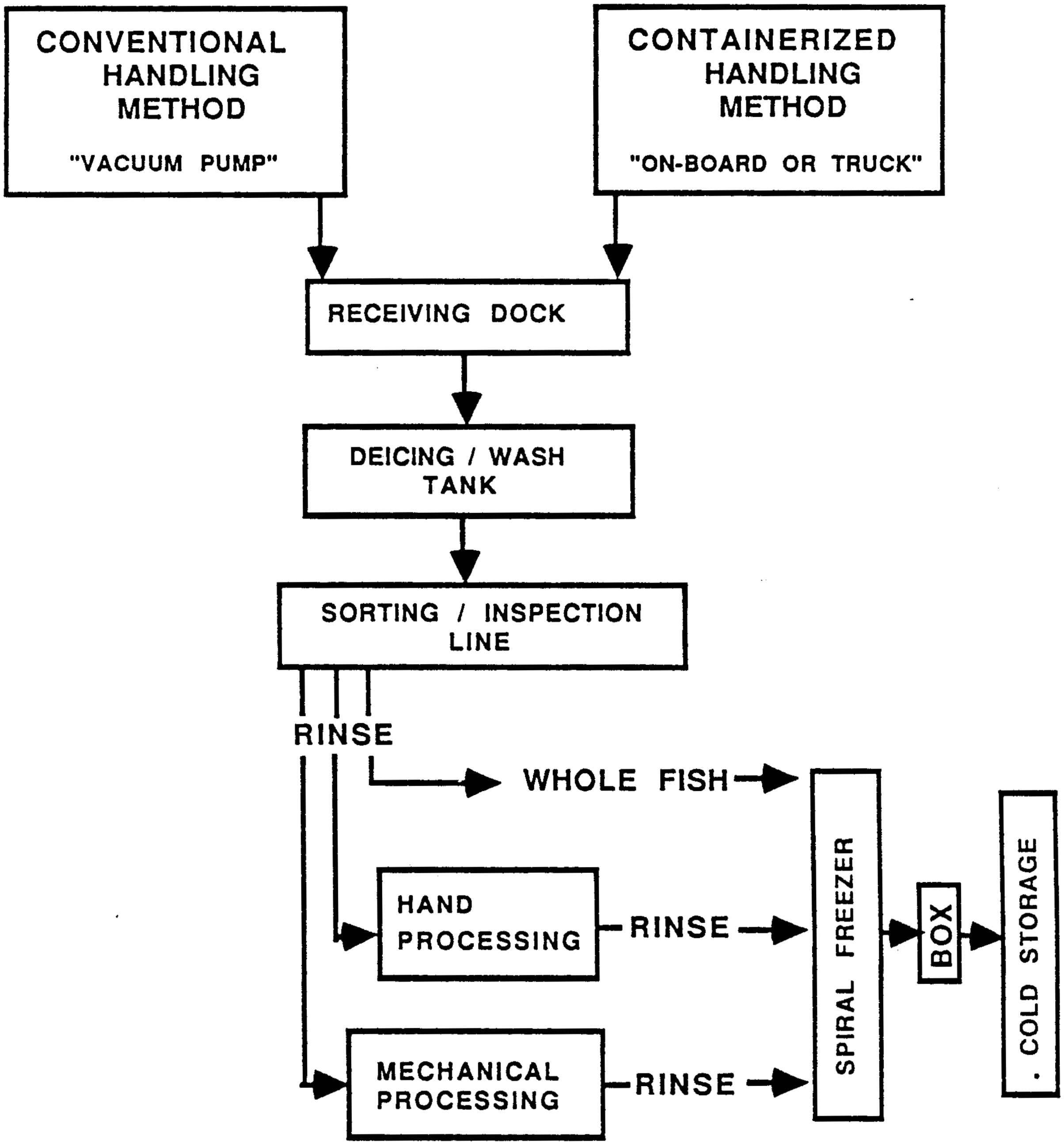
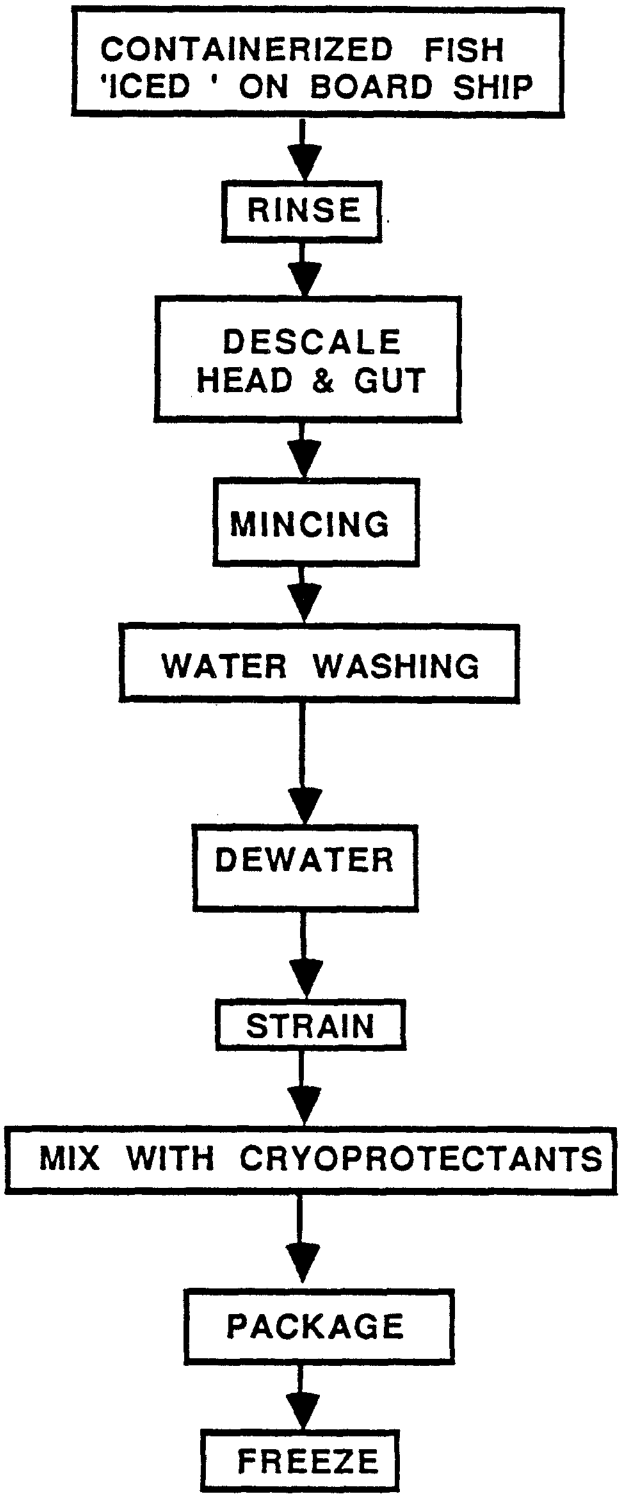


Figure 6. A Simplified Flow Diagram for Surimi Processing Operations



The cleaned, split fish or fillets are first washed to remove excess blood and other contamination and are then fed meat-side down (skin-side up) into a drum-type meat-bone separator. Proper adjustment of this machine is essential: too much belt pressure will force more bone and scale through the drum orifices along with the meat, while too little pressure will result in low meat yields. Adjustment of the belt pressure will also control the quantity of dark muscle incorporated.

The deboned meat is then dumped into a stainless steel tank. In traditional processing, from 3 to 5 parts fresh water are added for every one part meat (weight basis). The water should be low in mineral content and as cold as possible--preferably less than 10 C (50°F). To aid in the removal of water-soluble components when washing the meat of pelagic species such as herrings, the Japanese have recommended that sodium bicarbonate (baking soda) be added to the first wash at a level of 0.1 – 0.2 percent. NCSU investigations have not verified this improvement.

In any case, the pH (acidity) of the water should be carefully controlled in the range of 6.8-7.0 (near neutral). Higher acidity (lower pH) may result in partial denaturation of the fish proteins and loss of gelling properties. Low acidity (higher pH) can result in losses of desirable protein and cause difficulty in dewatering of the meat because meat particles may swell in the water. The pH can be adjusted with sodium bicarbonate or a weak solution of either hydrochloric acid or sodium hydroxide (food grade).

The meat is usually washed three times with agitation, each time at the same meat:water ratio. If the fish meat is high in fat content, the first washing tank should be equipped to skim off the fat which floats to the top during washing. Washing should be completed within 30 minutes if possible. Too long a washing time may result in excessive swelling of the meat and difficulty in subsequent dewatering. Between washes, the water may be separated from the meat by allowing the meat to settle followed by decanting. Alternately, the meat may be briefly screened (rotating screens work best) or even centrifuged between washes.

Following the final wash, the meat is screened or centrifuged for partial dewatering. Next the meat may be strained through a refiner before final dewatering, or it may be dewatered and then strained. Traditionally the final dewatering is carried out with a screwpress, which removes any heat added during refining. However, a high-speed centrifuge may also be used to dewater.

The washed, dewatered meat normally possesses a water content about equal to that of the whole fish meat, unless the fish is fatty. In this case, the moisture content of the surimi will be higher than the whole fish, but the fat content will be much lower. In other words, the protein content of the surimi whole fish muscle should be approximately equal (about 15 to 16 percent).

The meat is then placed in a silent cutter/mixer, or a ribbon/paddle miser, and cryoprotective substances are added. Traditionally this has been about 8 to 9 percent of a 50:50 blend of sucrose (sugar) and sorbitol (the sweetener used in sugarless chewing gum). Other cryoprotectants include sodium glutamate and polydextrose.

The refining/straining step in pollock surimi manufacture is a means of removing any stray bone, scale or skin which may have passed the deboning step earlier in the process. In the case of menhaden, this step plays a much more important role. It is in the strainer that final separation of the light and dark meat is accomplished.

The meat is then shaped into blocks (about 10 kg each) by an extruder and rapidly frozen. Plate freezing is preferable since it is faster than blast freezing in most cases. Storage should be at -30°C with little fluctuation of the temperature.

Water Use and Waste. Surimi processing operations are highly-water intensive. Most of the water use and wastes are related to the washing of the minced fish. A rough material balance would give a 35 percent yield of fish before mincing. An additional 20 percent is lost during washing resulting in a surimi yield of 15 percent of the raw fish input. The incorporation of such an operation into Beaufort Fisheries would require the utilization of the meal plant for the 65 percent solids and the solubles condenser for the 20 percent lost during washing and processing with full recovery of the wastewater.

