Group I, Phase II

Development Document for Interim Final and Proposed Effluent Limitations Guidelines and New Source Performance Standards for the

Fruits, Vegetables and Specialties

Segment of the

Canned and Preserved Fruits and Vegetables

Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OCTOBER 1975

DEVELOPMENT DOCUMENT

for

INTERIM FINAL AND PROPOSED EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

FRUITS, VEGETABLES AND SPECIALTIES SEGMENTS OF THE CANNED AND PRESERVED FRUITS AND VEGETABLES POINT SOURCE CATEGORY

Russell E. Train
Administrator

Andrew W. Breidenbach, Ph.D.
Acting Assistant Administrator for Water and Hazardous Materials

Allen Cywin
Director, Effluent Guidelines Division

James D. Gallup
Donald F. Anderson
Project Officers

October 1975

Effluent Guidelines Division
Office of Water and Hazardous Materials
U.S. Environmental Protection Agency
Washington, D.C. 20460

ABSTRACT

This document presents the findings of a study of the fruits, vegetables, and specialties segments of the canned and preserved fruits and vegetables industry for the purpose of developing waste water effluent limitations guidelines, and Federal standards of performance for new sources in order to implement Section 304 (b) and 306 of the Federal Water Pollution Control Act Amendments of 1972 (the "Act"). An earlier development document (EPA-440/1-74-027a) established effluent guidelines for portions of the apple, citrus, and potato processing segments of this industry. This report covers effluent limitations guidelines for the remaining segments of the fruits and vegetables point source category.

Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available" and the "Best Available Technology Economically Achievable", which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, or other alternatives.

The regulations for July 1, 1977, are based on in-plant waste management and operating methods, together with the best practicable secondary biological treatment technology currently available for discharge into navigable water bodies. The recommended technology is represented by preliminary screening, and secondary biological treatment, either aerated or aerobic lagoons, or activated sludge.

The recommended technology for July 1, 1983, is in-plant waste management and preliminary screening, the best biological secondary treatment, and disinfection (chlorination). In addition, final multi-media or sand filtration may be required for "large" point source processors. The new source performance standards are the same as the best available limitations for 1983. The technology is either the same as for existing sources for 1983 or land treatment. Land treatment is especially attractive because land availability requirements can be an important part of new source site selection criteria.

Land treatment systems are effective and economic alternatives to the biological systems described above. When suitable land is available, land treatment is the preferred technology for July 1, 1977, for July 1, 1983, and for new source performance standards.

TABLE OF CONTENTS

FIGURES

TABLES

SECTION I

CONCLUSIONS

For the purpose of establishing effluent limitations guidelines and standards of performance, the fruits, vegetables, and specialties segments of the canned and preserved fruits and vegetables industry which were studied, have been separated into 58 subcategories as follows:

Fruits	Vegetables	Specialties
Apricots	Asparagus	Added Ingredients
Caneberries	Beets	Baby Food
Cherries	Broccoli	Chips
Sweet	Brussels Sprouts	Corn
Sour	Carrots	Potato
Brined	Cauliflower	Tortilla
Cranberries	Corn	Ethnic Foods
Dried Fruit	Canned	Jams & Jellies
Grape Juice	Frozen	Mayonnaise &
Canning	Dehydrated Onion/	Dressings
Pressing	Garlic	Soups
Olives	Dehydrated Vegetables	Tomato-Starch-
Peaches	Dry Beans	Cheese Specialties
Canned	Lima Beans	
Frozen	Mushrooms	
Pears	Onions (Canned)	
Pickles	Peas	
Fresh Pack	Canned	
Process Pack	Frozen	
Salting Stations	Pimentos	
Pineapples	Sauerkraut	
Plums	Canning	
Raisins	Cutting	
Strawberries	Snap Beans	
Tomatoes	Canned	
Peeled	Frozen	
Products	Spinach	
	Canned	
	Frozen	
	Squash	
	Sweet Potatoes	
	White Potatoes	

The major criteria for the establishment of the commodity subcategories were the water usage, the five-day biochemical oxygen demand (BOD_5) and the total suspended solids (TSS) in the plant wastewater. The basis of the subcategorization was primarily the raw materials processed and the products produced. Technical evaluation of factors such as age, size, and location of plant, production processes, and similarities in available treatment and control measures substantiated this industry subcategorization. Three size groups with separate limitations were necessitated for each commodity subcategory as a result of an economic analysis of the industry.

At this time, available data shows that at least 22 plants are achieving all of the 1977 - best practicable control technology currently available (BPCTCA) effluent limitations. This level of technology suggests land treatment and/or biological treatment, either aerated or aerobic lagoons or activated sludge, as capable of achieving the BPCTCA guidelines.

The 1983 - best available technology economically achievable (BATEA) effluent limitations are achievable by suggested in-plant controls and improved performance of BPCTCA technology with the addition of multi-media filtration for large plants. Each of the BOD5 and TSS limitations without filtration are presently met by eleven industry plants; the TSS limitations based on filtration as a part of BATEA are currently achieved by six industry plants including five plants without filtration.

New source performance standards (NSPS) reflect in-plant improvements which are presently being achieved by a number of plants in the industry and end-of-pipe treatment practices which are currently available. The basic treatment and control processes which are suggested as a means of meeting these performance standards are similar to those for existing plants by 1983. The preferred technology is land treatment because land availability requirements can be an important consideration in new source site selection.

Land treatment systems are effective and economic alternatives to the biological systems described above. When suitable land is available, land treatment is the preferred technology for July 1, 1977, for July 1, 1983, and for new source performance standards.

SECTION II

RECOMMENDATIONS

The effluent limitation attainable through the application of the Best Practicable Control Technology Currently Available are based on the performance of 27 secondary biological systems treating waste water from the fruits, vegetables, and specialties segments of the canned and preserved fruits and vegetables industry. The suggested Best Practicable Control Technology Currently Available includes screening and secondary biological treatment, either aerated or aerobic lagoons or activated sludge. In addition to biological treatment, BPCTCA for some commodities may include nutrient addition, air flotation, primary sedimentation, a roughing filter, and/or sludge handling. Where sufficient quantities of suitable land are available, land treatment systems such as spray irrigation provide an attractive alternative to biological treatment in order to achieve the BPCTCA effluent limitations. The BPCTCA effluent limitations guidelines are proposed for medium plants (2,000 to 10,000 total tons per year) and promulgated (interim final) for large plants (greater than 10,000 total tons per year) in all subcategories, based upon potential economic impact in the medium size group of plants. The BATEA effluent limitations guidelines are proposed for all plant sizes in all subcategories.

The ranges in the BPCTCA effluent limitations among the various commodity subcategories, in terms of raw material or finished product as appropriate, are summarized as follows: the annual average BOD_5 ranges from 0.03 - 2.29 kg/kkg, the maximum thirty day BOD_5 ranges from 0.04 - 3.47 kg/kkg, and the maximum day BOD_5 ranges from 0.07 - 5.31 kg/kkg; the annual average TSS ranges from 0.06 - 4.67 kg/kkg, the maximum thirty day TSS ranges from 0.10-6.36 kg/kkg and the maximum day TSS ranges from 0.12 - 8.64 kg/kkg; and the pH ranges from 6.0 to 9.5. In the specialties segment, the oil and grease concentrations are limited to 20 mg/l. BPCTCA effluent limitations for all subcategoires are tabulated in Section IX of this document.

The effluent limitations attainable through the application of the Best Available Technology Economically Achievable are based upon the improved performance of the BPCTCA secondary treatment plus disinfection, and in-plant controls. For large plants, multi-media filtration may be needed as an integral part of BATEA. Where sufficient quantities of suitable land are available, land disposal systems such as spray irrigation again provide an attractive alternative to biological treatment in order to achieve BATEA limitations.

The ranges in the BATEA effluent limitations among the various commodity subcategories, in terms of raw material or finished product as appropriate, are summarized as follows: the annual average BOD_5 ranges from 0.009 - 0.597 kg/kkg, the maximum thirty day BOD_5 ranges from 0.017-1.460 kg/kkg, and the maximum day BOD_5 ranges from 0.027 - 2.356 kg/kkg; the annual average TSS ranges from 0.009 - 1.389 kg/kkg, the maximum thirty day TSS ranges from 0.017-2.175 kg/kkg, and the maximum day TSS ranges from 0.027 - 4.288 kg/kkg; and the pH ranges from 6.0 to 9.5. In all segments, the fecal coliform MPN is limited to 400 counts per 100 ml and in the specialties segment, the oil and grease concentrations are limited to 20 mg/l. BATEA effluent limitations for all subcategories are tabulated in Section X of this document.

The new source performance standards are the same as those attainable through the application of BATEA. These limitations are possible because of the present availability of internal control and treatment technology to attain this level of effluent reduction. In addition and perhaps more important, new source site selection can assure land availability for land treatment facilities such as spray irrigation. Thus, the best available demonstrated technology for new sources is the best available technology economically achievable.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

On October 18, 1972, the Congress of the United States enacted the Federal Water Pollution Control Act Amendments of 1972. The Act in part required that the Environmental Protection Agency (EPA) establish regulations providing guidelines for effluent limitations to be achieved by "point sources" of wastewater discharged into navigable waters and tributaries of the United States.

Specifically, Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which require the application of the Best Practicable Control Technology Currently Available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which require the application of the Best Available Technology Economically Achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Section 307(b) and (c) of the Act requires the achievement of pretreatment standards for existing and new sources for introduction of pollutants into publicly owned treatment works for those pollutants which are determined not to be susceptible to treatment by such treatment works or which would interfere with the operation of such treatment.

Section 304(b) of the Act requires the Administrator to publish within one year of the enactment of the Act regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction practices achievable including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the fruits, vegetables, specialties segments of the canned and preserved fruits and vegetables processing industry category. The effluent limitations for the apple, citrus and potato segment of the industry were promulgated in the March 21, 1974, Federal Register (39 FR 10862).

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973, (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the fruit and vegetable industry source which was included within the list published January 16, 1973. An earlier development document (EPA - 440/1-74-027-a) established effluent guidelines for portions of the apple, citrus, and potato processing segments of the canned and preserved fruits and vegetables point source category. This report contains effluent guidelines for the remaining segments of the fruits and vegetables point source category.

SUMMARY OF METHODS USED DURING STUDY

Initial Survey

This study was initiated to gather the necessary information upon which to base recommended effluent guidelines and standards of performance for commodities within the fruits and vegetables point source category. These commodities represent differences in raw material, production processes, and products and by-products which frequently bear a direct relationship to the quality and quantity of wastewater.

The initial approach was to undertake a literature search and screening program to identify all processing plants in each commodity. Directories which describe the commodities and products and styles processed by each plant in the industry were utilized, along with industry journals, direct plant contact, trade associations, regulatory agencies, and staff knowledge.

An integral part of the initial screening program was a telephone survey which attempted to develop basic information about each processing plant. The primary purpose of the survey was to locate plants which warranted on-site field investigation due to the availability of historical data pertinent to raw waste generation and/or waste treatment performance. Another purpose was to determine how the available data might be obtained. Source data might be located at the plant itself, at a corporate headquarters, at a city or state regulatory agency, or, in some cases, through a university or private researcher. Another purpose of the survey was to locate those plants utilizing various types of treatment systems. Pertinent information obtained included relative percentages of plants discharging to municipal systems, direct discharging to surface waters, and those using land disposal for zero discharge. Detailed information from this survey is summarized in Tables 2 to 4.

On-Site Investigation

The information developed during the initial survey was evaluated to determine which plants in each commodity could provide the information necessary to subcategorize the industry and to identify BPCTCA. The selection of a plant for an on-site visit was made on the basis of the availability of historical raw waste data and availability of performance data from a biological treatment facility. Other factors influencing plant selections included the relative importance of the commodity, the number of representative plants in the commodity, and the treatment system's discharge quality. Approximately 300 plants were contacted for field visits. If practical, plants were visited during the processing of major commodities. Field engineers toured and evaluated production processes and waste treatment facilities to verify the quality of the production and wastewater data generated by the plant. Historical data including flow, production, and wastewater constituents were collected from processing plants and from city, county, or state agencies. In-plant processes were as thoroughly described as possible, and treatment and control costs were estimated as accurately as possible.

Wet sampling of effluent streams was conducted where necessary to verify the historical data collected or develop a data base for commodities. Time-interval automatic samplers were used to obtain 24-hour composite samples. The samples were collected in iced containers and transferred to three smaller bottles, two of which were frozen and one of which was acidified and chilled. The chilled bottle and one frozen bottle were air-shipped to the laboratory for analysis. The third bottle was retained frozen at the plant. Section VI of this report describes the analytical methodology.

Data Reduction

A computer assisted data handling and reduction system, which proved to be a very efficient tool for analyzing and presenting characterization data, was developed. The key to identifying, storing, sorting, and retrieving information in this system are the data codes which define the source and type of each item of data. Several related computer programs, which proved to be very efficient tools for analyzing and presenting characterization data, were used. The first program, was used to list the raw data, sort the data by code or source, and calculate for each commodity and each plant, by log normal distribution, raw waste load flow, BOD5, and TSS means, standard deviations, maxima, minima, range, standard error, and coefficient of symmetry.

Once a decision was made on subcategorization, the data from the selected plants in each subcategory were used by the next program, to compute and tabulate estimates of averages and minimums and maximums for each important wastewater parameter. The statistics were also based on a log normal distribution, as this was considered to be the best model for most of the data. More discussion of each aspect of the data handling and reduction system is presented in Section V.

DESCRIPTION OF INDUSTRY

The fruit and vegetable processing industry provides a market for a large part of the nation's fruits and vegetables. Approximately 90 percent of the beets; 80 percent of the tomatoes; 75 percent of the asparagus, lima beans, and leafy vegetables; 70 percent of the apricots, cranberries, and pears; 60 percent of the green or snap beans, peas, and sweet corn; and 50 percent of the peaches and cherries are preserved by the industry.

The industry operates approximately 2000 plants (as of 1967 census of manufacturers) and processes about 30 million tons of raw fruits and vegetables annually. Table 1 shows the distribution of processing plants by commodity as well as the estimated annual raw tonnage processed by commodity. Individual plants range in processing volume from about 500 to 700,000 tons of raw commodity per year. Average industry employment is approximately 200,000, ranging from about 40 in the smallest plants to 4,000 in the largest. On the average, where processing of raw foods is a part of the business community, approximately seven percent of the local work force is employed at least part-time by the processor. The industry's plants operate an average of eight months per year and process 75 percent of their raw products in four months for sales of about five billion dollars annually.