Handling Fish. The strong gel-forming properties in a quality surimi emerge from maintaining the fish protein in a state most nearly like that in the live fish--the so-called "native" state. This can be accomplished by rapid chilling of the fish to slow natural enzymatic and microbial degradative processes, coupled with other handling procedures which isolate the muscle proteins from any degradative agents. Such procedures might include gutting to remove digestive enzymes and bacteria, and controlling pH (acidity) and salt-content of the chilling medium to minimize changes in the solubility or other properties of the fish protein.

Handling procedures for menhaden intended for surimi production are still being developed. The fish must be handled more in the manner of a food fish rather than by present methods as an industrial fish. This will require measures to prevent crushing during transport, as well as proper chilling. Further, possibly some pre-processing at sea, and/or sorting of the catch into sizes to facilitate machine-processing would be advantageous.

Even with proper icing, menhaden may require processing within eight to twelve hours of harvest when a light-colored surimi is desired. The use of "run-boats" in the fishery has been suggested to ensure rapid delivery of fish from the harvest grounds. These smaller boats could take on a portion of the haul from a purse seine alongside a traditional menhaden boat, and then chill and possibly pre-process the fish while rushing the catch to the surimi processing plant. Sorting might be accomplished at sea or on land, whichever proves to be most economical.

WATER USE, WASTE LOAD, PRODUCT LOSS AND BYPRODUCT RECOVERY

Introduction

To evaluate the effectiveness of a water and waste management control program, management and the research team surveyed the current processing operations at the plant. Even though measurement of existing operations were prevented because of the hot weather, flow and waste loads for all operations were predicted based on the limited observation of processing that was available, literature values and best judgement of the research team.

In-Plant Control Measures

There are many effective measures that management of a seafood plant can use to efficiently and economically reduce water use, product losses and waste loads. Operating efficiency is a prerequisite for a company considering the options available to them for expanding current processing operations. For any plant the controlling factors in accomplishing these goals will always be management attitude and action. Table 12 lists some measures known to effectively manage water use, product loss and waste. Management must do its part to foster an effective water and waste control program. Their role must include the following for a successful program:

1. Understanding water and waste control
    a. Needs for program
    b. Economic benefit
    c. Awareness of all interrelated factors

2. Developing job descriptions for all personnel

3. Providing an environment that permits supervisors the authority to manage and control water use, product losses, and waste load

4. Utilizing an effective and continuing education program for management and employees

Fish Handling Practices

In practice, methods for handling fish on board ship vary from doing little or nothing to chilling or freezing, depending on the type of vessels, area of catching and fish species. Management needs to realize that reducing waste and minimizing water use at the plant begins with proper handling of fish on board ship. Industrial species intended for use other than traditional meal and oil production must be handled as any other high-valued food fish. Fish must be washed and sorted by species. When on-board sorting is not practical, the raw material can be stored in containers and mixed with ice until use. If possible, the fish should be kept in the same containers without emptying and reicing. This is known to be the best means of maintaining quality.

Care must also be taken when unloading fish from the vessel in order to avoid bruising and skin abrasions. While some damage may be acceptable for lower value end uses (i.e. bait fish), fish intended for direct human consumption or processed food product (surimi) must be handled correctly.

Table 12. Measures to Control Water Use, Product Loss and Waste Load

Number	Measure
1.	Management understanding, interest and support
2.	Installation of modern equipment and piping to reduce loss of product and maximize recovery of byproducts
3.	Appointment of water-waste supervisor
4.	Employee training
5.	Accurate records of water use and waste
6.	Scheduling to reduce water use and waste
7.	Proper cleaning procedures
8.	Wastewater monitoring
9.	Planned maintenance program to reduce losses and waste
10.	Planned quality control program to reduce losses and waste
11.	Planning systems for wasted product and byproducts
12.	Development of alternatives for wasted product recovery

Traditional food fish are iced when they are caught. Unless the water is cold, menhaden boats in North Carolina do not normally chill their fish. However, Gulf coast menhaden boats, which are often larger vessels, are equipped with tanks in which fish are chilled. This process is known as using chilled seawater (CSW) or refrigerated seawater (RSW).

Unloading

Traditionally, industrial fish such as menhaden have been subjected to much abuse on board and during unloading. By contrast, food fish are handled much more carefully. If menhaden are to be used as a fish for human consumption, the handling practices during unloading must be improved.

Currently, menhaden are unloaded utilizing a vacuum system as shown in Figure 4 . The top layer of fish is siphoned from the hold prior to normal flooding and pumping operations designed to move fish into the meal plant. The fish are discharged into the vacuum chamber where they are then delivered to the wash tank. The transport water is recycled and can become contaminated with residuals as fish are washed and crushed, losing scales, blood and other body fluids.

Other methods for unloading could include:

1. Pumping through scales/volume device to rolling conveyors for transport to tanks, etc.

2. Heaving to the quay in baskets, by electrical dock hoists or by use of vessel’s own winch, then tipped into containers before gutting or transport

Phase I - Frozen Fish - Bait Fish Processing

The bait fish processing operations have been described previously and are displayed in Figure 3. The in-plant survey conducted by the research team on current bait fish processing operations revealed that the primary source of wastewater generated was from washing of whole fish prior to sorting and inspection operations. Cleanup practices result in additional water use within the process facility itself. Other water uses include water needed for cooling the compressors and cooling tower waters.

Estimated water use for the bait fish operation is given in Table 13. Water use was estimated based on an assumed three-hour operating period for bait fish processing with compressors and generators running 8 hours. Water use totaled 8,220 gallons equivalent to 460 ga1/1000 lb.

Wastewater characteristics and waste load are given in Table 14. Waste loads were calculated utilizing the estimated water use and wastewater Characteristics. Waste loads were estimated at 128 lb BOD5 and 188 lb TSS. This is equivalent. to 7.1 lb BOD5/1000 lb and 10 lb TSS/1000 lb.

Cleanup practices for food-grade operations will require additional water. While minimal water use and dry handling methods can be efficiently incorporated

Table 13. Estimated Water Use in Bait Fish Processing[a]

Operation	Water Use			
	Initial Use	Process Use	Other	Total
	(gal)	(gal/hr)	(gal)	(gal)
Wash Tank	5,000	300		5,900
Cleanup			1,200	1,200
Compressors		120		960
Generators		20		160
Cooling Tower		R[b]		
TOTAL				8,220

[a] Assume average bait fish run = 3 hrs; compressors and generators run = 8 hrs.
[b] R = Recycled

Table 14. Estimated Wastewater Characteristics and Waste Load from Bait Fish Processing

Operation	Wastewater Characteristics		Waste Load	
	BOD_5	TSS	BOD_5	TSS
	(mg/l)		(lbs)	
Wash Tank	2,000	3,000	98	148
Cleanup[a]	3,000	4,000	30	40
Compressors	NA	NA	—	—
Generators	NA	NA	—	—
Cooling Tower	NA	NA	—	—
TOTAL			128	188

[a] Assumes dry cleanup preceding wash down

into existing systems, a significant amount of water is required for handling food grade products in cleaning and heading/gutting operations.

Phase II - Frozen Fish - Direct Food Uses

Frozen fish operations that could be used for menhaden have been described in Chapter V and are shown in Figure 5 . Sources of wastes reviewed by the research team are given in Table 15. Water use for frozen fish operations in conventional handling is presented in Table 16. Wastewater characteristics and waste load estimates for conventional handling are given in Table 17.

Water Use. Water use was estimated for whole frozen, hand cutting and mechanical utilizing conventional handling practices (Table 16). Whole fish processing was estimated to consume 710 ga1/1000 lb. while cut fish processing required 1260 ga1/1000 lb. for hand cutting and 1310 ga1/1000 lb for machine cutting. Common water uses included in these totals were 70 ga1/1000 lb for clean-up, 120 ga1/1000 lb for compressors and 20 ga1/1000 lb for the generator.

Wastewater. Wastewater characteristics were estimated for whole frozen, hand cutting and mechanical processing utilizing conventional handling practices. Waste loads from whole fish processing were estimated to be 3.9 lb BOD5/l000 lb and 5.4 lb TSS/1000 lb while hand cut fish processing was estimated to be 11.9 lb BOD5/l000 lb and 16.9 lb TSS/1000 lb and machine processing was estimated to be 27.7 lb BOD5/l000 lb and 36.7 lb TSS/l000 lb.

Phase III - Surimi Processing

The next step in the evaluation of menhaden processing would be the production of surimi from menhaden. The process is described in Chapter V and shown schematically in Figure 6. Surimi processing would dramatically affect water use and waste loads.

Water use. Estimated water use for surimi processing is found in Table 18 and totaled 4,600 ga1/1000 lb fish. The washing operations used 65 percent of the total estimated water use.

Wastewater. Wastewater characteristics and loads were estimated as detailed in Table 19. Wastewater would be discharged with a BOD5, of 8,000 mg/l and a TSS of 1,250 mg/l as estimated by the research team. The washing operations contributed 76 percent of the estimated BOD5 load. Total load was estimated at 310 lb BOD5/1000 lb fish and 48 lb TSS/1000^{3}1b fish.

Table 15. Sources of Waste in a Frozen Fish Factory

Number	Description of Source
1.	Fish Handling on Board: Manner in which fish are conveyed from nets to hold can reduce quality and yield from cut fish
2.	Unloading Fishing Vessels: Use of water to convey fish to wash tank for rinsing
3.	Fish Handling Operations on Land: Conveyors from waste tank to processing rooms
4.	Cleanup Operations in Processing Room: Wash down of processing equipment
5.	Compressors/Cooling Tower Water
6.	Solid Waste Through Mishandling of Whole Fish

Table 16. Estimated Water Use for Frozen Fish Operations (Conventional Handling)

Operation	Water Use
	(gal/1000 lb)
Whole Fish	
Deicing/Rinsing	500
Cut Fish	
Sealing	300
First Rinse	300
Cutting	150
Second Rinse	300
Mechanical	
Processing	800
Rinse	300
Common	
Cleanup	70
Compressors	120
Generators	20
Cooling Tower	R[a]

[a] Recycled

Table 17. Estimated Wastewater Characteristics and Waste Loads for Frozen Fish Operations (Conventional Handling)

Operation	Characteristics BOD_5	Characteristics TSS	Load BOD_5	Load TSS
	(mg/l)		(lb/1000 lb)	
---------- Whole Fish ----------				
Deicing/Rinsing	750	1,000	3.0	4.2
---------- Cut Fish ----------				
Scaling	1,000	3,000	2.5	7.5
First Rinse	750	1,000	1.9	2.5
Cutting	2,500	3,000	3.1	3.8
Second Rinse	1,000	750	2.5	1.9
---------- Mechanical ----------				
Processing	3,500	5,000	23.	33.
Rinse	1,500	1,000	3.8	2.5
---------- Common ----------				
Cleanup	1,500	2,000	0.9	1.2
Compressors	NA	NA	____	____
Generators	NA	NA	____	____
Cooling Tower	NA	NA	____	____

Table 18. Estimated Water Use in Surimi Processing

Operation	Water Use	Wastewater
	(gal/1000 lb)	(gal/1000 lb)
Rinse	300	300
Descale/Head/Gut	800	800
Mincing	—	—
Washing	3,000	2,700
Dewater	—	300
Strainer	—	—
Cleanup	500	500
TOTAL	4,600	4,600

Table 19. Estimated Wastewater Characteristics and Waste Loads

Operation	Characteristics			Load	
	BOD_5	TSS		BOD_5	TSS
	(mg/l)			(lb/1000 lb)	
Rinse	750	1,000		1.9	2.5
Descaling/Head/Gut	3,500	3,000		23.	20.
Mincing					
Washing	10,400	670		235	15.
Dewater	16,000	2,500		40	6.3
Strainer					
Cleanup	2,500	1,000		10.0	4.2
Plant Wastewater	8,000	1,250			
			TOTAL	310	48

COSTS, RETURNS AND IMPACT OF WASTE-RELATED PROCESS ALTERNATIVES

Introduction

Five process changes to decrease water use or BOD5 load were evaluated individually and collectively. Some of the changes are being used by operative seafood plants, but most will require further design work and testing to work in a plant such as Beaufort Fisheries. Further, most of the recommendations for process changes make the basic assumption that Beaufort Fisheries will move aggressively in that new direction. They can only afford to make these bold moves after careful study and economic analysis to assure reasonable chance of financial success.

Process alternatives evaluated include:

1. Water reuse and solids recovery system
2. Offloading redesign to reduce water use and recycle wash water
3. Containerized handling of fish
4. Counter - current surimi washing
5. Centrifugal decanter system for surimi

Product loss, water use and product recovery estimates represent the best judgment of the research team. These estimates may not necessarily be indicative of actual product loss and recovery. Waste load (BOD5), pollution recovered (BOD5) and pollution prevented are estimates based on limited observations and information.

To arrive at actual statistics, real losses and potential recoveries would have to be measured and documented. A recovery system appropriate for the Beaufort Fisheries plant would need to be designed. Materials recovered by this system and suitable for use in reclamation would mean increased revenue and reduction in pollution load.

Costs for systems are estimates based on limited costs from suppliers and vendors. The hypothetical processes reviewed would need to be refined before more accurate costs could be assessed. However, the research team feels that the cost data presented is realistic and that even greater savings may be possible when detailed drawings and specifications are prepared.

A conceptualized representation of the process changes evaluated is presented in Figure 7. Proposed process alternatives are located on Figure 2 to enable the reader to visually see the suggested relationship between the changes and the various plant operations.

Summary

Process changes were studied for water use reduction, waste load reduction (BOD5), initial cost, increased cost and savings. A tabulation of all the suggested changes is presented in Table 20. The couter-current surimi numbers are not included in these totals as only one surimi system would be installed.

Figure 7. Conceptualized Integrated Design for Process Alternatives

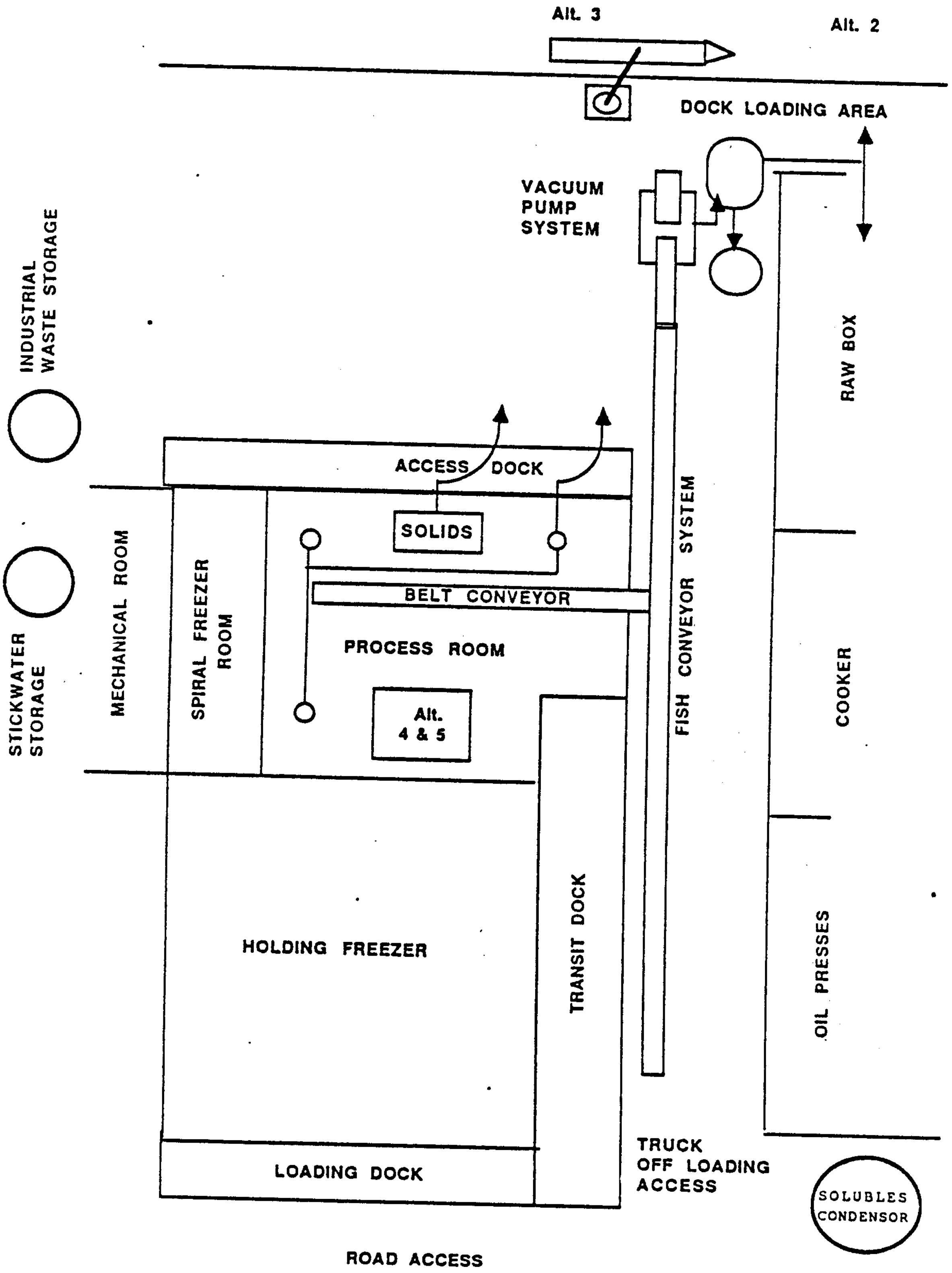


Table 20. Summary of Water Use and Waste Reduction (BOD_5), Costs and Savings

Effect[a]		Amount[a]
Water Use Reduction	(gal/yr)	15,120,000
Waste Reduction	(lb BOD_5/yr)	248,020
Initial Costs		312,500
Annual Increased Costs		308,377
Net Savings Per Year		889,963

[a] Four changes selected

Initial Costs

Initial costs are developed with the methods and procedures detailed by Carawan, 1977. The estimated initial costs (Table 21) for the process alternatives ranged from $250,000 for the decanter based surimi system to $14,500 for the offloading redesign. Costs for materials and installation were estimated by the team. The lack of similar operations in NC and the USA may have prevented as accurate cost estimates as may be desirable. Building costs for the process alternatives were not estimated because any of the process alternatives considered can become a part of either current or expanded facilities.

Budgets

Budgets are developed with the methods and procedures detailed by Carawan, 1977. Annual budgets are summarized in Table 22. Increased revenues are shown for recovered material used as a product. Values used for calculations of costs, savings and revenues are given in Appendix I.

Reduced costs include treatment cost surcharge and loss prevention. The value used for the potential surcharge prevention was $0.20 per lb. Actually, Beaufort Fisheries is not treating its wastewater. The value used is comparable to the costs believed necessary for coastal discharge in North Carolina. Treatment costs could exceed the $2.50/lb BOD5 used because of the size of the plant. Municipal discharge could lower these costs as a larger system would benefit from economies of scale.

Loss prevention is calculated as a reduced cost. Loss prevention emcompasses energy cost, employee labor, etc. for products which are not lost but recovered. The values used are $0.05/lb surimi, $0.02/gal oil and $0.05/gal for food grade oil and $0.025/gal solubles.

Increased costs are summarized in Appendix II and calculated from the figures in Appendix I. Increased costs include maintenance, interest, depreciation, labor and utilities. Utilities include water use, energy cost and chemicals necessary for cleaning.

Increased revenue and reduced costs are added together for total savings (Table 22). Changes with no reduced costs or increased revenue would be shown with a negative savings or loss.

Water Reuse and Solids Recovery

The proposed water reuse and solids recovery system was studied for incorporation in Phase I-Frozen Fish-Bait operations. However, the concepts studied would be readily adaptable and equally effective for phase II and III operations. The process alternative is shown diagramatically in Figure 8. Included are a collection system for floor drain and process discharge wastewaters and for scraps, rejects, floor recovery and process solid residuals.