Fruit and vegetable processing plants are major water-users and waste-generators. Raw foods must be rendered clean and wholesome for human consumption, and food processing plants must be sanitary at all times. Therefore, relatively large volumes of clean water are used and sometimes reused prior to discharge. While many variations in wastewater strength and volume can be controlled through good in-plant management, some variations will be unavoidable and these must be recognized in the treatment design. Tables 2, 3, and 4 summarize wastewater disposal methods developed from the initial telephone survey. Table 2 summarizes treatmentl methods by state, and Tables 3 and 4 summarize treatment methods by commodity. The tables summarize data provided by 770 of over 1000 plants contacted. Generally, 55 percent discharged to municipalities, 33 percent discharged to land, and 12 percent discharged to navigable waters.

Since processing plants are operated by different plant management staffs and the availability of water and other

TABLE 1

TOTAL NUMBER OF PLANTS PROCESSING VARIOUS COMMODITIES AS REPORTED BY JUDGE'S DIRECTORY ; AND ESTIMATED ANNUAL RAW PRODUCT TONNAGE AS COMPILED BY SCS ENGINEERS FROM VARIOUS SOURCES

Commodity	Number of plants	Annual 10^3 tons
Apricots	49	146
Blueberries	--	19
Caneberries	100	32
Cherries	101	147
Cranberries	13	74
Figs	15	35
Grapes	21	256
Peaches	70	739
Pears	38	348
Pineapple	23	1,096
Plums	66	25
Prunes	26	597
Rhubarb	--	6
Strawberries	110	84
Artichokes	1	--
Asparagus	75	99
Beets	59	190
Broccoli	33	213
Carrots	104	169
Cauliflower	53	96
Corn	125	2,114
Green beans	223	613
Lima beans	60	91
Mushrooms	55	116
Okra	22	17
Olives	48	54
Onions (canned and dehydrated)	--	19
Peas	189	512
Peppers and chilis	59	4
Pickles	132	571
Pimentoes	19	30
Pumpkin and squash	21	110
Sauerkraut	58	193

TABLE 1 (Continued)

Commodity	Number of plants	Annual 10^3 tons
Spinach	84	196
Brussel sprouts	33	57
Sweet potatoes and yams	--	94
Tomatoes	270	5,805
White potatoes	50	60
Zucchini	50	9
Canned dry beans	25	100
Soup	--	--
Potato chips	--	--
Sauces and dressings	--	242
Canned specialties	--	--
Dehydrated vegetables	--	61
Dry fruits (peaches, pears, apricots)	--	36
Baby food	--	425

(1) Many plants process several commodities and are therefore included more than once.

TABLE 2

SUMMARY OF DISPOSAL METHODS USED BY STATE AS REVEALED BY TELEPHONE SURVEY

State	Municipal	Navigable waters	Land	Total
Alabama	2	0	2	4
Arizona	2	0	0	2
Arkansas	8	2	3	13
California	107	9	22	138
Colorado	8	0	2	10
Delaware	4	5	3	12
Florida	8	0	5	13
Georgia	3	1	4	8
Hawaii	1	1	2	4
Idaho	2	5	6	13
Illinois	6	1	9	16
Indiana	9	14	13	36
Iowa	3	3	4	10
Kentucky	2	0	1	3
Louisiana	3	0	4	7
Maine	9	9	4	22
Maryland	7	2	20	29
Massachusetts	7	1	0	8
Minnesota	3	10	15	28
Michigan	12	11	38	61
Mississippi	0	1	2	3
Missouri	1	0	1	2
New Hampshire	0	1	0	1
New Jersey	14	3	7	24
New York	19	12	27	58
North Carolina	4	1	6	11
Ohio	19	7	16	42
Oklahoma	3	0	3	6
Oregon	37	10	21	68
Pennsylvania	33	6	34	73
South Carolina	0	1	0	1
Tennessee	1	0	3	4
Texas	13	2	4	19
Utah	3	0	0	3
Virginia	4	10	19	33
Washington	26	9	26	61
West Virginia	1	1	0	2
Wisconsin	25	19	37	81
Totals	409	157	363	929

(1) Some plants discharge separate waste streams to more than one disposal point and are counted more than once.

TABLE 3

SUMMARY OF DISPOSAL METHODS USED BY PLANTS PROCESSING VARIOUS FRUITS, AS REVEALED BY TELEPHONE SURVEY

Commodity	Municipal	Navigable waters	Land	Total
Apricots	16	1	3	20
Caneberries	21	4	13	38
Blueberries	12	9	5	26
Cherries	25	11	40	76
Dates, figs, prunes	16	1	14	31
Grapes	11	0	6	17
Peaches	26	5	11	42
Pears	10	4	4	18
Pineapple	2	1	1	4
Plums	10	2	15	27
Raisins	3	0	2	5
Rhubarb	5	1	6	12
Strawberries	29	4	15	48
Cranberries	3	0	1	4
Preserves	4	0	0	4
Totals	193	43	136	372

Notes:

1. Many plants process several commodities and are therefore included more than once.
2. The telephone survey included approximately 800 plants nationwide.

TABLE 4

SUMMARY OF DISPOSAL METHODS USED BY PLANTS PROCESSING VARIOUS VEGETABLES, AS REVEALED BY TELEPHONE SURVEY

Commodity	Municipal	Navigable waters	Land	Total
Artichokes	1	0	0	1
Asparagus	10	5	20	35
Beets	12	2	13	27
Broccoli	17	2	2	21
Carrots	38	6	24	68
Cauliflower	15	3	6	24
Corn	22	7	58	87
Garlic (dehydrated)	3	0	0	3
Green beans	38	11	37	86
Lima beans	22	3	15	40
Mushrooms	13	0	5	18
Okra	6	1	2	9
Olives	10	1	3	14
Onions (canned and dehydrated)	8	1	6	15
Peas	40	13	48	101
Peppers and chilis	19	4	10	33
Pimentos	4	1	4	9
Pumpkin and squash	13	3	12	28
Spinach and greens	36	5	19	60
Brussel sprouts	6	2	2	10
Tomatoes	45	9	41	95
Pickles	33	14	16	63
Sauerkraut	5	2	9	16
Canned dry beans	19	4	18	41
Soup	2	1	1	4
Total	437	100	371	908

Notes

1. Many plants process several commodities and are therefore included more than once.
2. The telephone survey included approximately 800 plants nationwide.

resources varies from plant to plant, wide ranges of wastewater volume and organic strength are generated per ton of raw product among plants processing the same product. Different waste volumes and strengths are also generated from different styles of the same product, such as peeled versus pulped style. Product quality is influenced by the weather and may vary among regions and years; it also affects the generation of wastes. Wastewater volume and organic strength also vary among days of the operating season and periods of the operating day. Facilities to treat these wastewaters must therefore be designed to handle large volumes intermittently rather than constant flow rates and constant organic concentrations.

During the past twenty years there has been a constant consolidation of smaller fruit and vegetable operations into larger, more centralized process operations, resulting in greater usage of water and more discharge of wastes per operation. Thus, during the highly seasonal periods of operation in the industry, it is not unusual for a process operation to utilize much more water and to generate more waste than the community in which the operation is located. The waste loads in the industry are generated within a relatively small harvest period during the year while treatment systems must be geared to prevent pollution at periods when rainfall and stream flow are at a minimum. Further, where the wastes are channeled into municipal systems, controls should be exercised to ensure these systems are not overtaxed in capacity or inadequate for the community requirements.

In order to lessen the problems created by the necessity of using relatively large volumes of water, some segments of the fruit and vegetable processing industry have engaged in programs of research and demonstration projects. Significant achievements have been made and will continue to be made in the following:

Reduction of fresh water requirements through use of recycled systems.

Segregation of strong wastes for separate treatment.

Modification of processes to minimize waste generation.

Education of plant personnel regarding pollution control and water conservation.

Cooperative efforts with government agencies in wastewater characterization and development of more sophisticated or less costly treatment procedures.

Some processors discharge their cooling waters directly without treatment. These waters should be relatively uncontaminated and should be handled separately from process water. The BOD_5 concentration usually can be controlled at about 10 mg/l average, 20 mg/l maximum and with caution could be discharged to navigable waters directly in many cases. An exception may be when large amounts of cooling water are recycled and reused. In this case, the cooling water BOD_5 concentration may exceed 20 mg/l while the load in kilograms per unit of production may be significantly reduced from similar plants not reusing cooling waters. Depending on water quality requirements this water may require treatment prior to discharge.

The fruit and vegetable industry discharges a much higher proportion of its liquid waste to public sewers and to land treatment than do manufacturers as a whole. Discharges to land are principally by irrigation, mostly by spray irrigation, but also by seeping from ponds or lagoons and by pumping into non-productive wells. Land treatment generally removes very high percentages of the pollutional load.

GENERAL PROCESS DESCRIPTIONS

Harvesting

Mechanical harvesting has been applied recently to many crops, and further developments are to be expected. Certain crops such as green peas, lima beans, snap beans, spinach, corn, tomatoes, cranberries, cherries, beets, peaches, apricots, carrots, and turnips are now wholly or in part mechanically harvested. Formerly, certain wastes, such as vines and stalks, were accumulated during harvest and disposed of in one manner or another, usually as mulch or animal feed. However, other unusable parts of vegetables and fruits are not always separated at the field or orchard but are transported to temporary storage or to the processing plant. Separation of cull material by hand during mechanical harvesting is being done to some extent for tomatoes and potatoes.

Mechanical harvesting, while beneficial economically, in other respects may be accompanied by certain undesirable effects:

Greater physical damage to the crop, such as split skins on tomatoes, bruises on peaches and cherries, broken ends of snap beans, smashed kernels of corn, and damage to plant or tree.

Inclusion of soil with the harvested crop, particularly with vegetables, and greater numbers of microbes adhering to the product surface.

Loss in yield and delivery of products at non-optimal maturity from non-selective harvesting.

Physically damaged areas of products such as tomatoes frequently become focal points for lodging of soil, sand, and dust which may lead to microbial growth of various types of organisms. Rotting may readily occur at the damaged areas.

Certain crops such as asparagus, artichokes, broccoli, brussels sprouts, cauliflower, pears, and apricots must still be hand harvested for any of several reasons, including:

> Maturation of fruits or vegetables differs from one part of the plant or tree to another; e.g., peaches, brussels sprouts.
>
> Mechanical harvesting would damage the easily bruised crop; e.g., pears, peaches.

In-Field Processing

In-field processing or preparation of the crop for subsequent processing has been used in one form or another for a considerable period. Recent developments include devices to assist in the removal of "trash" (stems, sticks, leaves, soil) from various crops which have been mechanically harvested or mechanically loaded, such as tomatoes and cucumbers.

Some mechanical harvesting devices also sort the products according to size. Experimental systems for sorting tomatoes by color have been developed. The concept of pre-washing and pre-sorting snap beans has been used in receiving stations to facilitate central process plant operations.

There are several advantages to such in-field treatment, including prompt processing after harvest, elimination of much damage and loss of solids during transport of fresh fruit, and retention of wastes, culls, seeds, peel, and soil near the points of production. Separated wastes can be retained for disposal in field soils.

Transport to Plant

Harvested commodities require transport to a treatment or process facility. In some instances multiple transportation is involved. The procedures in handling crops for transport have changed materially in the last decade. A significant development has been the direct transfer from mechanical harvesters into dry bulk loading trucks (e.g., beets, carrots, peas, corn, tomatoes, and beans), and tote bins, or boxes, eliminating the use of smaller containers such as sacks, baskets, hampers, or lug boxes. There has been some transport of crops such as cherries in water. Tomatoes and potatoes have been transported in water experimentally.

Transport of crops in water is believed to provide possible economic advantages as well as such benefits as partial wash or soak, cooling, and ease of transfer through fluming at destination. However, the successful utilization of water as a transport medium for harvested crops depends on several factors:

The adaptability of the commodity to such treatment. Tomatoes transported in water, for example, are subject to splitting.

The limitation of container size to that at which undersirable pressures on the product, which could cause bruising during handling, do not occur.

The availability of water.

The control of microbial growth.

The economics of increased freight rates.

The new methods of transport have been applied for economy, improvement in quality, and adaptation to other phases of the operations. The integration of mechanical harvesting with bulk transport facilities has decreased the delay between field and processing plant, and has permitted improved management of the harvesting and processing operations.

Storage

Generally, vegetables and fruits grown for processing are prepared and processed soon after harvest, usually within a few hours. However, instances occur when it is necessary to hold the raw products for significant lengths of time before they can be packed. Such delays may be occasioned by one or more of the following circumstances:

The necessity of accumulating sufficient supplies to justify the start of processing operations.

The necessity of having products available in the morning before the day's harvest is in from the fields.

The necessity of assembling and transporting raw products grown considerable distances from the processing plant.

The necessity of holding over weekends and holidays.

Accumulations of raw products at peak periods of harvest over the capacity to handle them.

Interference with operations because of unanticipated breakdown in equipment or lack of labor.

The desirability of extending the operations beyond the normal period of harvest.

The improvement in yield and quality where controlled harvesting, storage, and ripening techniquest are employed (e.g., pears).

Pears, peaches, and apricots are commonly held in cold storage and/or ripening rooms to control ripening and achieve the desired texture for processing. Temperature and humidity are closely controlled in these operations.

Cherries for glacing, maraschinos, and fruit cocktail are stored in wood tanks under brine containing sulfur dioxide and calcium salts.

Olives for black ripe curing may be stored under salt brine to hold until they are processed. New techniques have replaced some of the salt brine storage. These are accomplished through the use of anaerobic tanks and are proven successes to olive processors.

<u>Receiving</u>

Receiving is generally in 40-50 pound lug boxes, half-ton bins, or larger bulk loads. Bulk loads may be unloaded by opening side or tail gates and driving the truck or trailer upon a sloping ramp so that the commodity can be moved by gravity to a mechanical or hydraulic conveying system. Stacks of bins and lug boxes are unloaded by fork lift trucks, and are usually inverted mechanically into a dump tank or onto the in-plant conveyance system. Recent developments utilize water to bulk flood tomatoes into receiving gondolas at the plant and subsequently flume the product from the container to the processing facility.

<u>Washing and Rinsing</u>

Fruits and vegetables for processing are washed and rinsed. These treatments are applied for a number of reasons:

Removal of soil, dust, pesticides, microbial contamination, insects, and their residuals.

Removal of adhering juices of exudate, products of respiration or of spoilage.

Removal of extraneous matter such as leaves, stems, dirt, stones, and silk.

Removal of occluded solubles or insolubles such as occur during cutting, coring, peeling, and blanching.

Cooling.

Extraction of solubles such as preservative salts or acids.

The quantity of water used in wash and rinse operations may be as much as 50 percent or higher of the total usage in process operations. These washings may be accomplished by flumes, soak tanks, water sprays, flotation chambers, or any combination of these methods. Not uncommonly, water which has previously been used for cooling may be reused for washing (and fluming) of raw products.

Detergents are being increasingly used to wash vegetables, particularly those grown in contact with the soil or harvested by mechanical harvesters. Ultrasonic techniques are being tested for increasing cleaning efficiency. Hot water and steam blanching serve to promote cleanliness of vegetables subject to this treatment, for reducing entrapped air, inactivating enzymes, and setting colors.

Winnowing in an air blast removes dust and lightweight contaminants from many raw products, including shelled peas and beans.

Sorting (Grading)

For size grading, the shape and size of commodities determine the type of grader which is suitable. For some products sizing is done by hand. However, decks of vibrating slots, or perforated sheets (or screens) with increasingly large perforations, serve to mechanically size most commodities. A variation uses perforated cylindrical screens. Tapered or canted rolls are alternately used for other commodities (pineapples). Diverging cables are used for sizing olives without bruising.

Sizing is important for many commodities because it facilitates handling operations (pitting, peeling, filling) and affects the number of servings or pieces that can be secured from a package of a specified size. Many sizing operations are performed to utilize a particular machine design that has been present for a certain size fruit or vegetable.

Fruit to be mechanically pitted, such as peaches, and fruit or vegetables to be peeled, whether mechanically or by other means, often have to be size graded. Corn huskers and green bean snippers and cutters operate best for size graded material.

Density graders employing brine of controlled density are used to separate over-mature peas and beans from products of optimum maturity. Weed seeds, chaff, heavy stones, and earth pellets may also be separated by density and in froth separators.

Grading for appearance may be accomplished by mechanical means in limited instances. Beans are separated for color by devices which scan for color, and accept or reject particles automatically.

More commonly, sorting for appearance and texture is accomplished by visual inspection by trained graders on conveyors under special lights. Traveling roller conveyors rotate individual tomatoes or other fruit so that all surfaces are exposed. Blemished fruit and over- and under-mature fruit are identified and diverted to waste or special uses (as nectar for green or soft-ripe apricots). Hand trimming of blemishes is often sufficient to prevent undesirable material from entering juices and purees. Hand trimming of products like tomatoes and freestone peaches enables processors to meet requirements of government inspection agencies.

Pressure testers (penetrometers) and mechanical chewing devices (tenderometers) are used in the field and laboratory for estimating the maturity of fruits and vegetables as a guide for harvesting and also for grading of processed products.

Cranberries received from the field or after refrigerated storage are sorted to eliminate soft fruit by bouncing individual berries over a barrier. Those that fail in three attempts are discarded.

Stemming, Snipping, Trimming

Stemmers and bunch breakers are used to remove stems from grapes, cherries, blueberries, etc. The design of these machines varies. Thompson seedless grapes, intended for canning alone or in cocktail, are stemmed by pulling from the bunches in reels which also separate cap stems from the stemmed grapes. Similar grooved cylinders are used to stem and seed raisins and snap beans. The ends are snipped from green pods by snippers which tumble the beans in reels until the ends protrude through slots and are cut off by knives.

In-Plant Transport

Various means have been adapted for conveying fruit or vegetable products at unloading docks into and through the processing plant. These include fluming, elevating, vibrating, screw conveying, air propulsion, negative air conveying, hydraulic flow, and jet or air blasting. Water, in one way or another, has been extensively used in conveying products within plants because it has been economical in such use and because it serves not only as conveyance but also for washing and cooling.

It has been traditional to consider water an economical means to transport fruits and vegetables within a plant and to assume there was some sanitary significance to such use, not only for the product, but also for the equipment. A significant disadvantage, however, may be leaching of solubles from the product, such as sugars and acids from cut fruit; and sugars and starch from cut corn, beets, and carrots. Alternative systems to decrease such losses from water have been investigated, such as osmotically equivalent fluid systems.

Peeling

Many fruits and vegetables are peeled for processing. This serves the multiple purpose of removing residual soil, pesticide residues, and coarse, fuzzy, or tough peeling with unpleasant appearance, mouth feel, or digestive properties.

Peeling is accomplished mechanically by cutting or abrasion; thermally by puffing and loosening the peel by application of steam, hot water, hot oil flame, or blasts of heated air; or chemically, principally using caustic soda (with optional surfactants) to soften the cortex so it may be removed by high-pressure water sprays. Table 5 shows methods for peeling fruits and vegetables.

Root crops, including carrots, potatoes, and beets, have a thick cortex which is commonly removed by first softening and loosening by steam under pressure. When the pressure is reduced suddenly, the peel puffs and can be removed by high-pressure sprays of water. Steaming before exposure to lye increases efficiency of lye peeling.

Hot caustic soda solutions used for chemical peeling range in strength from one percent for thin-skinned produce to as high as eighteen percent for some tough-skinned commodities. Temperature of caustic solution, design of soak tank, and length of contact with lye also determine concentration required. In large operations, the caustic soda may be received in tank cars as a concentrated solution and diluted to the desired strength as needed. The peeling solution is recirculated until it becomes contaminated. The strength is maintained by periodic checking and adjustment, or continuously, by automatic devices. Residual caustic soda is thoroughly rinsed from the surface of peeled fruits and vegetables. If a change in pH is undesirable, commodities may be subjected to a rinse with dilute sulfuric or citric acid.

Abrasion peelers may be of batch or continuous type. The batch peelers comprise separate disk bottoms and cylindrical bowl sides covered with a water resistant abrasive. Continuous abrasive peelers are constructed of rotating rollers covered with abrasive, over which the product is conveyed.

Thin-peeled fruits such as tomatoes are easily peeled and may be cored simultaneously in automatic machines. In these and other automatic peelers, or combination peelers and coring devices, individual fruit are positioned in "cups" or an equivalent, either by hand or by mechanical positioners which use jogging to orient the fruit into the desired position.

In flame peeling, now principally used for pimentoes and peppers, the commodity is exposed to high temperature gases or combustiom momentarily, to puff and loosen and sometimes char the peel, which is then removed by high-pressure water sprays.

Recently, the use of "dry caustic" peeling has gained wide acceptance for commodities such as peaches, potatoes, tomatoes, onions, carrots and beets. After normal exposure to hot lye, the skins are "scrubbed" from the fruit while minimizing peel removal

TABLE 5

METHODS FOR PEELING FRUITS AND VEGETABLES

Method of Peeling	Action	Products	Comments
Hot water	Disintegrates tissue beneath peel, causing peel to become loose, and easily removed.	Tomatoes, very ripe peaches, beets, sweet potatoes, freshly dug potatoes	Excellent
Live steam	Same as above.	Same as above.	Good, often not uniform.
Steam pressure	Develops pressure beneath peel which when suddenly released removes peel by explosion.	Sweet potatoes, potatoes, other root crops, and apples.	Good, but must be controlled.
Hot oil (450°F)	Disintegrates tissue beneath peel, causing it to become loose.	Pimientos.	Fair, there may be an oil residue.
Flame (1,000°F or higher)	Blisters, chars, flakes, disintegrates peel.	Pimientos, onions, small potatoes, other root crops.	Limited use; wasteful of product.
Abrasion	Rotates product against abrasive surface, wearing away peeling to the desired depth.	Potatoes, beets.	Good, but wasteful.
Lye	Disintegrates peel, tissue, "eyes" to desired depth.	Peaches, pears, grapefruit segments, sweet potatoes, potatoes, carrots, tomatoes, apricots, and others.	Good, efficiency improved by wetting agent. Waste may be high.
Knives	Special designs: by hand or mechanically operated blades.	Apples, pears, root crops.	Good, but limited capacity, wasteful.

TABLE 5 (Continued)

Method of Peeling	Action	Products	Comments
Freezing	Breaks down tissue beneath peel, causing latter to loosen.	Non-browning peaches and other fruits.	Poor
Ultrasonics	Same as above.	Tomatoes, very ripe peaches, ripe fruits.	Little known, but promising.

water volume. In some cases, the semi-moist peel may be removed from the plant without ever entering the waste stream.

Pitting and Coring

Many fruits used for canning and freezing contain seeds or cores which are removed for processing. This is usually done mechanically. Pears are cored in machines with special contour blades which remove the cores.

Tomatoes are cored by pressing the stem end against a whirling burr reamer. Onions and carrots may be cored or "hydrouted" by a similar whirling knife reamer. Peaches and apricots are pitted and halved simultaneously. Pits are removed by knives, or by twisting the halves in opposite directions. Cherries are pitted by specially designed plungers. Dates and olives are pitted by similar techniques.

Slicing and Dicing

Slicing is often combined with pitting and coring or accomplished in a separate machine. The commodity may be halved, or it may be cut in wedge-shaped "segments" or in flat rings, or it may be diced, as peaches and pears for fruit coctail, etc.

Dicing is accomplished by simultaneous two-directional cutting. The product to be cut may be delivered through a hopper into a stationary chamber. Rotating impeller blades whirl the product at high speed. As a steady stream of slices passes out of the chamber over an immobile knife, an external rotary knife cuts the product into square cross-section strips. The latter move at high velocity into a set of circular knives that cut the strips into cubes which are ejected through a discharge spout.

Pureeing and Juicing

Widely varied techniques are used for pressing and separating fluid from fruits and vegetables. Equipment includes reamers and a wide variety of crusher-presses, either batch or continuous in operation. Juice presses include:

Batch Hydraulic Presses. The whole or chopped material is placed in bags which are stacked alternately with separator grids and subjected to hydraulic pressures.

Pulpers. These involve tapered screws or paddeles ehich mash and/or squeeze juice and puree through a cylindrical screen while carrying the pomace for separate dry handling.

Finishers. These use brushes or paddles to knead and squeeze the juice or fine puree through a cylindrical screen discharging the pomace at the end of the screen.

Reels and Vibrating Screens. Reels, usually with lifting flights, tumble the pomace and allow the juice to drain through the cylindrical screen. Vibrating screens, both rectangular and circular, are used for straining juice and for classifying purees by particle size (using multiple decks). Vibration causes the pomace to flow from the feed to the discharge and prevents the screen from clogging.

Wilmes Presser. Has a "balloon" in the center which, when inflated, presses the puree against a perforated screen. The puree is first mixed with rice hulls to facilitate the flow of juice.

Deaeration

The oxygen and other gases (nitrogen, carbon dioxide) present in freshly pressed or extracted fruit and vegetable juices may be effectively removed by deaeration under vacuum. The liquids to be deaerated are pumped into an evacuated chamber either as a spray or as a thin film. Modern deaerators operate at a vacuum of 29 inches or above. Deaeration properly carried out not only improves color and flavor retention, but reduces foaming during filling and also reduces separation of suspended solids.

Concentration by Evaporation

In the concentration of solutions by evaporation, the liquid to be concentrated continuously flows across a heat exchange surface which separates it from the heating medium. The heating medium may range from high-pressure steam at 365°F to ammonia vapor at 60°F. The heating surface is usually a metal wall in the form of a tube plate or kettle wall. "Thermo-siphon," or natural circulation, is circulation of the product resulting from reduction in the specific gravity of the solution on heating and from pressure generated by vapor evolved at the heat exchange surface. Natural circulation evaporators are usually inexpensive but are difficult to use for concentration of viscous solutions such as 30 percent tomato paste. For such products, a circulating pump is used to ensure high velocity across the heating surface. Such systems are called forced circulation evaporators.

There are various types of evaporators, including: open kettles, shell-and-tube heat exchangers, flash evaporators, rising- and falling-film evaporators, plate type evaporators, thin-film centrifugal evaporators, vapor separators, vacuum evaporators, and heat pump evaporators.

The process involves heating the product to evaporation and separating the vapors from the residual liquid.

Size Reduction

A wide range of size reduction equipment is required to produce different types of particulated solids. Selection of a machine which can most economically produce desired results is affected by physical characteristics of the material and by the required particle size and shape. Often special modifications of equipment are required to prevent damage to such qualities as flavor or appearance.

Mechanical devices used to particulate foods are limited to four fundamental actions:

Compression. Using a more-or-less slow crushing action.

Impact. Producing a shattering or splattering action.

Attrition. Wearing off the smaller particles by abrasion.

Shearing or cutting using a slicing or chopping action.

Blanching

Blanching of vegetables for canning, freezing, or dehydration is done for one or more reasons: removal of air from tissues; removal of solubles which may affect clarity of brine or liquor; fixation of pigments; inactivation of enzymes; protection of flavor; leaching of undesirable flavors or components such as sugars; shrinking of tissues; raising of temperature; and destruction of microorganisms.

Water blanching may be accomplished in several different ways. The most common type of water blancher consists of a continuous stainless steel mesh conveyor situated in an elongated tank (typically four to five feet wide and twenty to thirty feet long) which is usually half-filled with heatted (150-210°F) water. The product to be blanched is continuously fed onto the mesh conveyor at a constant rate (to maintain desired bed depth) so that the product is totally submerged. Residence times vary with the type of end product desired and the vegetable being processed.

A second type of hot water blancher is a tube or pipe type arrangement through which the vegetable is conveyed by pumping heated water and product together (e.g., peas and sliced or diced carrots). The length of the pipe, the velocity of the hot water-product combination, and the temperature of the water are all variables that can be changed to produce the desired end product.

A third type of water blancher typically used on dry beans consists of an auger which screw-conveys the product through heated water.

Steam blanching is typically done in an elongated (three to five feet wide and twenty to thirty feet long) stainless steel tank through which a continuous stainless steel mesh chain is passed. The chamber is typically fed by several inputs of steam so that when vegetables are run through the blancher, they are surrounded and permeated by the steam. Length of blancher, product bed depth, and speed of conveyor are the controlling variables.

In almost all cases for preparation of vegetables to be frozen, it is imperative that the blancher processes be terminated quickly. Consequently, some type of cooling treatment is used. Typically, if the product has been water blanched, the vegetable is passed over a dewatering screen and cooled either by cold water flumes or cold water sprays. Product to be canned is usually not cooled after blanching.