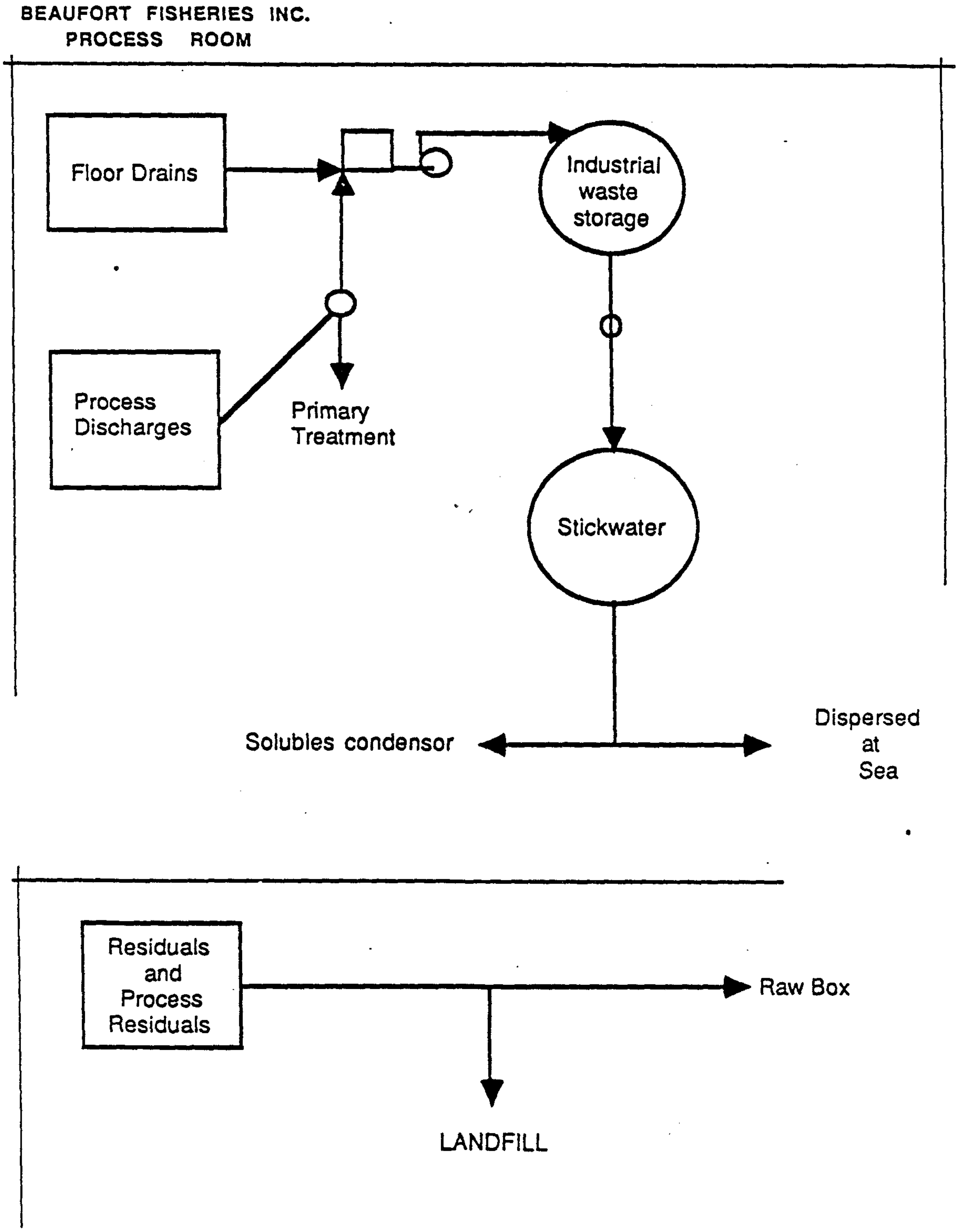
Table 21. Estimated Initial Costs for Changes

Change	Initial Cost
	($)
1. Water Reuse and Solids Recovery	24,500
2. Offloading Redesign	14,500
3. Containerized Handling	23,500
4. Counter-Current Surimi Washing	62,000
5. Centrifugal Decanter System	250,000

Table 22. Annual Budgets for Changes

Change	Increased Revenue	Reduced Costs: Treatment Prevention	Reduced Costs: Loss Prevention	Total Savings	Increased Costs	Savings (Loss)
	($)	($)	($)	($)	($)	($)
Water Reuse & Solids Recovery	118,170	69,250		187,420	94,970	92,450
Offloading Redesign	4,000	32,220	720	36,220	6,750	29,470
Containerized Handling	180,000	69,300		249,300	116,657	132,643
Counter Current Surimi Washing	180,000	410,800		490,800	157,806	332,994
Centrifugal Decanter System	252,000	450,000	9,000	725,400	90,000	635,400

Figure 8. Water Reuse and Solids Recovery



Wastewater from the floor drains and process equipment would be recovered with a collection system. A sump and pump would be necessary as would a storage tank. Collected waters would be handled similar to stickwater. They would be fed to the solubles condenser or pumped to ships for ballast and disposal at sea. An obvious problem will be created by detergents and sanitizers if the plant moves to Phase II and III operations.

Solids would be recovered by containers in the process room. The collected materials would be disposed of by dumping directly in the raw box or by disposal to a sanitary landfill. As the size of the operations would increase, a belt conveyor or a vacuum system may be both economical and feasible.

Initial Costs

The estimated costs for the water reuse and solids recovery systems are detailed in Table 23. Necessary items included floor drain plumbing ($2,000), pump ($1,500), tank ($7,500), sump box ($7,500), residue containers ($10,000) and another pump with controls with a total initial cost of $24,500.

Increased Costs

The increased costs for the two systems were estimated and are detailed in Appendix II. Increased costs were estimated to total $94,970. Utilities was the largest cost include condensing solubles and drying meal. Labor necessary for moving and dumping the solids recovery containers was the second largest cost and was assumed to be 200 hours per year. Both systems were assumed to run 100 days per year with 3 hour process days.

Annual Budget

Revenue and cost projections were combined to develop an annual budget as presented in Table 24. Increased revenues came from meal and solubles collected. Reduced costs were for treatment eliminated. Net savings were estimated to total $92,450 annually.

Offloading Redesign

The current technology for receiving fish from ships is to partially flood the holds and then to vacuum the fish from the ship (Figure 4). The fish are separated from the water in the separator. Then the fish are conveyed to the next operation. Excess water is often used in this operation. Current design allows losses of both water solid waste. An offloading redesign was thought appropriate to recover solids, minimize water use and help prevent loss of solids (BOD5) to the dock, etc.

The offloading redesign is shown in Figure 9. Major components include a tangential screen, solids collection hopper, sump, pump with float controls, storage tank, and the necessary piping to tie the system together.

Table 23. Initial Costs for Water Reuse and Solids Recovery

Item	Description	Total
1. Floor drain plumbing	drain collection system-PVC pipe and fittings	$ 2,000
2. Sump	500 gal fiberglass box	1,000
3. Pump/Controls	5 HP pump, float control for sump, wiring, etc.	1,500
4. Storage tank	20,000 gal used tank - steel	7,500
5. Residual containers	pallet tote bins (20@ $500/ea)	10,000
6. Pump/controls	pump/controls - waste tank to solubles condenser - 5 HP and piping	2,500
Total		$24,500

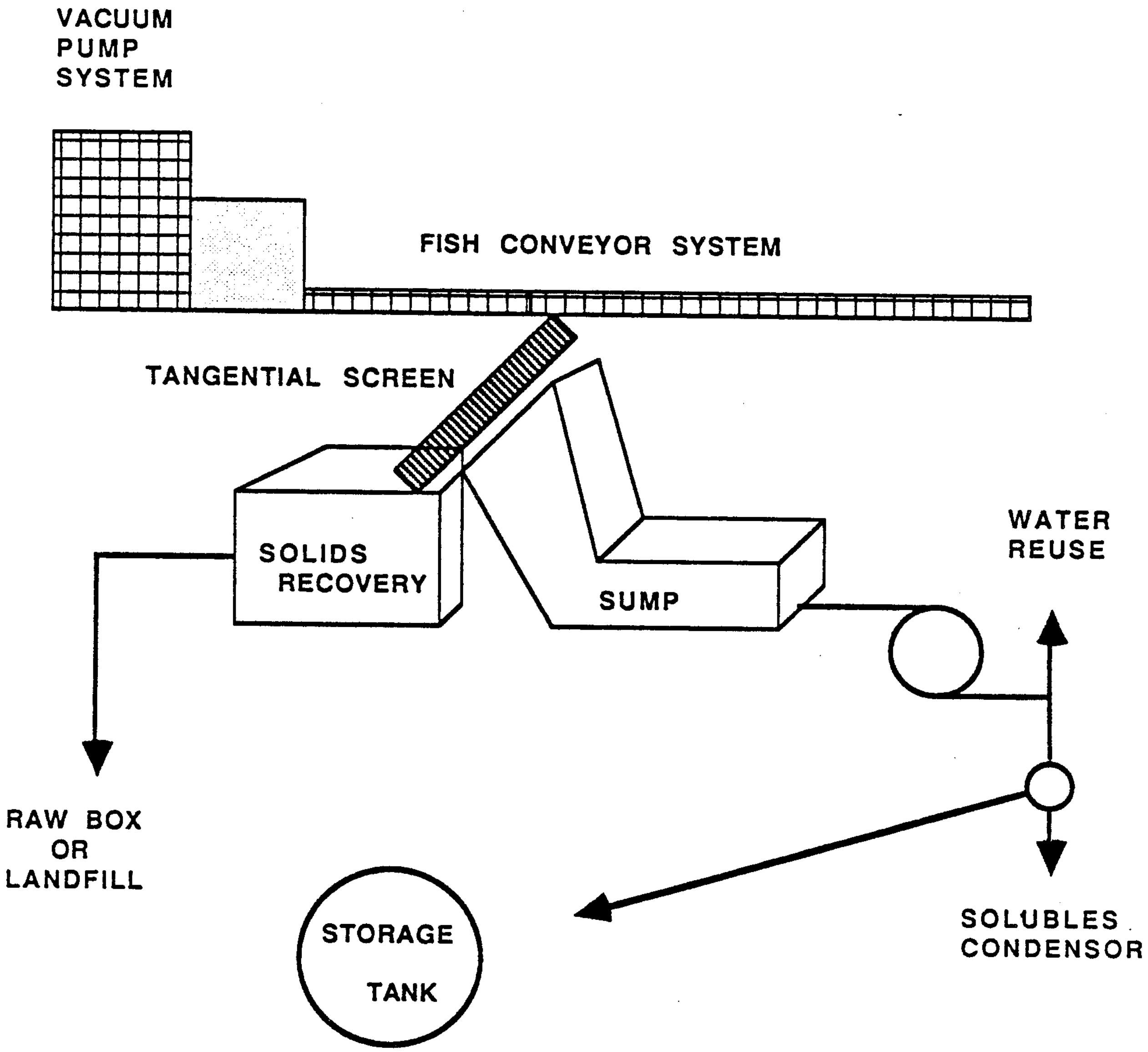
Table 24. Annual Budget for Water Reuse and Solids Recovery

Revenue/Costs	Description	Rate	Cost or (Loss)	Total
Increased Revenue				$118,170
Meal	15,000 lb	$0.15/lb	$ 2,250	
Solubles	165,600 gal	$0.70/gal	115,920	
Reduced Costs				69,250
Treatment	27,700 lbs BOD_5	$2.50/lb	69,250	
Savings				187,420
Increased Costs				94,970
Net Savings				$ 92,450

Notes/Assumptions

1. Output 300 hrs @ 6,000 lb/hr = 1,800,000 lbs
2. Water use 460 gal/1,000 lb = 828,000 gal
3. Waste (in wastewater) 7.1lb/1,000 lb = 12,780 lbs BOD_5
4. Loss potential 25 lb fish/1000 lb processed (8.3 lb BOD_5) = 14,940 lbs BOD_5

Figure 9. Offloading System



Costs were estimated for the new offloading system. They are included in Table 25. Items necessary included the solids collection hoppers ($1,000), screen ($3,500), sump ($1.000), pump with controls ($1,500), storage tank ($5,000) and necessary piping ($2,500). The total initial cost was estimated at $14,500 and this amount could vary widely depending on location and component selection criteria.

Increased Costs

The annual increased costs were tabulated and are displayed in Appendix II. Total increased costs were estimated at $6,750 annually. The largest increased cost was the maintenance with $2,175 per year increased cost.

Annual Budget

The annual budget for the redesign of the offloading system is presented in Table 26. Revenues and waste were projected by the team. Increased revenues were predicted from meal and solubles. Reduced costs were estimated for treatment elimination and water use reduction. Savings include increased revenues and reduced costs totaling some $36,200 annually. Increased costs (Appendix II) totaled $6,750. Net savings were found to be $29,470.

Containerized Handling of Fish

The proposed containerized handling system was studied for incorporation in Phase II of potential plant expansion. The concept is not only feasible for Phase III but would probably be necessary for a quality final product. Containerized handling would not be an attractive economic alternative in Phase I. The components necessary for the containerized handling of fish are presented in Figure 10. Included are containers, a hoist for removal from ships, container restraints on the ships and dock strengthening to facilitate transport and container movement.

Fish would be selected at sea for transport by container. First, employees on ship board would layer ice in the bottom of the container. Then they would mix ice and fish. Fish would be cooled quickly which is necessary for quality. Another benefit of the containers is that overpacking of fish which can cause crushing due to excessive weight would be eliminated. Split sides and lost body fluids would be minimized.

When fish are split open, squashed or mishandled, the blood, fat, body and intestinal tract fluids are lost. These fluids are high in soluble protein and BOD5. They are the reason that fish bail water has a reported TSS as high as 10,800 mg/l and one can expect a higher BOD5.

Modifying existing offloading procedures is essential to insure not only proper handling of whole fish but to reduce waste generated during subsequent rinse and process operations. The proposed containerized method of handling fish on board vessel requires redesign in offloading practice to successfully deliver undamaged whole menhaden to the processing facility. In containerized transit operations, a loading/offloading crane or boom is generally employed for such

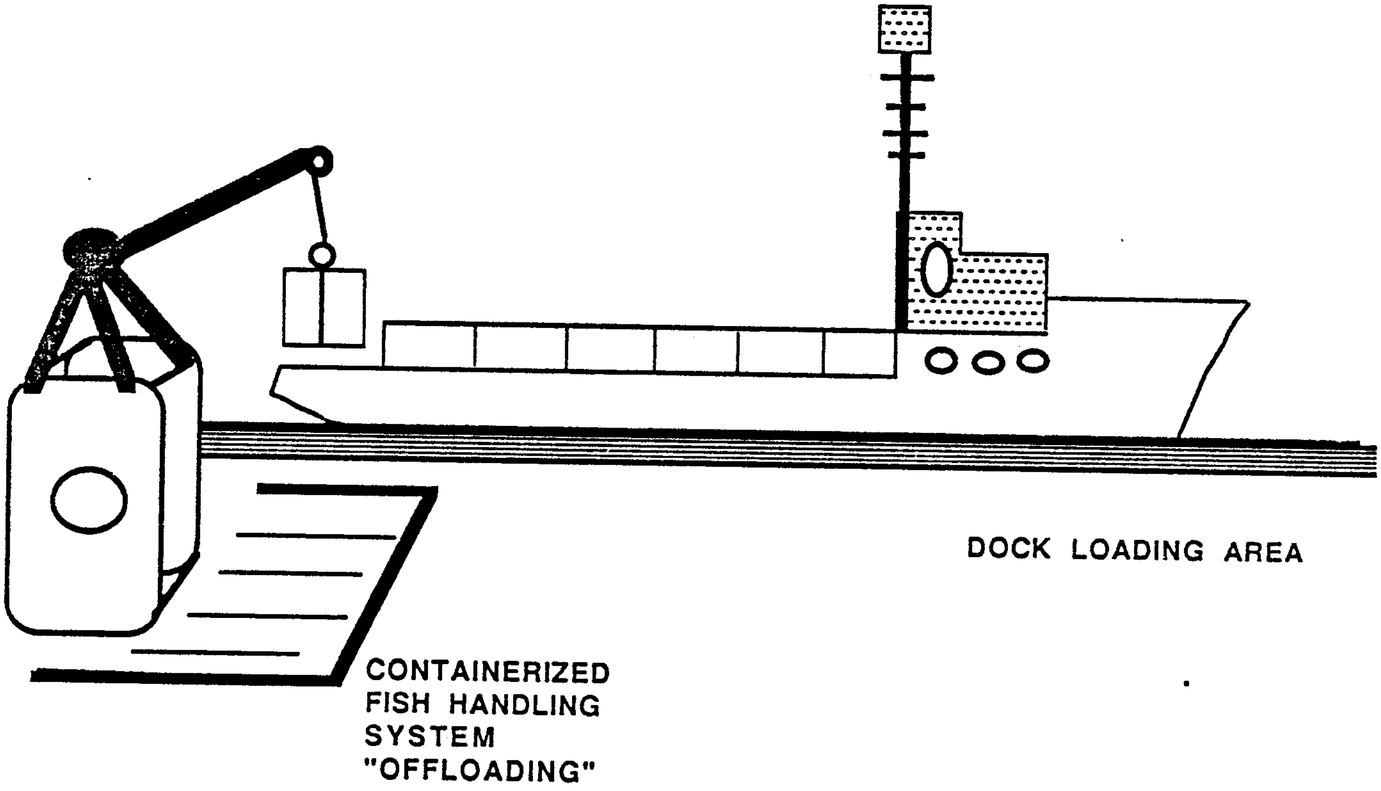
Table 25. Initial Costs for Offloading Redesign to Reduce Water Use and Recycle Wash Water

Item	Description	Cost	Total
1. Hopper	tote box for solids collection	2 - $ 500/ea	$ 1,000
2. Screen	tangential screen		$ 3,500
3. Pump/Controls	5 HP pump, float control, wiring		1,500
4. Tank	10,000 gal used steel tank		5,000
5. Piping			2,500
6. Sump	500 gal		1,000
			$14,500

Table 26. Annual Budget for Offloading Redesign to Reduce Water Use and Recycle Wash Water

Revenue/Cost	Description	Rate	Cost	Total
Increased Revenue				
Meal	10,000lb	$ .15/lb	1,500	
Solubles	15,000gal	$ .50/gal	2,500	$ 4,000
Reduced Costs				
Treatment	12,600lb	$2.50/lb BOD_5	31,500	
Water use reduction	720,000gal	$1.00/1000 gal	720	32,220
Savings				36,220
Increased Costs				6,750
Net Savings				$29,470

Figure 10. Schematic of Containerized Handling System.



operations. At Beaufort Fisheries, this can be achieved by use of either existing boom and riggings aboard ship or construction of a swing boom with hydraulic wrench dockside. The success of containerized icing of whole fish depends on minimizing handling between catching and processing of fish. This would replace existing wet (industrial) and vacuum (phase I, bait fish) pumping systems.

The research team proposed a dockside boom be constructed with the capability of handling 3,000 lbs dead weight adjacent to existing offloading facilities. Items needed would include containers, frame, swing, cable, hoist, hydraulic system and a harness for lifting the containers.

Initial Costs

The estimated costs for the containerized handling of fish are listed in Table 27. Items include containers, hoist and cable, container restraints for the ship and strengthening the docks for container handling. Initial costs totaled some $23,500.

Increased Costs

The increased costs with system implementation were estimated and are presented in Appendix II. Increased costs were found to total $116,657. The utilities costs were 62 percent of the total and most of the increase was due to the inclusion of the cost of icing the fish at $20/1000 lb.

Annual Budget

An annual budget was calculated and is detailed in Table 28. Increased revenues were estimated to be derived from upgrading the fish from industrial fish to food fish. Reduced costs included treatment cost elimination based on a 50 percent reduction in waste from that estimated for bait fish handling. Net savings for the changes are $132,643 annually.

Surimi Processing - Yield, Water Use and Waste Load

The conventional surimi process has been shown diagramatically in Figure 6 and explained in detail in Chapter V of this report. Evidence has been presented that water use for surimi processing may approach 5,000 gal/1000 lb fish processed. Also shown has been reported BOD5 values in excess of 7,000 mg/l. Thus, waste loads from surimi processing can be significant. The research team has reviewed available methods for minimizing water use and waste loads.

Estimated water use, waste load, yield and output: for the three systems studied are presented in Table 29. The estimates are very subjective and actual operations would be expected to vary widely based on species and quality of fish, maintenance, employee training and desired finished product quality.

Table 27. Initial Costs for Containerized Handling

Item	Description	Cost	Total
1. Containers	for icing of fish on board ship and for transport (30@	$450/ea)	$13,500
2. Hoist/Cable	for container transfer		1,000
3. Container restraints	on ship		4,000
4. Docks	strengthen for container movement		5,000
	Total		$23,500

Table 28. Annual Budget for Containerized Handling

Revenue/Cost	Description	Rate	Cost (Loss)	Total
Increased Revenue				
Industrial fish upgrade	to food fish 3,600,000 lb	$.05/lb	$180,000	
Reduced Costs				
Treatment	Eliminate 50 percent of waste 7.7 lb BOD_5/1000 lb fish = 27,720 lbs	2.50/lb BOD_5	69,300	
Savings				$249,300
Increased Costs				116,657
Net Savings				$132,643

Table 29. Yield, Water Use and Waste Load from Surimi Processing

	Process		
	Conventional	Counter-Current	Decanter
	(gal/1000 lb fish)		
Water Use	6,000	3,000	2,000
	($lb\ BOD_5$/1000 lb fish)		
Waste Load	125	150	75
Yield (%)	50	45	70
Output (%)	14	13	19

$$\text{Output} = \frac{\text{surimi out}}{\text{fish in}}$$

$$\text{Yield} = \frac{\text{mince solids out}}{\text{mince solids in}}$$

Water use would range from 6,000 gal/1000 lb fish for conventional surimi processing to 2,000 gal/1000 lb fish for the decanter based system. The decanter based system also gives a 40 percent increase in output efficiency. This increase in output can be directly related to waste load and the decanter based system has only 50 percent of the waste load of the counter-current system.

Water Reduction in Surimi Processing

A concern in the surimi manufacturing process is to lessen the water requirement without affecting the product quality. Water consumption would be reduced, and the solubles and particulates removed from the fish mince during the washing process would be concentrated, thus making water treatment and/or by-product recovery more economical.

The conventional method for washing the minced fish involves several washing stages. Fresh water is added at each stage and the wastewater subsequently removed by the screening or settling of the meat before the next washing stage (Figure 11). The approach makes efficient use of the water in the first stage where the bulk of solubles are removed, but the last wash is merely a rinse of the washed meat.