The pollution loads from blanching are a significant portion of the total pollution load in the effluent stream during the processing of certain vegetables.

Canning

The sanitary codes of most states require that cans be washed before being filled. There are usually three steps in the can cleaning operation. First, the cans travel a short distance in the inverted position; second, they are flushed with a relatively large volume of water under high pressure; and third, they travel another short distance in the inverted position for the purpose of draining excess water. This is usually accomplished mechanically.

The commodity is then filled into the can by hand, semi-automatic machines, or fully automatic machines, depending on the product involved. In some products, there is a mixture of product and brine or syrup. In other cases, brine or syrup is added hot or cold as top-off liquid. When the top-off is cold, it is necessary to exhaust the headspace gases to achieve a vacuum and maintain product quality.

Exhausting

Exhausting is usually accomplished mechanically by one of three methods:

Thermal exhaust or hot filling. The content of the container are heated to a temperature of 160° to 180°F, prior to closing the container. Contraction of the contents of the container after sealing produces a vacuum.

Mechanical. A portion of the air in the container headspace is pumped out by a gas pump.

Steam displacement. Steam is injected into the headspace in such a way as to sweep out air, replacing it with steam. The container is immediately sealed. A vacuum is produced when steam in the headspace condenses.

TABLE 6

NATIONAL CANNERS ASSOCIATION WATER ECONOMY CHECK LIST

Operation or Equipment	May Recovered Water be Used?	May Water From This Equipment be Reused Elsewhere in Plant?	Source of Water for Reuse in Equipment*
1. Acid dip for fruit	yes	no	Can coolers
2. Washing of product			
A. First wash followed by 2nd wash	yes	yes*	Can coolers
B. Final wash of product	no	yes*	
3. Flumes			
A. Fluming of unwashed or unprepared product (peas, pumpkin, etc.)	yes	yes*	Can coolers
B. Fluming partially prepared product	yes	yes*	
C. Fluming fully prepared product	no	yes	
D. Any fluming of wastes	yes	no	Any wastewater
4. Lye peeling	yes	no	Can coolers
5. Product-holding vats; product covered with water or brine	no	no	
6. Blanchers - all types			
A. Original filling water	no	no	
B. Replacement or make-up water	no	no	
7. Salt brine quality graders followed by a fresh water wash	yes	Only in this equipment	
8. Washing pans, trays, etc.			
A. Tank washers - original water	no	no	
B. Spray or make-up water	no	no	

TABLE 6 (Continued)

Operation or Equipment	May Recovered Water be Used?	May Water from This Equipment be Reused Elsewhere in Plant?	Source of Water for Reuse in Equipment*
9. Lubrication of product in machines such as pear peelers, fruit size graders, etc.	no	yes*	Can coolers
10. Vacuum concentrators	yes	in this equipment after cooling and chlorination	
11. Washing empty cans	no	no	
12. Washing cans after closing	yes	yes	Can coolers
13. Brine and syrup	no		
14. Processing jars under water	yes	for processing	Can coolers and processing waters
15. Can coolers			
A. Cooling canals			Waters from these coolers may be reused satisfactorily for cooling cans after circulating over cooling towers, if careful attention is paid to proper control of replacement water, and to keeping down bacterial count by chlorination and frequent cleaning.
1. Original water	no		
2. Make-up water	yes		
B. Continuous cookers where cans are partially immersed in water			
1. Original water	no		
2. Make-up water	yes		
C. Spray coolers with cans not immersed in water	yes	This water may be reused in other places as indicated.	
D. Batch cooling in retorts	yes		
16. Clean-up purposes			
A. Preliminary wash	yes	yes*	Can coolers
B. Final wash	no	no	
17. Box washers	yes	no	Can coolers

*A certain amount of water may be reused for make-up water and in preceding operations if the counterflow principle is used with the recommended precautions.

Cans and glass containers are usually mechanically sealed immediately after exhausting.

A can or jar of canned food contains a sterilized product which at normal room temperature will remain unspoiled indefinitely from a microbiological standpoint, and depending on the type of food will have a marketable quality shelf life from six months to two years or longer.

When a product is sterilized, it is free of viable micro-organisms. Commercial sterility is achieved through the various systems described below and may be defined as that degree of sterility at which all pathogens and toxin-forming organisms have been destroyed as well as other more resistant types which, if present, could grow in the product and produce spoilage under normal storage conditions.

Pasteurization may be defined as a heat-treatment that kills part but not all of the organisms present and usually involves the application of temperatures below 212°F. In pasteurized canned foods, preservation is affected by a combination of a heat treatment and other factors such as a low pH, a high concentration of sugar, a high concentration of salt, and storage at temperatures of 32° to 40°F. Canned foods preserved by a pasteurization process as defined are, generally speaking, commercially sterile. Foods with a pH of less than 4.5 are often preserved by pasteurization at temperatures of 212°F or below.

The lethal effect of heat on bacteria is a function of the time and temperature of heating and the bacterial population of the product. To design or evaluate an in-package heat process, it is necessary to know the heating characteristics of the slowest heating portion of the container, normally called the cold zone, the number of spoilage organisms present, and the thermal resistance characteristic of the spoilage organisms.

<u>Water Reuse</u>

The acceptability of procedures for reuse of water in processing operations requires certain considerations:

> Water is an excellent solvent and vector, and is readily modified, chemically, physically, and microbiologically. Thus, one use may or may not render water suitable for upstream application, such as primary washing.
>
> Recovered downstream, the water may be suitable for further use only when given enough treatment to be considered potable.
>
> The soil, organic, or heat loads in the used water may be such that considerable treatment is necessary to render it suitable for reuse.

Table 6 shows some reuse factors in the fruit and vegetable industry (taken from <u>Liquid Wastes from Canning and Freezing Fruits and Vegetables</u>, by NCA).

Clean-Up

Clean-up operations vary widely from plant to plant and from product to product. Normally the plant and equipment is cleaned at the end of the shift, usually by washing down the equipment and floors with water. In some plants it is desirable to maintain a continuous cleaning policy so that end-of-shift clean-up is minimized. Continous recirculation of waste water to clean gutters has also helped reduce clean-up wastes.

The washdown may be done with either water alone or with water mixed with detergent. Water is applied through either high-volume, low-pressure hoses or low-volume, high-pressure hoses.

In some operations, such as the mayonnaise processing operation, clean water is used to flush out the entire system at the end of the shift to remove any residues which might harbor bacteriological growth.

The water used in clean-up operations generally flows through drains directly into the water waste system.

COMMODITY SPECIFIC PROCESS DESCRIPTIONS

The process descriptions for each commodity are given below. A general commodity discussion is followed by a description of processing from harvesting to canning, freezing or dehydrating. Then the generation of wastes is discussed along with water reuse.

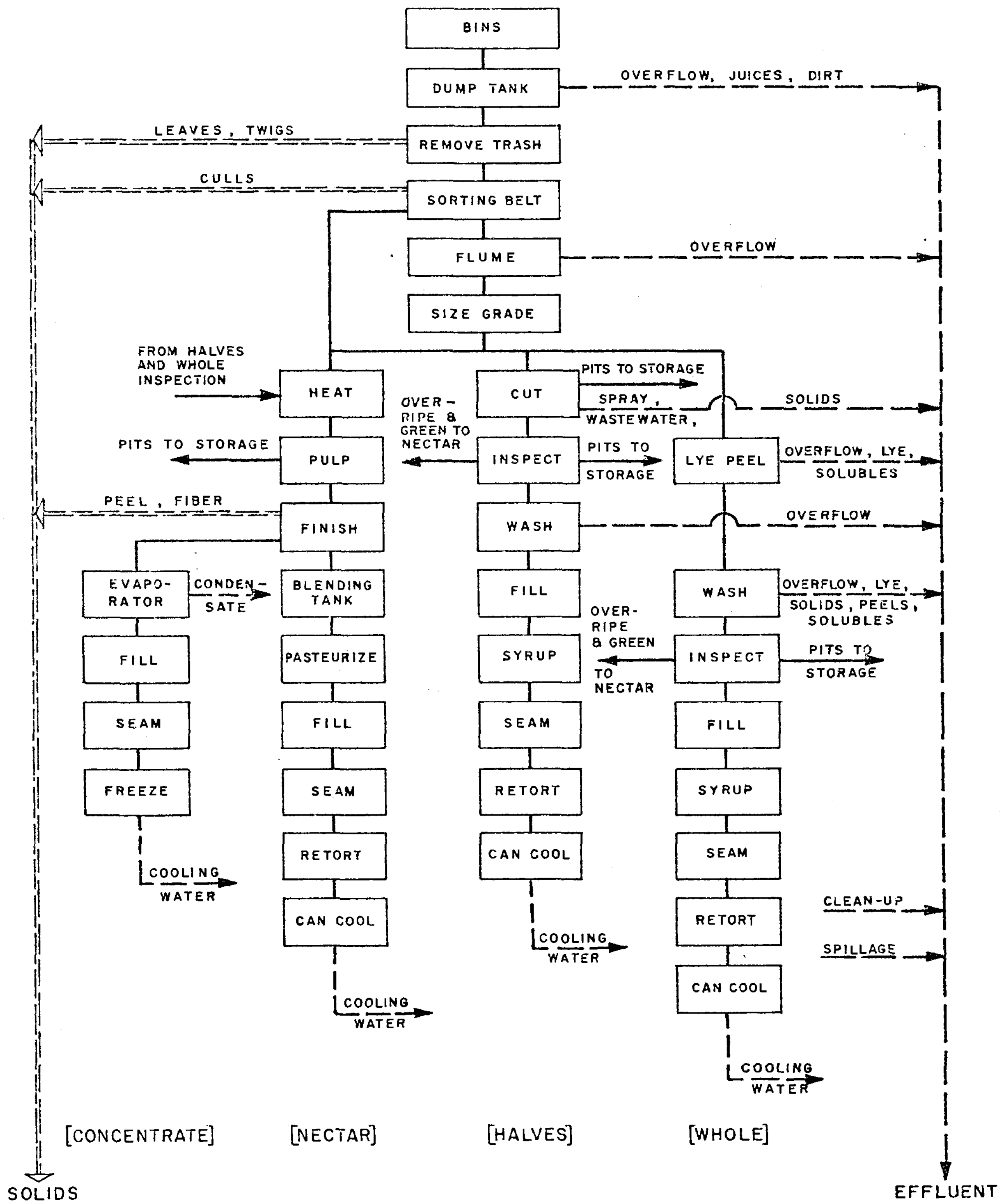
Apricots

Apricots are the seventh largest fruit pack in the United States, with virtually all growing and processing done in California. Canned apricots (whole peeled and unpeeled, halves unpeeled, slices, nectar) represent 80 percent of the total pack, dried apricots thirteen percent, and frozen product seven percent. For the purposes of this study, ten plants in California were field investigated to obtain historical information. In addition, a total of twelve wet samples were collected and analyzed to corroborate this data.

Apricots are tree ripened and harvested by hand from mid June to mid July. Normally, the field workers make several harvests during this season selecting only mature fruit and leaving the green fruit to ripen to maturity. In years of poor yields, however, economics force "orchard run" harvesting in which all fruit are stripped from the tree in one picking regardless of

FIGURE 1

TYPICAL APRICOT PROCESS FLOW DIAGRAM



maturity. Workers place the apricots in bins or boxes for immediate transfer to the processing plant.

The principal processes for the canning of apricots are surface cleaning and sorting, size grading, peeling (whole fruit style only), washing, and canning. Figure 1 shows a typical apricot process flow diagram. The process description for dried apricots is provided in a separate dried fruits section of this report. Initially, the fruit is dumped into a tank for preliminary washing and proceeds over trash removal belts which remove leaves, twigs, and other debris from the flow. Manual sorting along conveyor belts removes culls and large debris missed by the trash belts. Following this, the fruit is mechanically size graded and distributed to the whole, halve, nectar, or concentrate processing lines.

Apricots to be canned whole are usually peeled, but some operations do process unpeeled whole fruit. After passing through a cascade or immersion-type peeler (by-passed for unpeeled styles), the apricots are spray-washed while moving on shaker screens to remove peels and residual lye. The shaker screens ensure that all sides of the fruit are exposed to the wash. The whole fruit is then inspected, with overripe and green going to nectar or concentrate operations. The quality "cots" proceed to canning where they are tumble-filled into cans, syrup added, and steam closed. The cans are then washed with water sprays, retorted in continuous cookers, and cooled with water sprays.

Fruit to be canned as halves are not peeled, but proceed directly from storage and size grading to cutter machines. This operation halves the fruit, exposes the pit, and mechanically separates the fruit from the pits. (Pits are flumed or conveyed to a washing unit and subsequently stored for future sale to various related food and additive manufacturers.) An inspection follows where workers remove pits still clinging to the halved fruit; they also separate overripe and green fruit for transport to the nectar and concentrate lines. The halved apricots are given a final fresh water wash and proceed to the canning operation where they are tumble filled in cans and topped with hot syrup. The cans are steam closed, washed, retorted in continuous cookers, and cooled with water sprays.

The nectar operation is utilized by most plants as a means of using apricots of poorer quality not suited for normal canning. Fruit used in nectar includes the smallest size "cots" from the size grading operations and overripe and green fruit rejected from the whole and halves lines. The overripe fruit provides high-quality flavor and sugars to the nectar while the green fruit contributes the pleasant light color. The fruit selected for nectar initially enters a screw conveyor preheater to inactivate enzymes and to soften the fruit for pulping. The apricots are then pulped and the pits screened out, washed, and removed to storage bins. Finishers "fine pulp" the puree and remove peels and fiber as solid waste. The fruit juice enters blending tanks where sugar, water, and pulp are added and mixed in desired proportions. The resultant nectar is then pasteurized in heat exchangers and filled hot in cans. The cans are sealed in a steam flow seamer, washed, and either held at sterilizing temperatures to sterilize the container and lid or retorted. The cans of nectar are cooled with water sprays. As shown in Figure 1, fruit for concentrate is taken out of the finisher and fed to an evaporator where it is concentrated to the desired consistency. It is then filled in cans and placed in frozen storage.