A more efficient use of the wash water might he obtained through counter-current washing (Figure 12). In this procedure, the same water is used in all washing stages. However, the water moves in a direction counter to the flow of meat through the process. Table 30 presents the results of an experiment comparing the washing of fish mince by the conventional process (9-to-1 total water-to-meat volume ratio) to the same process conducted in a counter-current manner (3-to-1 total water-to-meat volume ratio).

Surprisingly, counter-current washing removes an equal or greater amount of soluble protein as the conventional process, but requires only one-third the volume of water needed for the conventional process. The effluent is therefore three times as concentrated as with the conventional process. It may be possible for this effluent stream, with or without further concentration, to be directly processed by existing menhaden reduction plants and be totally recovered for feed or fertilizer. Counter-current washing is now being scaled up to ensure that the surimi quality does not suffer from such a washing process and to work out the equipment parameters needed to conduct such a process on a large scale.

Another approach to water reduction in surimi processing has recently been reported from Japan. The process entails use of a vacuum chamber for the leaching process. Washing under reduced pressure is said to greatly accelerate the removal of the undesirable components. One wash, using no more than a 4:1 water:meat ratio, reportedly produces a product which is more bland, lighter in color and lower in fat than several washes with a conventional process. Studies are now being planned to test this concept in the washing of menhaden. If the approach is technically valid, there still may be problems in applying such a technique at the commercial level in terms of equipment design and cost.

Still another approach is to use a decanter based surimi production line. Costs for the line are greater but water use is reduced, BOD5 is reduced and recovery of product is enhanced.

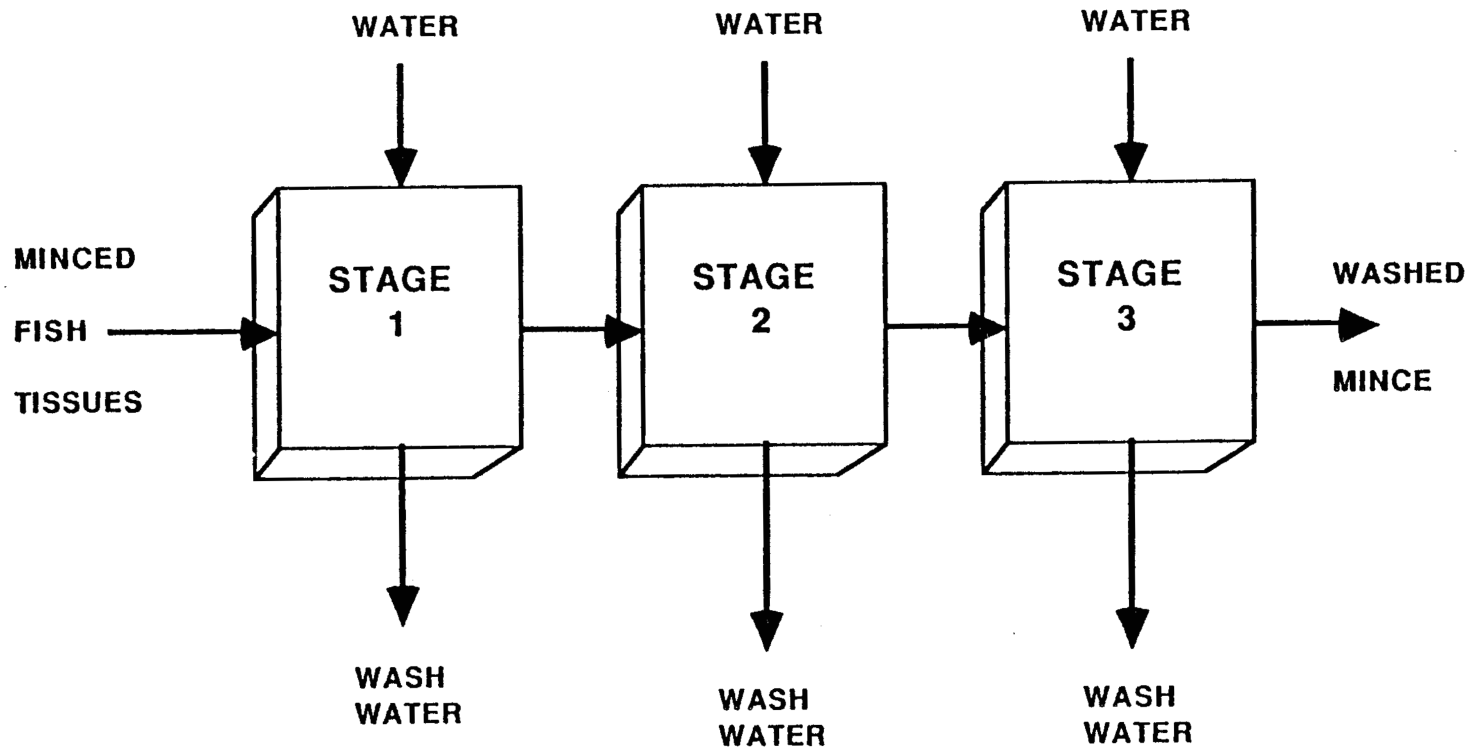


Figure 11. The Conventional Lateral-flow Washing Process used for Alaska Pollock Surimi Production

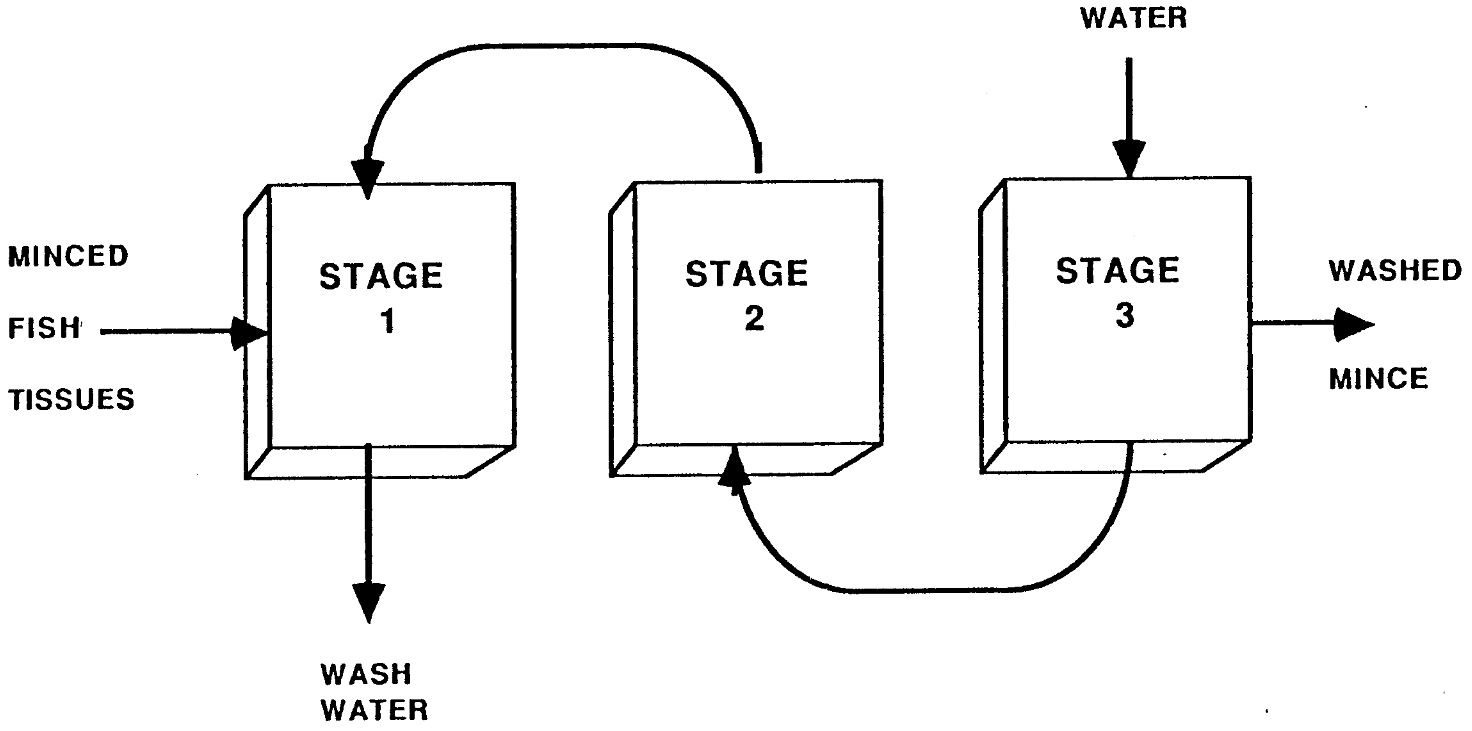


Figure 12. The Counter Current Washing Process used for Menhaden Project Work

Table 30. Washing Efficiency of Conventional Versus Counter-Current Process

Category	Meat[1]	Water[2]
Not Washed	33.73	----
Conventional	10.78	2.33
Counter-current	9.42	2.35

[1] Values are extractable water-soluble nitrogen as a percent of the total nitrogen in the washed meat.

[2] Values are total recovered water-soluble protein in the wash water as a percent of the total fish weight being washed.

Waste Reduction in Surimi Processing

Waste from surimi processing occurs in two forms. First, the scales, guts and heads are lost and can be processed into meal. Second, and more important, are the blood, fat and soluble proteins that are leached from the mince during processing. The high BOD$_5$ generated during surimi processing is a direct result of the intentional removal of these materials through washing. The quality of the desired final product is directly proportional to the efficiency of the washing process in removing the undesirable components. Since the soluble components can be recovered through several potential methods (eg. settling, centrifugation, ultrafiltration) for secondary product use, a significant reduction in waste load could be realized.

Counter-Current Surimi Washing

Counter-current surimi washing was described in the preceding section. A flow diagram of the necessary components for a system are included in Figure 13. Necessary items include surge tanks, pumps, piping, collectors and a screen.

Initial Costs

Estimated initial costs are detailed in Table 31. The costs for necessary items totaled $62.000. All parts of the system contacting the food or water reused to wash the food would need to be made of stainless steel, probably Type 316SS. Plastic piping ana valves such as PVC would be satisfactory for the wastewater discharge line.

Increased Costs

The details for the increased costs are given in Appendix 11. Total increased costs were estimated at $26,406. Costs included labor, maintenance, depreciation, interest and utilities. Maintenance was the item that was the largest percent of the total increased costs.

Annual Budget

Savings consisting of increased revenues and reduced costs were combined with increased costs to develop an annual budget. The budget appears as Table 32. The budget reflects decreased water use, reduced yield, recovery of secondary product and solubles and the reduction in BOD5. Net annual savings were predicted to be $332,994.

Centrifugal Decanter System for Surimi

The conventional surimi process is noted for high water consumption, large installation volume, difficult and time consuming cleaning procedures and considerable loss of solids into the plant effluent. At least one company has a centrifugal decanter system with an estimated 40 percent increase in mince recovery, requiring only about 30 percent of the water volume and the increased yield efficiency results in greatly reduced waste loads from the process. Although there are only limited commercial applications to date, the team thought

Figure 13. Counter-Current Surimi Washing System

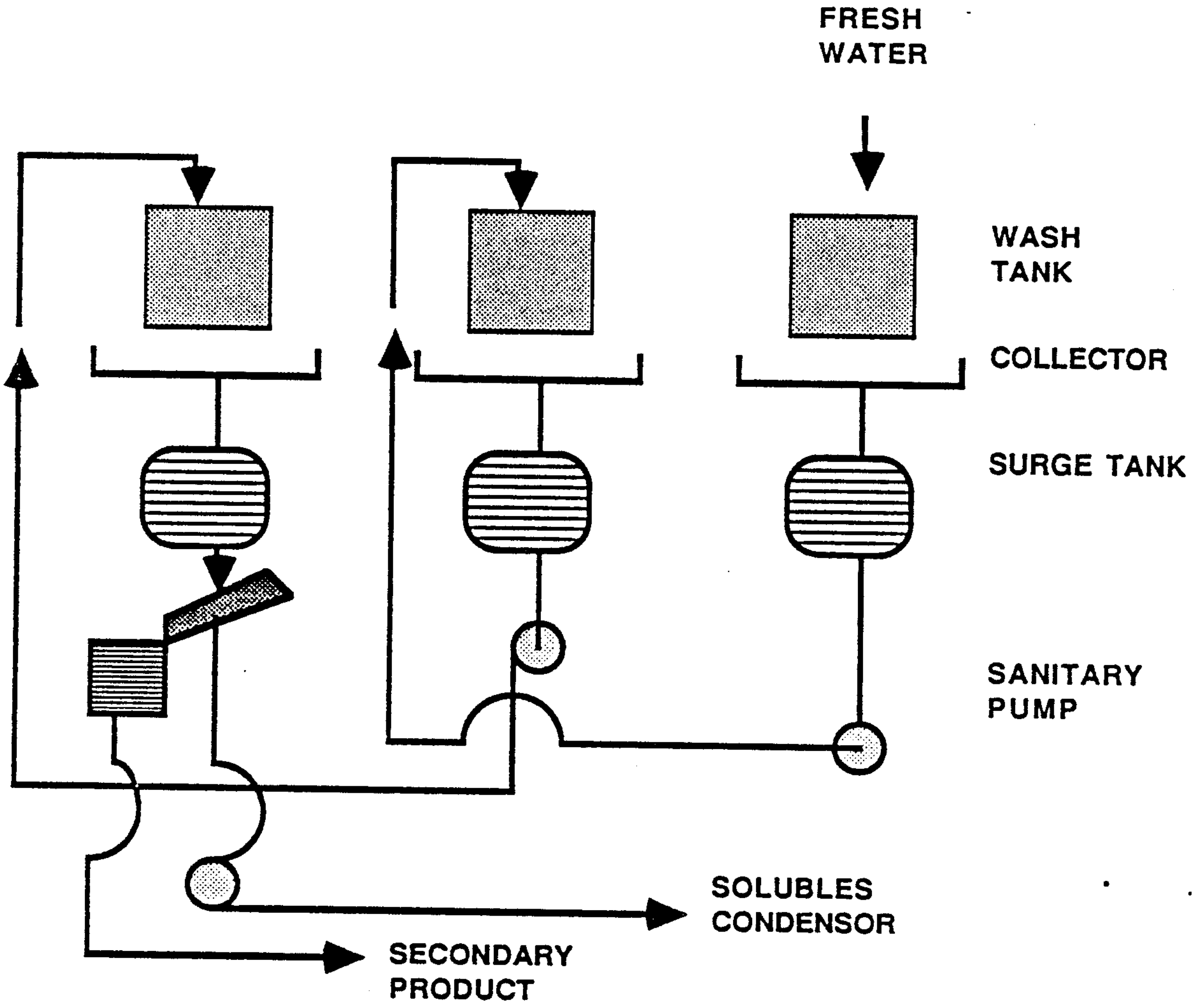


Table 31. Initial Costs for Counter-Current Surimi Washing

Item	Description	Units/Cost	Total
1. Tanks	surge tanks-100 gal stainless steel, sanitary	3@ $1,500/ea	$ 4,500
2. Pump	need sanitary pumps, 3 HP with fittings and controls	2@ 2,500/ea	5,000
3. Pump	need one (1) pump for wastewater discharge, 3HP with fittings and controls		1,500
4. Pan	collectors - stainless steel	3@ 2,500/ea	7,500
5. Piping/fitting	PVC - 2" dia valves Stainless - 2" dia		6,000
6. Screen	Tangential for solids recovery		30,000
7. Cleaning system	COP tank		7,500
	Total		$62,000

Table 32. Annual Budget for Counter-Current Surimi Washing

Revenue/Cost	Description	Rate	Cost (Loss)	Total
Increased Revenue				$180,000
Solubles	180,000 gal	$ .90/lb	$ 90,000	
Meal	100,000 lb		90,000	
Reduced Costs				410,800
Water Use reduction	10,800,000 gal/yr	1.00/1000 gal	10,800	
Treatment	BOD_5 recovered, not discharged 160,000 lb	2.50/lb BOD	400,000	
Savings				$490,800
Increased Costs			26,406	
Yield Decrease	36,000 lb	1.40/lb surimi	50,400	157,806
Utilities			81,000	
Net Savings				$332,994

it important to review the potential impact on water use and pollution for Beaufort.Fisheries.

The system is shown in Figure 14. The major components of the system include the mixer, retention cell, decanter, refiner, screw press and mixer. The decanter is the main component and is designed to effectively separate the solids with much lower solids losses than conventional processes.

Initial Costs

For this study, the initial cost for the entire system was assumed by the research team. And, the team concentrated its study on the cost difference between a conventional and a decanter based system. The additional costs were assumed to be about $250,000. The process is so new and unavailable that cost estimates are difficult and almost impossible to accurately predict.

Increased Costs

Increased costs for the centrifugal decanter based system were estimated to be $89,860. One must remember that these increased costs are derived from an assumed initial cost that may not be valid. However, the team believes that the estimates are realistic for the concerns studied in this report. Maintenance and depreciation were estimated to be the largest increased cost.

Annual Budget

An annual budget was developed and is presented in Table 33. Savings totaled some $635,400 per year. They came from both increased revenues and decreased costs.

Increased revenue came from the 40 percent increased product yield. Surimi is valued at $1.40/lb and increase in yield of so valuable a product adds up quickly.

Decreased cost included water use reduction, waste treatment reduction and loss prevention. The decanter based system was predicted to use some 14,400,000 gal of water less than a conventional system. Almost 180,000 lb of BOD5 would be eliminated using this system over a conventional system.

As net savings were predicted to be more than $600,000/yr, an investment in a decanter based system would be a wise investment if Beaufort Fisheries enters surimi processing.

Summary

Beaufort Fisheries may have the opportunity to expand its product line in the future. Water use, waste load and wastewater disposal become important concerns for this facility located on our sensitive esturine waters.

This study helps to demonstrate process changes to maximize yields and minimize waste loads and pollution. The relationship between water use and waste load is studied.

Figure14. Centrifugal Decanter System €or Surimi

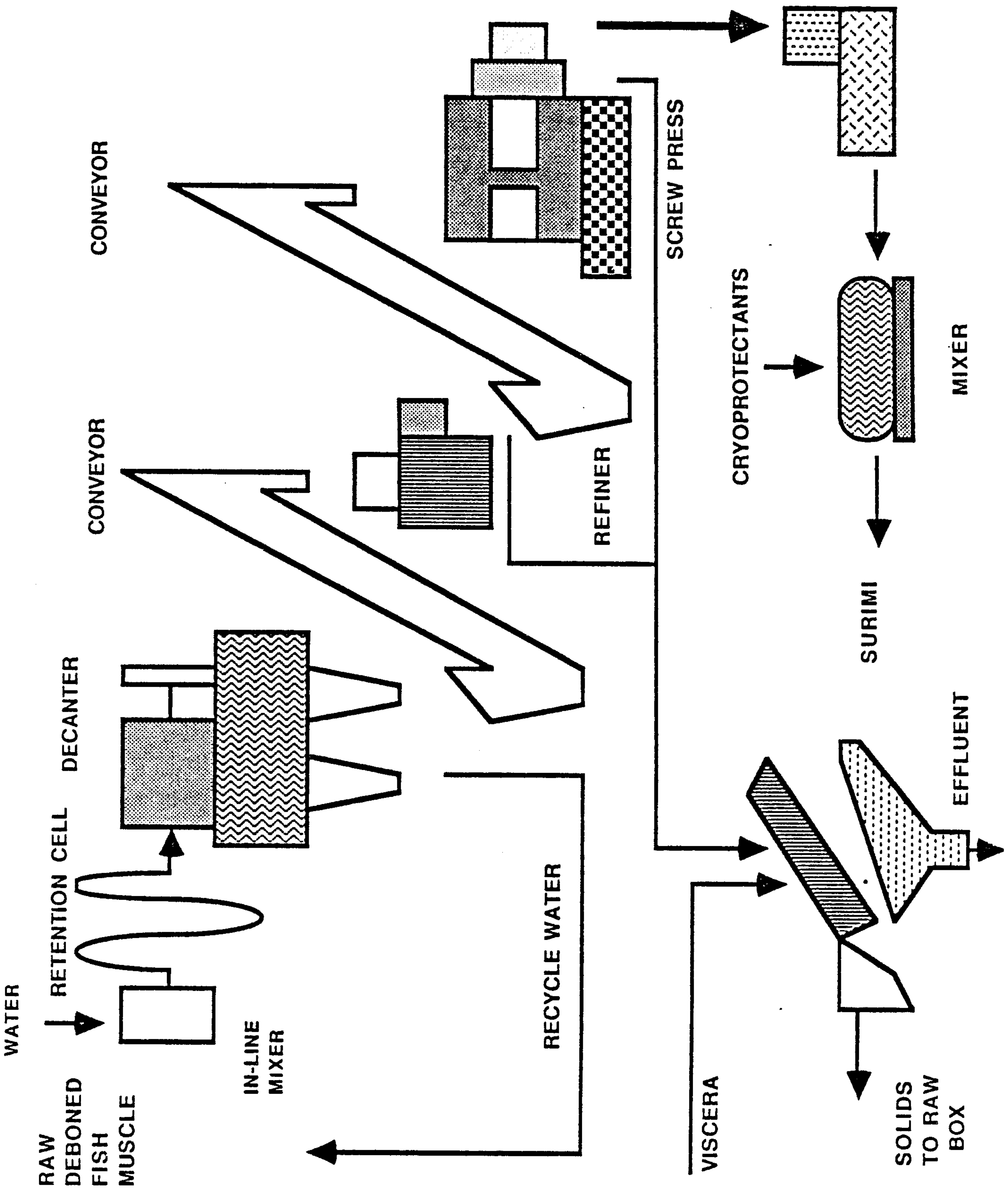


Table 33. Initial Excess Costs for Decanter System for Surimi

Item	Description	Units/Cost	Total
1. Excess Cost	decanter based system	$250,000	$250,000
		Total	$250,000