The main wastewater flows from apricot processing are: overflow from dump tanks and flumes, discharge from peelers and associated washers, can washing and cooling wastewater, and clean-up. The dump tank(s) and flumes are usually recirculating with fresh and/or reclaimed water make-up with continual overflow to the sewer. This wastewater contains dirt, pieces of leaves, wood, fruit, and juice. Periodic dumping of the lye peeler and continual overflow from the following washings contribute the main BOD load. This waste stream includes significant concentrations of lye, soluble organics, peels, and other fruit solids. Can wash water may contain solids and solubles from syrup and fruit spilled on the outside of the can. Can cooling water is usually one of the largest wastewater volume generating operations. The wastewater is usually of good quality and warm temperature. This cooling water is the main reclaimed water supply for reuse as described below. Concentrated end-of-shift clean-up, continuous equipment washdown, and spill clean-up also contribute a wastewater of significant suspended solids and BOD. It may contain dirt, pieces of fruit, juices, and various solubles. In addition, wash tanks are usually dumped during clean-up adding solids and solubles to the clean-up stream.

Nearly all dump tanks, flumes, and washers are continuously recirculated with fresh and/or reclaimed water make-up with continual overflow to the sewer. The major reuse at most apricot plants is can cooling water (50 to 150 gpm per cooler) reused in the initial dump and flume system with or without intermediate cooling towers to lower the water temperature. This relatively high-quality cooling wastewater (BOD and SS usually less than 20 ppm) can also be used for the washings following peeling. In this case, a fresh make-up spray wash follows the reclaimed water use.

Caneberries

Caneberries include several popular varieties: blackberries, boysenberries, raspberries, loganberries, gooseberries (the immature gooseberry is most often used), and ollalieberries. Blueberries are also included here. Many varieties are grown almost exclusively in the Northwest, especially in Oregon and Washington, although most blueberries are grown in Maine. For the purposes of this study, six plants in Oregon, one in Washington and one in Maine were visited for the collection of historical data. In addition, a total of twenty-three composite samples were collected and analyzed to verify this data. Because of their tendency to lose shape, color, and texture, nearly all caneberries are processed frozen (either whole or pureed), although a small percentage of some varieties are canned. The frozen berries are usually sold to processors for later use in jam and preserve production.

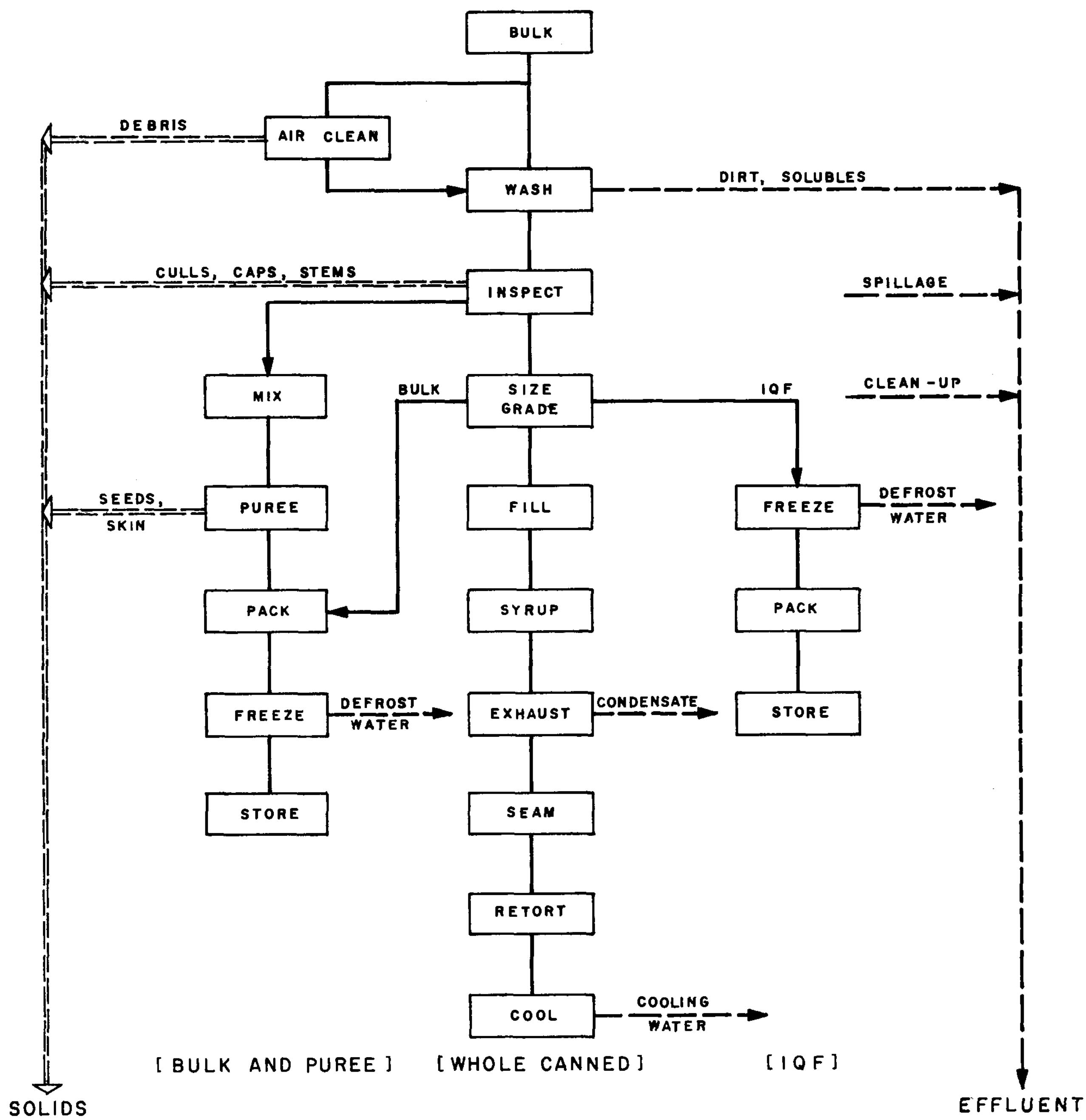
Caneberry harvesting is usually done from very late May or early June through late July or early August. The berries are picked and stemmed by hand just before they become soft. This ensures that they will remain in good condition for one or two days and will not soften excessively in processing. To facilitate the harvesting of the berries at the optimum stage of maturity, pickings must be done daily or every other day. The berries are gathered in shallow crates or trays with smaller boxes inside to ensure minimum injury from crushing, close packing together, or bruising. The crates are collected in the fields and sent by truck to conveniently located "weighing" stations established by the processor or directly to the processing plant for weighing and receiving.

Figure 2 shows a flow diagram for the typical caneberry processing plant. Berries are processed as quickly as possible after harvest because they begin to mold if they stand for extended periods of time. In the typical operation, the berries are hand-emptied from the crates immediately upon arrival at the plant into a shaker-type washer where they are immersed or sprayed, gently agitated, and gradually moved across a riddle where leaves, caps, stems, pieces of berry, and foreign material are removed. An alternate method is the use of small air blowers to remove leaves, stems, and other light debris. Strong sprays of water, often directed through a screen to prevent product damage, remove dirt that may cling to the berries as they emerge from the water. After washing, the berries may be passed over sizing riddles and then are separated according to grade or style of pack desired. When the berries are designated for canned pie packs, they may remain ungraded as to size. After the sizing and washing operations, the berries are inspected on belts, and culls and extraneous material are removed. Damaged fruit may be collected for disposal or saved and sold for concentrate or wine processing. From the inspection belt the berries for canning move to fillers. The berries are filled into the cans either by hand or mechanical hopper. Blueberries are packed in enamel-lined cans to prevent discoloration. Following filling, the cans go to a weighing station and are topped with syrup, exhausted, seamed, retorted, and cooled.

Caneberries may be frozen either by IQF or in bulk containers (30 lb tins or 50 gal drums). The method of freezing chosen depends upon the variety of the berry and the final product style for later processing. Berries frozen in bulk containers are filled either mechanically or by hand and are weighed after inspection. Berries to be IQF'd are transported from the inspection table by

FIGURE 2

TYPICAL CANEBERRY PROCESS FLOW DIAGRAM



belts and frozen by one of three processes: blast tunnel, fluidized bed, or cryogenic liquids. They are then refrigerated in bulk for later packaging. The inspected berries and often the damaged or broken pieces undergo a size reduction in a mixing tank. Sugar may be added to the fruit while it is in the mixing tank. The mixture is then put through a puree screen which breaks the berries up. Seeds and stems are removed by the screen and are dry collected while the puree is packed into 30 lb tins or 50 gal drums, frozen, and stored for later shipment to jam and jelly manufacturers.

The principal sources of wastewater generation are the washing operation, spillage, can cooling, and defrost waters. The wasteloadings from the washing operations usually consist of dirt and dissolved juices from the broken fruit. Liquid waste (small volume) is produced in the filling and syruping operations, but the high sugar content of the syrup can contribute significantly to the pollutant loading of the waste stream. Important reductions in water use have resulted from dry cleaning operations and the use of dry conveying. The wash water is recirculated in some plants as well as the can cooling water. Recycling of water has also been observed in operations such as crate washing.

Cherries

Approximately two-thirds of the total U.S. production of cherries is processed in Michigan with the remainder primarily in New York, Oregon, Washington, and California. For the purposes of this study, nine plants in Michigan, ten in Oregon, and one in Washington were visited for the collection of historical data. In addition, a total of seven composite samples were collected at two plants and analyzed to verify this data. There are two major processes employed on cherries: (1) sweet and tart cherry canning and freezing, and (2) sweet cherry brining for maraschinos. In 1973, canned sweet and tart cherries accounted for 50 percent of all cherry products, while frozen sweets and tarts made up eleven percent of the total. The remaining 39 percent of the cherry products were brined, juiced, and made into wine, of which brined (and subsequent maraschinoing) was the major item.

There are many cherry varieties but only a few are of commercial importance. The most important sweet cherry varieties are Bing, Tartarian, Royal Ann, Lambert, Republican, and Chapman. Principal varieties of sour cherries are the Montmorency, Earl Richmond, and English Morello. Sweet cherries are usually manually harvested and hauled to the plant in lug boxes, although mechanical harvesting is occasionally used. Tart cherries are usually mechanically harvested by devices which shake the fruit off the tree and convey it to tanks of chilled water, in which it is transported to the plant. At the plant, the cherries are processed differently, so they will be discussed differently.