Table 34. Annual Budget for Decanter System for Surimi

Revenue/Cost	Description	Rate	Cost (Loss)	Total
Increased Revenue				$ 252,000
Product	180,000 lb/yr surimi	@$1.40/lb	$252,000	
Reduced Costs				473,400
Water Use	14,400 gal/yr	@1.00/1,000 gal	14,400	
Treatment	180,000 lb/yr	@$2.50/lb	450,000	
Loss prevention	180,000 lb/yr	@ .05/lb	9,000	
Savings				$ 725,400
Increased Costs				90,000
Net Savings				$ 635,400

If four of the process changes studied were adopted by Beaufort Fisheries, pollution could be prevented at a rate of 248,000 lb BOD5/yr. Initial costs would exceed $300,000/yr and annual costs would be approximately $300,000/yr. Some 15,000,000 gallons of water could be saved annually. Total savings would be about $900,000 per year. Of course, readers must realize that several millions of dollars would be necessary for Beaufort Fisheries to implement all the processes studied.

Process concerns included higher quality products, reduced product losses, future diversification and expansion, effective use of current facilities and minimal costs. If food products become an integral part of production, detergents and sanitizers needed for cleaning become important concerns in water reuse and ultimate disposal.

CONCLUSIONS AND RECOMMENDATIONS

This study is a feasibility study for the reduction of waste load and water use in the Beaufort Fisheries plant as it considers expanding from traditional menhaden fish products (meal, oil, solubles) into other seafood areas. The plant and potential expansion processes were reviewed to identify sources of waste and water use patterns and to develop recommended practices to reduce water use and pollution load.

Practices and processes were recommended for fish handling, bait fish operations, fish processing for food and surimi processing. Specific recommendations include the following:

1. Redesign of offloading to reduce water use and minimize waste
2. Ship board containers for refrigerated storage of fish
3. Fish meal, oil and solubles processes to utilize wastes and minimize pollution
4. Efficient water use systems for surimi processing
    a) Counter-current washing
    b) Decanter-based system
5. Employee training to emphasize the importance of water use and waste reduction

Further study and investigation need to be made in these areas:

1. As more sanitary cleaning is needed for human food production, how can rinse waters containing detergents and sanitizers be handled?
2. Can screening, centrifugation or ultrafiltration be used to help increase the solids of wash and process streams?
3. Are there other potential uses for menhaden that would maximize profits and value - added?
4. How can water use and waste reduction practices be adopted with minimum effects on productivity and profits?
5. How can the results of this study be expanded, confirmed and implemented?
6. Can the city of Beaufort handle the plants wastewater discharge?
7. Can a treatment facility be designed and permitted to treat any wastewater not utilized in the solubles condensor?

Beaufort Fisheries faces many challenges in the years to come. They need to utilize the results of this study to increase profits while preventing pollution and helping to protect our estuaries which provide the fish that make a fisheries business possible.

GLOSSARY

BOD - Biochemical Oxygen Demand is a bioassay test which is a semi-quantitative measure of biological decomposition of organic matter in a water sample. It is determined by measuring the oxygen required by standard laboratory conditions.

BOD5 - A measure of BOD when the test is incubated for five days at 20°C.

COD - Chemical Oxygen Demand. Its determination provides a measure of the oxygen demand equivalent of that portion of matter in a sample which is susceptible to oxidation by a strong chemical oxidant. Obtained by reacting the organic matter in the sample with oxidizing chemicals under specific conditions. The COD value does not necessarily correlate with BOD.

CSW - Chilled sea water.

DS - Dissolved solids.

EPA - Environmental Protection Agency. The federal agency is sometimes referred to as such, but individual states may have an EPA. Preferably use U.S. Environmental Protection Agency when referring to the federal agency.

FOG - Abbreviation for fats, oils and grease.

IQF - Individually quick frozen.

RSW - Refrigerated sea water.

TKN - Abbreviation for Total Kjeldahl Nitrogen. A standard test for nitrogen availability in organic materials. This does not differentiate between nitrogen from proteins and from other sources.

TSS - Total suspended solids

APPENDIXES

LIST OF APPENDIXES

Appendix I. Notes on Costs and Budgets

Number	Cost Item		Cost per Unit
1.	Maintenance	-	15% of material cost
2.	Interest	-	9.0%
3.	Installation labor	-	$20/hr
4.	Plant labor	-	$8/hr
5.	Electricity	-	$0.06/kwh
6.	Trucking	-	$0.60/mile
7.	Depreciation hoses, nozzles, tanks, lines, etc	-	14.3% buildings, 20 yrs - 5.0%
8.	Treatment	-	$2.50/lb BOD5
9.	Surimi	-	$1.40/lb
10.	Secondary food grade product	-	$0.90/lb
11.	Meal	-	$390/T
12.	Oil	-	$0.70/gal
13.	Condensed Solubles	-	$0.50/gal
14.	Food grade oil	-	$1.50/gal
15.	Loss prevention surimi oil solubles	- - -	$.05/lb food oil - $.05/gal $.02/gal $.025/gal
16.	Water Cost	-	$1.00/1000 gal
17.	Ice	-	$20/1000 lb fish
18.	Utilities	-	$28/T meal ($19 oil and $9 electric) $.45/gal solubles

Appendix II. Increased Costs for Changes

Change	Labor	Maint.	Deprec.	Int.	Util
	($)	($)	($)	($)	($)
Water Reuse and Solids Recovery	2,100	3,750	3,575	1,125	84,420
Offloading Redesign	1,600	2,175	2,074	652	250
Containerized Handling	38,400	2,175	2,524	1,058	72,500
Counter-Current Surimi Washing	4,800	9,300	8,866	2,790	650
Centrifugal Decanter System	3,200	37,500	35,750	11,250	2,160

Where: Maint. = Maintenance
Deprec. = Depreciation
Int. = Interest
Util. = Utilities
Labor = Additional time needed to incorporate change (includes cleaning)

REFERENCES

Brinsfield, R.B.; Phillips, G.; and Winn, P.N. "Characterization, Treatment, and Disposal of Wastewater from Maryland Seafood Plants." Journal Water Pollution Control Federation (August 1978): 1943-1952.

Bewick, Michael W.M., gen. editor. "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs," by E.G. Dudley, G.R. Swanson, and K.J. Williamson. Handbook of Organic Waste Conversion. New York: Van Nostrand Reinhold Company, 1980.

Carawan, Roy E.; Chambers, James V; and Wilkowske, Roger W.; and Zall, Robert R. Seafood Water and Wastewater Management, North Carolina Agicultural Extension Special Report No. AM-18F (1979).

Carawan, Roy E., and Thomas, Frank B. Assisting North Carolina Seafood Processors in Meeting Water Pollution Requirements. Proceedings of Seafood Waste Management in the 1980's Conference - Report No. 41. Florida Sea Grant College: 10-25.

Chao., Allen C.; Green, David: Lanier, Tyre C.; and Tzou, Leon. Strategies for Handling Soluble Wastes Generated during Minced Fish (Surimi) Production. Proceedings of 39th Industrial Waste Conference. Purdue University: 565-572.

Chowning, Larry S. "Small-Scale Menhaden Purse Seining is Alive and Well on the Chesapeake." National Fisherman. Vo1.67, No.7. 1986. 54-56.

Civit, E.M.; Lupin, H.M.; and Parin, M.A. "Recovery of Protein and Oil from Fishery Bloodwater Waste: Effect of pH and Temperature." Water Resources (1982): 809-814.

Davis, R.V. and Paessler, A.H. "Wastewaters from Menhaden Fish Oil and Meal Processing Plants." Proceedings of 11th Industrial Waste Conference. Purdue University: 371-388.

Food and Agriculture Organization of the United Nations. Planning and Engineering Data: 2. Fish Canning, by A. Myrseth. Circular No. 784 (1985).

Ishikavoa, Shizuhiro, and Kato, Kenji. "Fish Oil and Protein Recovered from Fish Processing Effluent." Water and Sewage Works (October 1969): 412–416.

Lanier, Tyre C. Menhaden: Soybean of the Sea. UNC Sea Grant College Publication UNC-SG-85-02 (1985).

Lawson, Thomas B., and Wheaton, Fredrick W. Processing: Aquatic Food Products Wiley-Interscience. New York (1985).

Miller, T.M. Systems Approach for Preserving Menhaden and Underutilized Fish Entering into Human Food Products. Gulf & South Atlantic Fisheries Processing, Water Pollution Control Research Series (1971).

National Oceanographic and Aeronautic Administration. Fishery Statistics (1985).

Ohta, Fuyuo, gen. editor. "Process Techniques in Fisheries," by Suisan Kako Gijutsu.

Parin, M.A.; Civit, E.M.' and Lupin, H.M. 1979. Characterization of Blood Water Effluent of Fish Meal Factories. Latin Am. J. of Chem. Eng. & Appl. Chem. 9:155-154.

U.S. Environmental Protection Agency. Canned and Preserved Fish and Seafoods Processing Industry, by Environmental Associates, Inc. (1973).

U.S. Environmental Protection Agency. Current Practice in Seafoods Processing Waste Treatment. Water Pollution Control Research Series Pubn. No. 12060ECF04/70 (1970).

U.S. Environmental Protection Agency. Economic Analysis of Interim Final Effluent Guidelines: Seafood Processing Industry, by David L. Jordening and Thomas R. Eyestone. Pubn. No. EPA-230/1-74-047 (1975).

U.S. Environmental Protection Agency. Economic Analysis of Proposed Effluent Guidelines: Seafoods Processing Industry, by R. E. Seltzer, D. L. Jordening and J.K. Allwood. Pubn. No. EPA-230/1-73-025 (1973).

U.S. Environmental Protection Agency. Pollution Abatement and By-product Recovery in Shellfish and Fisheries Processing, Water Pollution Control Series Pubn. No. 72130 FJQ 06/71 (1971).

U.S. Environmental Protection Agency. Water and Waste Management in Poultry Processing, by Roy E. Carawan, William M. Crosswhite, John A. Macon and Byron K. Hawkins. Environmental Protection Technology Series Pubn. No. EPA-660/2-74-031 (1974).