FIGURE 3

TYPICAL CHERRY PROCESS FLOW DIAGRAM

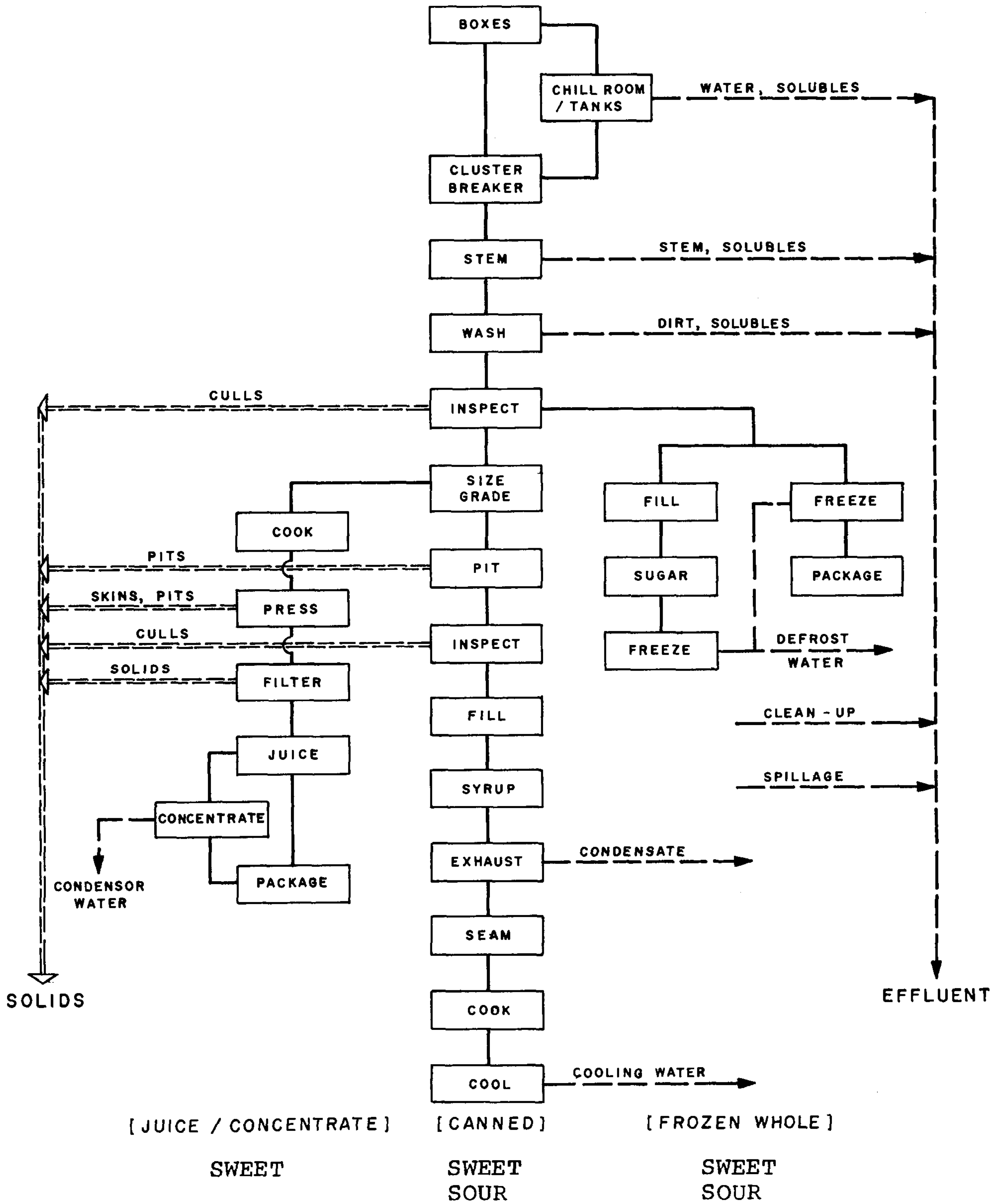


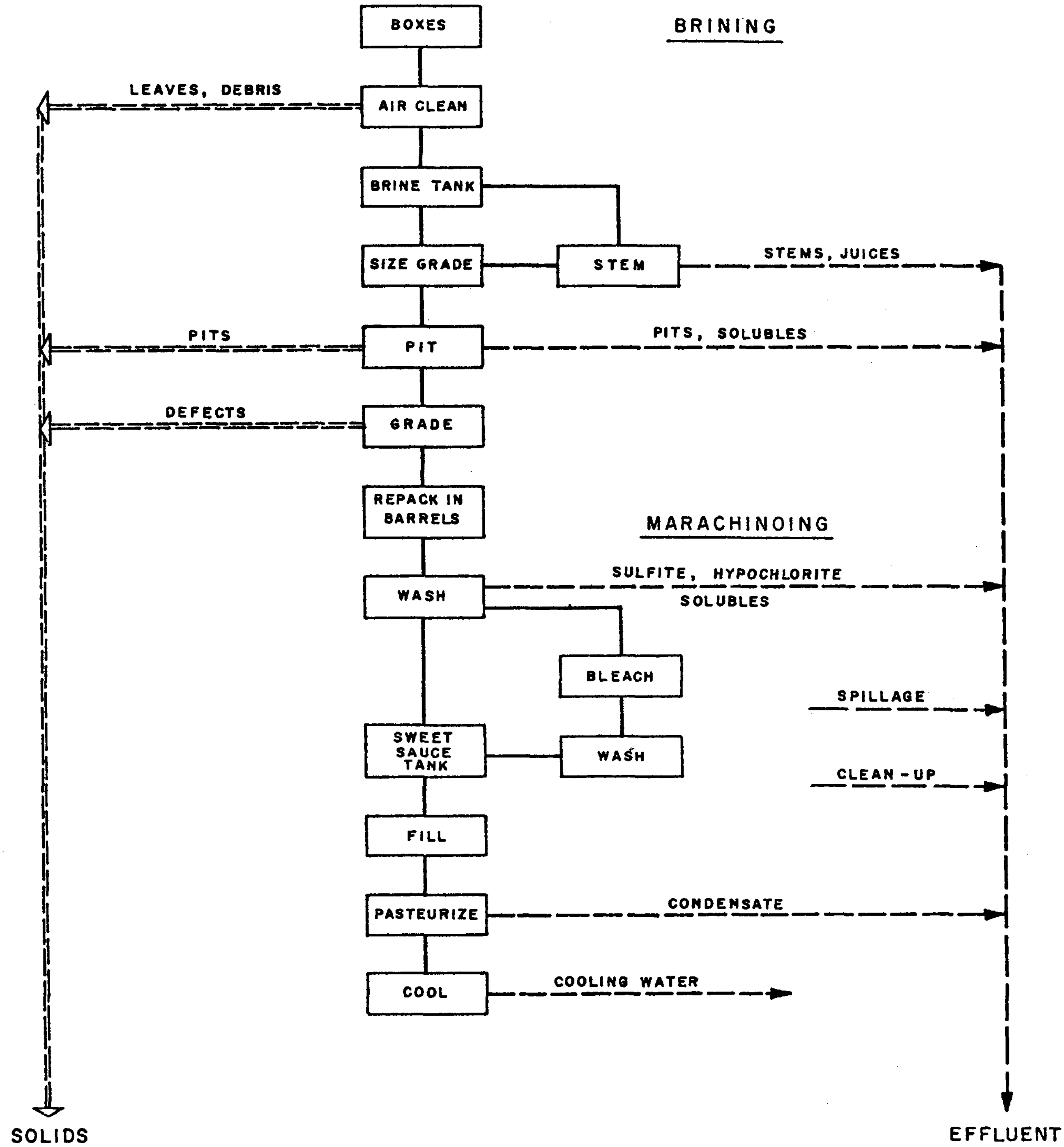
Figure 3 shows a diagram for a typical sweet and sour processing plant. Sweet cherries are typically placed into field boxes after harvesting. Upon arrival at the plant, those cherries to be pitted are cooled either in continous flow hydrocoolers or chilling rooms. Cherries to be packed whole are not chilled. Chill rooms, unlike hydrocoolers, do not generate wastewater, but they are less efficient in cooling the product.

Sweet cherries are first put through a cluster breaker prior to de-stemming to assure they are single. They next go to the de-stemming machine which uses an oscillating belt and a rotating blade to remove the stems from the fruits. The operation is dry, but water is used to flume the stems away and into the wastewater stream. The de-stemmed fruits are conveyed to the washer, of which several types are in use. Reels on tanks with sprays are common, and they produce a large proportion of the wastewater from the process. The cherries are inspected, and damaged fruit, culls, and defects are removed. From this point, the processes for freezing and canning diverge. Cherries to be canned are put through a size grader, which consists of a vibrating table perforated with the propersized holes. Smaller cherries are removed to the juice and concentrate line, while the larger ones are usually conveyed to the pitter. The pitters hold the cherries in individual cups, and plungers push the pit out of the cherry. Pitting uses water to keep the machine operating properly and to flume the pits away. Occasionally, the pits are screened before the water enters the wastewater stream, and they are used in landfill, as feed, processed into charcoal briquets, or are ground and used as a salt replacement on icy winter roads. Some sweet cherries are canned with the pits not removed. The next operation is an inspection to remove any incompletely pitted and damaged cherries. The good fruit then goes to fillers and into cans or glass, and syrup is added. The containers are exhausted, closed, cooked, and cooled. If the cherries are to be frozen, they are routed to the freezing line after the first inspection. Individually Quick Frozen (IQF) cherries are put through fluidized bed, air blast, or cryogenic liquid freezers, after which they are stored in bulk or packaged. Other cherries are packaged into cartons, sugar is added, and they are frozen in air blast or plate freezers.

Sour cherries are mechanically-harvested into chilled water and dumped into chill tanks at the plant. The water lost during this dump is often reused in a later operation. The chill tanks have a continuous overflow, and dirt and residues are rinsed off the product and into the waste stream. From the chill tanks, the product is flumed to a de-stemming machine like that used for sweet cherries, and then is conveyed to an "eliminator." This device has closely spaced parallel rollers which eliminate leaves, stems, and other debris, which are subsequently flumed into the wastewater system. Sometimes the waste is collected dry. Next the product is sorted, in most cases by electronic "spectrosorters." These check the color of each fruit automatically and remove discolored or bruised ones. Two basic

FIGURE 4

TYPICAL BRINED/MARASCHINO CHERRY PROCESS FLOW DIAGRAM



types of sorters exist. The most common sorter does not utilize water as a transport medium while the less common type does. The dry machine was not originally designed for cherries and does experience problems. Complete recirculation of water is employed in the less common wet type of machine. After electronic sorting, a manual inspection is often used to remove any defects the machines missed.

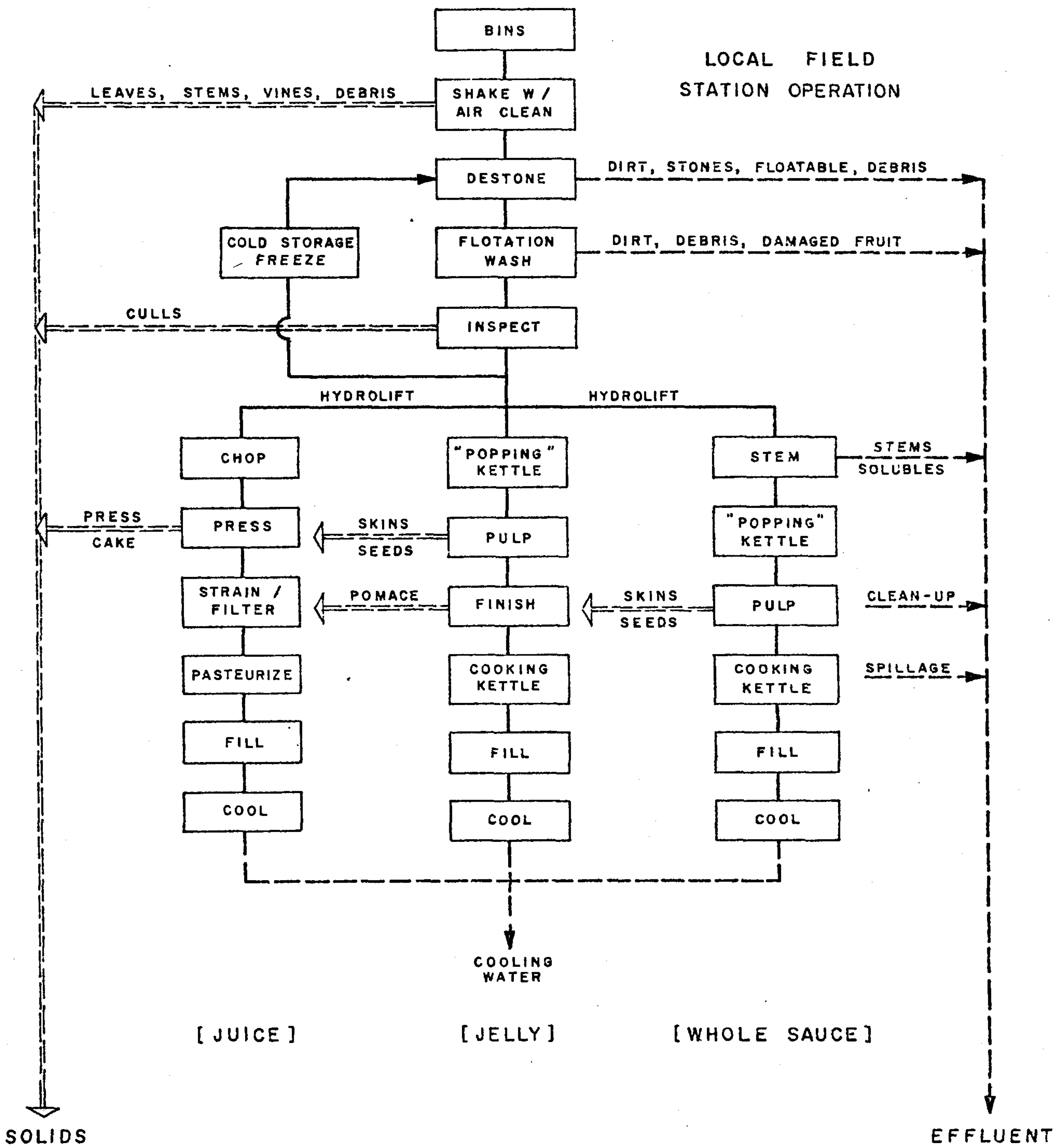
Cherries processed as pitted products are fed through a mechanical pitter. Some plants were observed to have a juice collecting apparatus installed in conjunction with the pitters. After pitting, a visual inspection is made to insure that no poor quality cherries will be canned. The cherries to be canned are filled into cans, topped with syrup if desired, exhausted, closed, and cooked in either hot water or retorts, after which the cans are water cooled. Sour cherries are frozen two ways: Either packaged into containers or Individually Quick Frozen (IQF). The frozen packaged cherries are filled into retail-sized or larger bulk containers, sugar is sometimes added, and the product is frozen in blast freezers. The IQF product is sent directly to air blast or fluidized-bed freezers, then is packaged immediately or stored in bulk for later packaging. The freezing operations produce little wastewater, usually only that from spillage from the filler and sugaring.

Figure 4 shows a flow diagram for a typical brine cherry and maraschino processing plant. Sweet cherries are usually used and come to the plant in boxes. First, extraneous material such as leaves and stems are removed from the cherries by an air blower, and this debris is removed dry from the plant. The cherries are then placed in large tanks filled with high-strength brine containing sulfur dioxide and calcium (about 10,000 ppm sulfur dioxide and 15,000 ppm calcium). The cherries remain in the brine for several months during which time the brine bleaches the color and firms up the structure of the cherries, as well as acting as a preservative. After the cherries are sufficiently bleached, they are transported into the plant, where they are either destemmed first or sent directly to the size grader. After sizing, the brined cherries are pitted in the typical manner, then graded according to color and appearance. The cherries are then repacked in the sweet brine from the brine tanks in barrels and either shipped or stored for later use. Some plants incorporate a secondary bleaching process using sodium chlorite to further de-color the cherries prior to repacking.

The brined cherries in barrels are transported to the maraschino cherry process, which is either at the same plant or at a different plant than where the brining was done. The barrels are dumped, and the packing brine is discharged to the waste stream. The first step is a wash, in which more brine is bleached out of the cherries. At this point, some plants use the secondary sodium chlorite bleach to assure total color removal from the cherries. The cherries are held in sodium chlorite brine for a

FIGURE 5

TYPICAL CRANBERRY PROCESS FLOW DIAGRAM



short time and then are washed, which generates more wastewater high in sodium chlorite. In all cases, the bleached, washed cherries are held in a "sweet sauce" containing sugar, coloring, and flavoring ingredients. The strength of this sauce is gradually increased to the proper level, and the maraschino cherries are filled into retail-sized jars or bulk containers and topped with the sweet sauce. The jars are pasteurized and subsequently cooled.

The hydrocooling operations produce a sizable volume of wastewater containing some surface residues and dissolved juices. Another large volume waste generation occurs in the various style washers. In some cases, depending on the incoming quality of the fruit, the pollutant loadings of these streams might be significant. Both cooking (glass) and cooling operations consume large quantities of low load water. These may be recycled through a cooling tower to be reused for either additional cooling or initial washing. Defrost water, as is typical with most frozen food processors, may be captured and reused for initial washing. The brining and processing of maraschino cherries yields wastes very separate and distinct from normal cherry operations. Both the sulfur dioxide and calcium wastes, necessary for the product characteristics are extremely concentrated and may affect a treatment plant's microorganisms. As mentioned above, recycling of cooling water is commonly used to conserve water. In addition, recirculating pumps were observed in several installations to provide continuous reuse of chill tank waters and the various water flumes.

Cranberries

Massachusetts and New Jersey produce most of the cranberries for processing in the U.S. with the remainder produced primarily in Washington, Oregon, and Wisconsin. For the purposes of this study, one plant in Washington and two in Wisconsin were visited for the collection of historical data. In addition, a total of seven composite samples were collected and analyzed to verify this data. Approximately 37 percent of all processed cranberries are canned as cranberry sauce, with the remainder being canned as jelly or juice.

Cranberries are grown in peat bogs with high acid soils (pH range of 3.2 to 4.5). The bogs are periodically flooded as a means of irrigation, insect control, and frost prevention. The cranberries are ready for harvesting in the late summer and into the fall. Whether harvesting is done manually or mechanically, the berries must be handled carefully to reduce the chance of bruising, since such damage leads to rapid spoilage. The berries are transported to field stations for cleaning, weighing, and sometimes freezing prior to delivery to the processing plant which may be several hundred miles distant.

Figure 5 shows a flow diagram for a typical cranberry processing plant. Upon arrival at the plant or field station, cranberries are fed into a shaker with an air cleaning device which blows out leaves, stems, vines, and debris. The cranberries then are conveyed by water flume to a destoner, which removes stones and floatable debris, and subsequently into a flotation washer which removes dirt, debris, and damaged fruit. Although not usually size-graded, cranberries are inspected for quality and in addition must pass the bounce test: ripe whole cranberries will bounce, while damaged or soft berries will not. Cranberries are fed into a series of three steps with barriers; those cranberries which don't bounce over all three steps are considered damaged and are discarded as waste. With respect to plants in the Northwest and Midwest, the above processing steps take place at field stations and do not contribute to the plant waste stream.

Cranberries for whole sauce processing are fed into a mechanical stemmer (which may be a mechanical abrasion vegetable peeler) to remove the stems. The berries are then fed into a steam-jacketed "popping" kettle where they are cooked with water, popping or splitting open the skins. They are conveyed into a pulper which removes the skins and seeds, usually by forcing the pulp through a wire mesh screen. The pulp is cooked in a cooking kettle with sugar and other ingredients, and filled into cans. The hot cranberry sauce is over-filled into the can as there can be no headspace; the overflow is treated as waste. The cans are cooled before packing and shipment. The process for cranberry jelly or strained sauce is identical to that for whole sauce with the addition of a finisher being used after the pulper. Cranberries for juice processing are fed into a mechanical chopper and then into a mechanical press, which separates the liquid or juice from the solids. Wastes consist of bits of fruit, juice from the chopper, and press cake from the pressing operation. The berries enter a strainer and filter to remove any remaining seeds and stems, after which the juice is pasteurized and filled hot into cans or glass bottles. The containers are cooled prior to packaging.

In as much as some of the basic cleaning and washing operations occur at field stations, a large volume of wastewater is returned to the field. Once the cranberries have been brought to the plant, the major generation of flow is typically from can or jar cooling water. Those plants that totally process the berries and bypass field stations, have, in addition to cooling water, a considerable volume of flume and wash water. Heaviest organic loads occur in the washing and fluming operations where the juices of ruptured or damaged berries enter the waste stream. In-plant clean-up, including kettle washings, also contributes significantly to a typical processor's wasteload.

Both fluming water and cooling water may be reused for initial washing operations. Wastewater reduction has been successfully accomplished through the use of air cleaners which serve to eliminate (dry) stems, vines, and other organic debris.

Dried Fruit

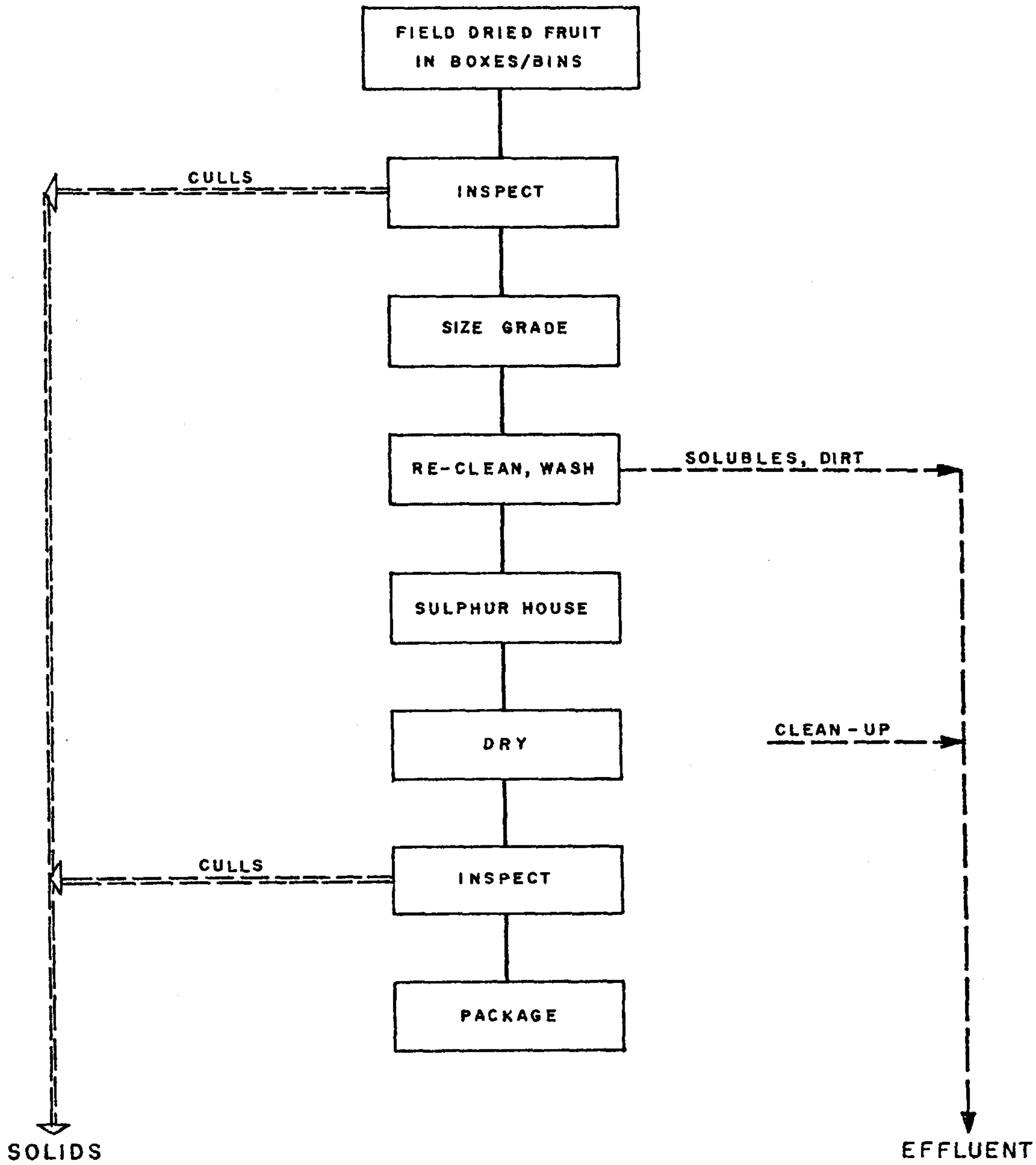
Sun drying in direct or diffused sunlight (shade drying), one of the earliest methods of food preservation, is still used for the production of dried fruits. Sun-dried fruits can be produced only in climatic areas with relatively high temperatures, low humidities, and freedom from rainfall during the drying season. In the U.S., the inland valleys in California are the most important producing areas. Fruits, other than prunes and raisins, most widely dried today are apricots, peaches, apples, and pears. For the purposes of this study, three plants in California were visited for the collection of historical data. Commercial fig producing in the U.S. is mainly restricted to California, but production is increasing in Arizona, New Mexico, and Texas. For the purposes of this study, two plants in California were visited for the collection of historical data. Almost all processed figs are dried, although some Kadota figs are canned.

Plums are one of the most widely distributed fruits in the country, being grown in nearly every part of the United States. Only one type of plum is designated a prune, however, and these prunes for drying are produced almost entirely in California. By 1900, prune orchards in California covered 90,000 acres. Today there are about 100,000 "high production" acres concentrated in the Santa Clara, Sacramento, Sonoma, Napa, and San Joaquin Valleys. Currently, these areas produce 98 percent of the U.S. total and 69 percent of the world supply. Harvesting begins in late August, and the main processing season continues from September through the winter months. For the purpose of this study, six plants were visited in California for the collection of historical data. In addition, a total of five composite samples were collected and analyzed to verify this data. Prune plums have several distinguishing features which enable them to be easily dried. First, they are dark purple and elongated or oval shaped, as opposed to the round reddishpurple plums for canning, freezing, and fresh utilization. They have a firmer flesh, higher sugar content, and often a higher acid content than plums. More especially, they can be dried without fermenting when the pit is left in.

Figure 6 shows a typical dried fruit process flow diagram. Apricots, pears, peaches, and apples are all harvested in the same manner. After the fruit has ripened on the tree, it is hand picked, loaded in boxes, and taken to a field shed where it is halved and pitted, or cored in the case of pears. Placed cup up on wooden trays, the fruits are stored overnight in sulphur houses where they are exposed to burning sulphur (sulphur dioxide gas). The fruit is then dried in the sun from one to five days and stacked to dry in the shade for one or two weeks. Once dried to roughly fifteen to twenty percent moisture, the fruit is taken to the packing shed where it is graded by size, recleaned, resulphured, redried, and packaged.

FIGURE 6

TYPICAL DRIED FRUIT PROCESS FLOW DIAGRAM



Apricots and freestone peaches are hand-picked at maturity, placed into lug boxes, and transported to a cutting shed. The fruit is halved, the pit removed, and the fruit placed cup up on a flat, pre-cleaned wooden tray (approximately three-four feet wide, six-eight feet long and one to two inches deep). The filled trays are exposed to sulphurdioxide fumes (burning elemental sulphur) for about twelve hours. This prevents browing of the fruit during the drying process. After "sulphuring," the trays are transferred to a field where they are placed on the ground, exposing the fruit to "full sun." Apricots are allowed to dry in this manner for one day, after which time the individual trays are transferred to a shady area and stacked three to four feet high. They are allowed to dry in the "stack" for approximately one additional week, then removed from the trays, placed into boxes or bins, and ultimately delivered to a "packing-plant." Similarly the freestone peaches, after sulphuring, are placed in full sun for two to three days, at which time they are transferred to shady "stack" storage, dried for several additional weeks, removed from the trays, transferred to boxes or bins, and delivered to the "packing plant." Both apricots and peaches may receive longer exposure times than mentioned above depending on the availability of "full" sun.

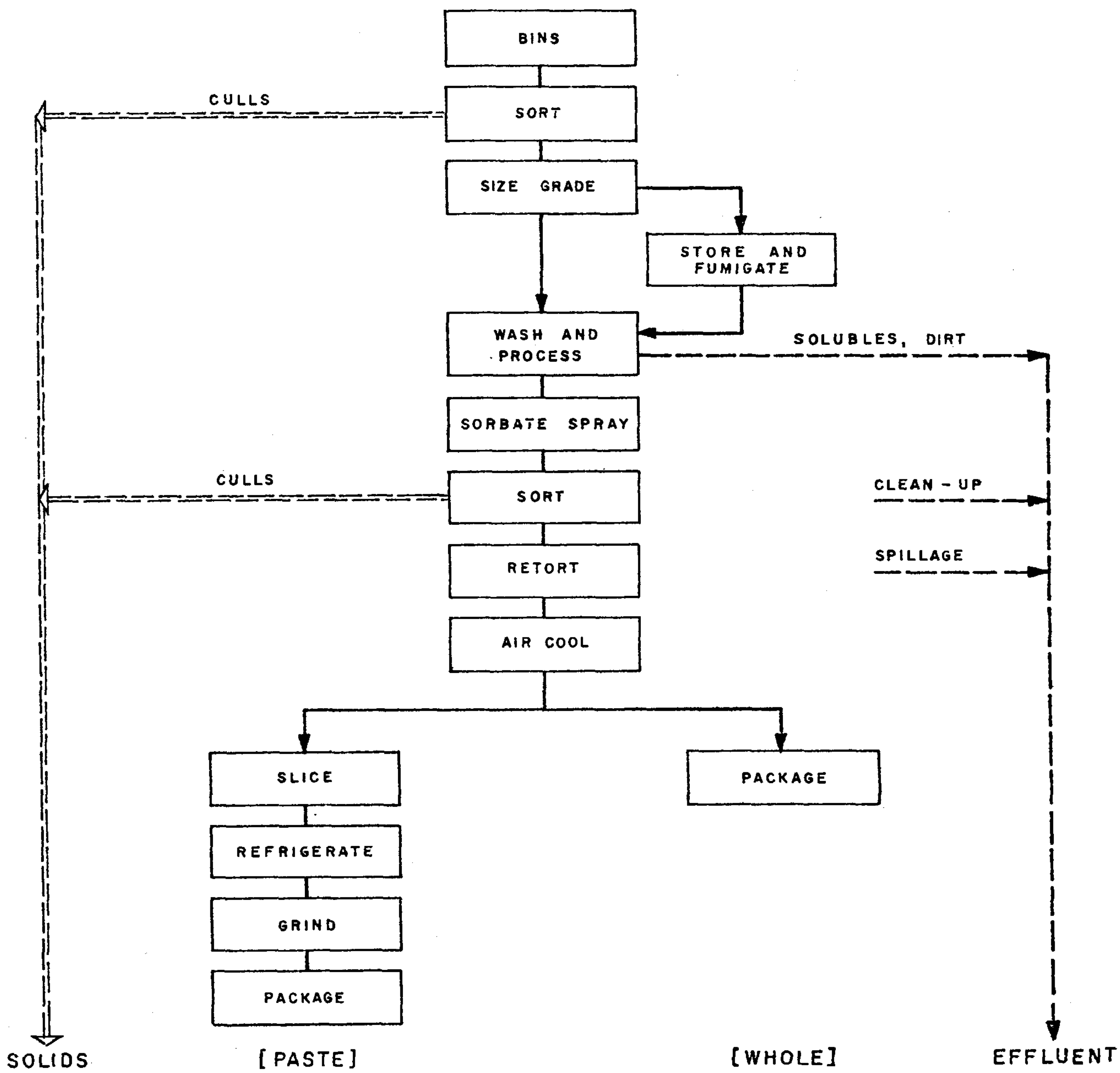
Pears that are to be dried are allowed to ripen on the tree. They are then hand picked and transported to cutting sheds where they are cored and halved by hand. Placed cup up on wooden racks, they are stored overnight in sulphur houses where they are exposed to burning sulphur to prevent browning. The pear halves are removed from the "sulphur house" and dried in the sun for four to eight days and then transferred to stacked storage for an additional two to three weeks.

Once dried, the fruit is delivered to the packing plant where it is processed usually to fill orders. The dried fruit from the field may sometimes be stored as long as several years before being repacked. Typically, the fruit is graded for size and appearance, handinspected to remove undesirable pieces (off color, "slabs," insect damaged, etc.), and then sent through a re-cleaning operation. This is normally a high-speed, reel-type cleaner fitted with brushes which both softens and loosens any dirt, wood, or insect particles which may have become attached to the fruit during the field drying process. Partial rehydration occurs, and as a consequence the fruit must be re-sulphured and re-dried prior to adding preservatives (yeast and mold inhibitors) and final packing.

Figure 7 shows a typical fig process flow diagram. There are four basic varieties of figs used by the processors - Calimyrna, Mission, Adriatic, and Kadota. The Adriatics are mainly used for the production of paste. Figs are usually allowed to partially dry on the tree. In some cases, the trees are lightly shaken at intervals. Figs are usually mechanically gathered from the ground and are typically dry enough to be loosely packed in boxes or bins, although sometimes they are further dried on trays in

FIGURE 7

TYPICAL FIG PROCESS FLOW DIAGRAM



the sun to approximately seventeen to eighteen percent moisture content. Some varieties of figs are lightly sulphured in the field, but this is not a typical operation. Figs are transported to the plant in sweat boxes or bins. Figs are normally screened, graded for size, and then undergo a thorough inspection at which time insect damage and culls are removed. The screening is necessary to divide the figs into the required finished product styles. After the first sorting and grading operation, the figs to be stored for later processing are packed in boxes and placed in an airtight chamber and fumigated. This operation is repeated several times over a two-week holding period. The figs to be processed are conveyed through a cold water reel washer to remove loose adhering dust and foreign material. They are then directed to a "processing" unit at which time they are immersed in hot water (200°F) for approximately five to ten minutes. Soak time depends upon size and variety of fruit being processed. The figs at this point have absorbed some water and because of increased susceptibility to mold, are sprayed with potassium sorbate. They are conveyed, typically, over a dewatering belt where they may either be put into small plastic tubs to equilibrate, or they may be placed into retorts directly. The figs are placed into metal trays which are pushed into horizontal retorts. Exposure to live steam for two or three minutes further softens the fig. The fruit is air cooked and directly packaged.

Figs (usually Adriatic variety) for paste are treated in a similar manner as the whole fruit with several exceptions. In some cases, the size grading operations may be bypassed, and the figs to be processed are sent directly to cold water pre-washers. This is followed by screen-shaker separations mainly designed to remove foreign material. The fruit is then usually transported through one or two consecutive warm water washers to further clean the fruit. It is then mechanically sliced and divided into lots for official quality inspection and grading. Refrigeration typically follows for an approximate twenty-four hour interval. This serves to harden the fruit so that grinding into paste will be facilitated. The final step in the process is grinding, usually through a "meat" type grinder. The product is packed into bulk containers and refrigerated prior to shipping.

Ordinarily, a prune tree starts to bear fruit four to six years after planting, and reaches its full production capacity (300 to 600 lbs of raw fruit per year) sometime between its eighth and twelfth year in the ground. The orchards will then continue to bear quality fruit on a commercial basis for about 30 years. The prune tree is deciduous and goes dormant during the winter months. It is at this time that the grower cuts back and prunes each tree to regulate shape, control fruit size, and maintain a healthy plant. By late August, the orchards are ready for harvesting which generally takes about 30 days. The predeterminant of harvest time for prune plums is ripeness, in that they are one of the few fruits allowed to fully ripen before they are picked for processing. Fruit firmness and natural sugar content determine the picking date. Today, most of California's

FIGURE 8a

TYPICAL PRUNE PROCESS FLOW DIAGRAM

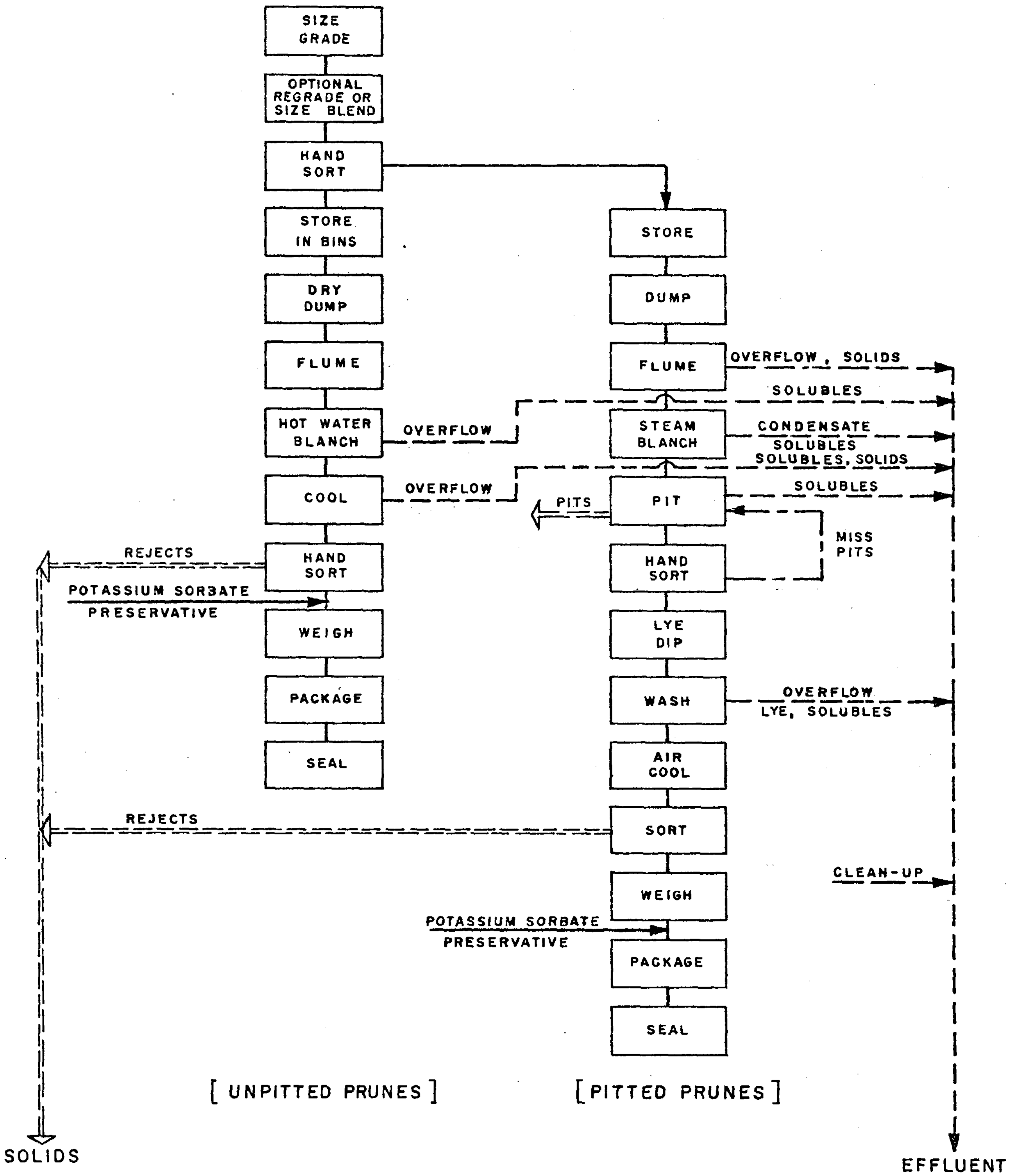
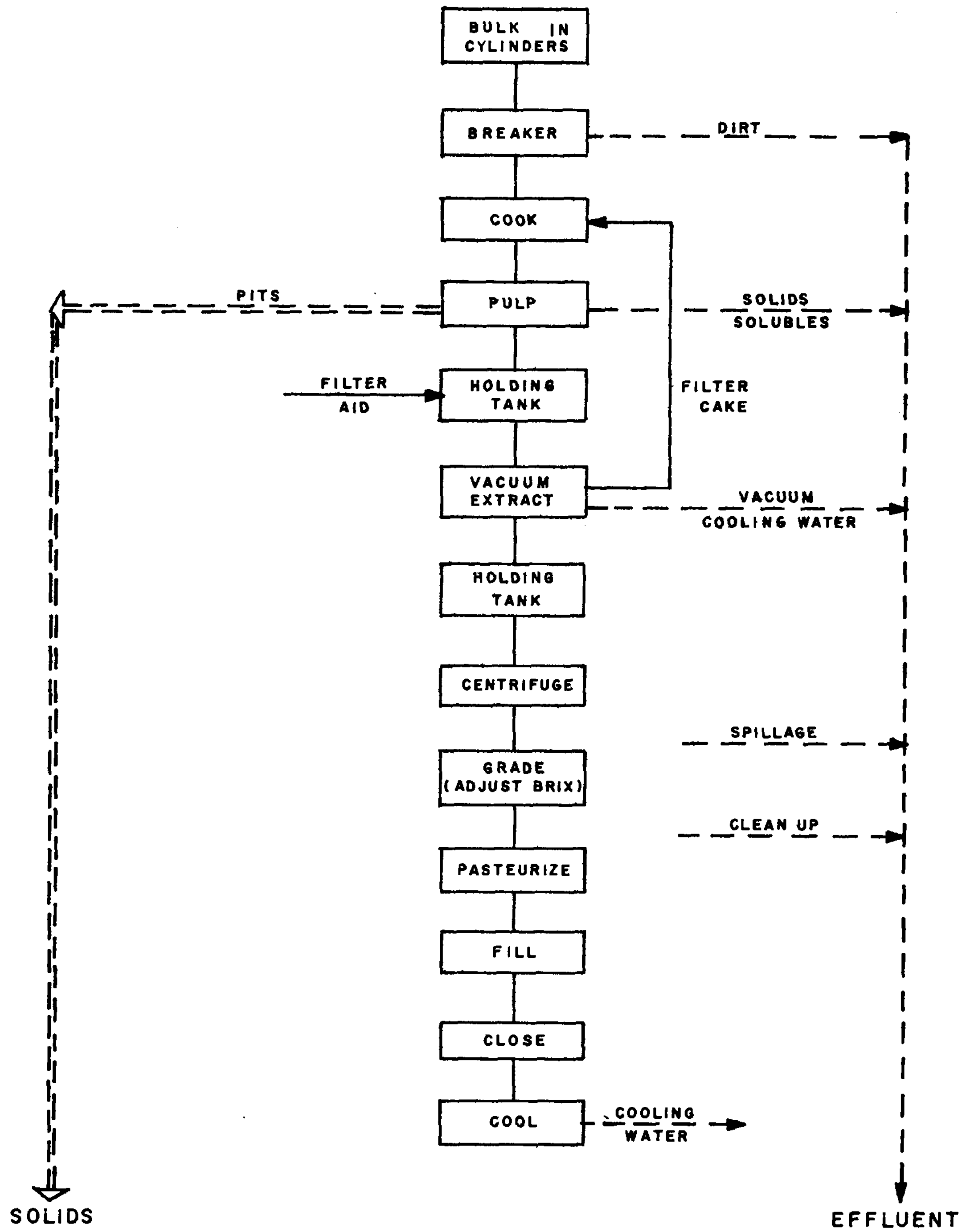


FIGURE 8b

TYPICAL PRUNE JUICE PROCESS FLOW DIAGRAM



prune production is harvested by machine. In this process, a mechanical shaker takes hold of a main limb or the trunk, a fabric catching frame is spread under the tree; and in a matter of seconds, the fruit is shaken off the tree, and transferred via conveyor belt into bins in which it goes to the dehydrator. Because of the ever-increasing industry emphasis on fruit quality, the historical method of allowing fruit to ripen and drop before gathering has all but disappeared. This method required three or four "pickings" to completely strip an orchard of its fruit. Immediately after harvesting, the orchard-ripe fruit is taken to the dehydrator yard where it is washed, placed on large wood trays, and dehydrated in a series of carefully controlled operations. Held in these hot air (210-220°F) dehydrators for ten hours, the fresh fruit is reduced to 1/3 its initial weight through water loss.

Figure 8a shows a typical prune process flow diagram. Prunes are processed through a series of screenings, gradings, and washings. The first screening, a dry screening, removes clods and debris and breaks up prune clumps. The second screening removes loose dirt. The prunes are then mechanically graded and separated according to sizes ranging from 23 to 150 prunes per pound. They can then be warehoused in wooden bins (up to two years storage) or can be processed for packing. Hand sorting for cull removal follows, after which the prunes are conveyed to a blancher (hot water or steam) where they are held from eight to twenty minutes to deactivate enzymes and preserve color and flavor. Potassium sorbate and fresh water are then sprayed onto the prunes to maintain proper water moisture content and add further preservative. Fruit to be pitted is sent through automatic pitting machines that either squeeze the pit out with mechanical fingers or punch it out as does an olive pitter. The pitted or unpitted prunes are again hand sorted for rejects, automatically weighed into boxes or sacks, sprayed with potassium sorbate preservative, and sealed.

Prepared prunes are delivered to the plant typically in fiber-board cylinders. The fruit is dumped into a breaker and conveyed directly to a cooking tank. The cooking cycle renders the fruit to a pulp to both prepare the pulp for filtering and to break the prunes sufficiently for pit removal. The hot slurry is pumped to a pulper where the pits are removed as solid waste, and the prune pulp is further reduced in size. The pulped juice is pumped to a tank, filter aid is added, and a second pump transports the prune mass to a vacuum filter press. The filtered juice is pumped to a holding tank, further solids are removed by a centrifuge, the Brix level is adjusted to approximately 18.5°, and the juice is pumped through a heat exchanger for pasteurization. Fill temperature is between 195° and 200°F. The jars or cans are hot filled, closed, and cooled. Figure 8b shows a typical prune juice flow diagram. Juice recovery is usually aided by the recycling of the filter cake.

The cake is continuously removed from the vacuum filter and recooked to extract any remaining juice.

The wastewater generation in the prune juice operation varies somewhat from the processing of dried prunes. The vacuum filter press requires significant amounts of "no contact" cooling water. This essentially dilutes the effluent stream and increases the water usage on a raw ton basis. Container cooling water, in terms of dilution, also affects waste strength levels. Clean-up operations also contribute a heavy proportion of loadings to the waste streams. Materials such as pulper and centrifuge wastes, if kept from the effluent stream, can contribute a measurable decrease in the BOD and suspended solids levels.

Water usage in an operation such as described in this chapter is usually kept to a minimum to prevent excessive leaching of soluble solids from the fruit. Consequently, wastes generated from the recleaning operation are usually low in volume but highly concentrated in terms of BOD. The principal constituents are almost always dissolved solids (sugars) from the fruit. Clean-up wastes add significantly to the volume of effluent discharged but are not as concentrated as those from the processing of the fruits.

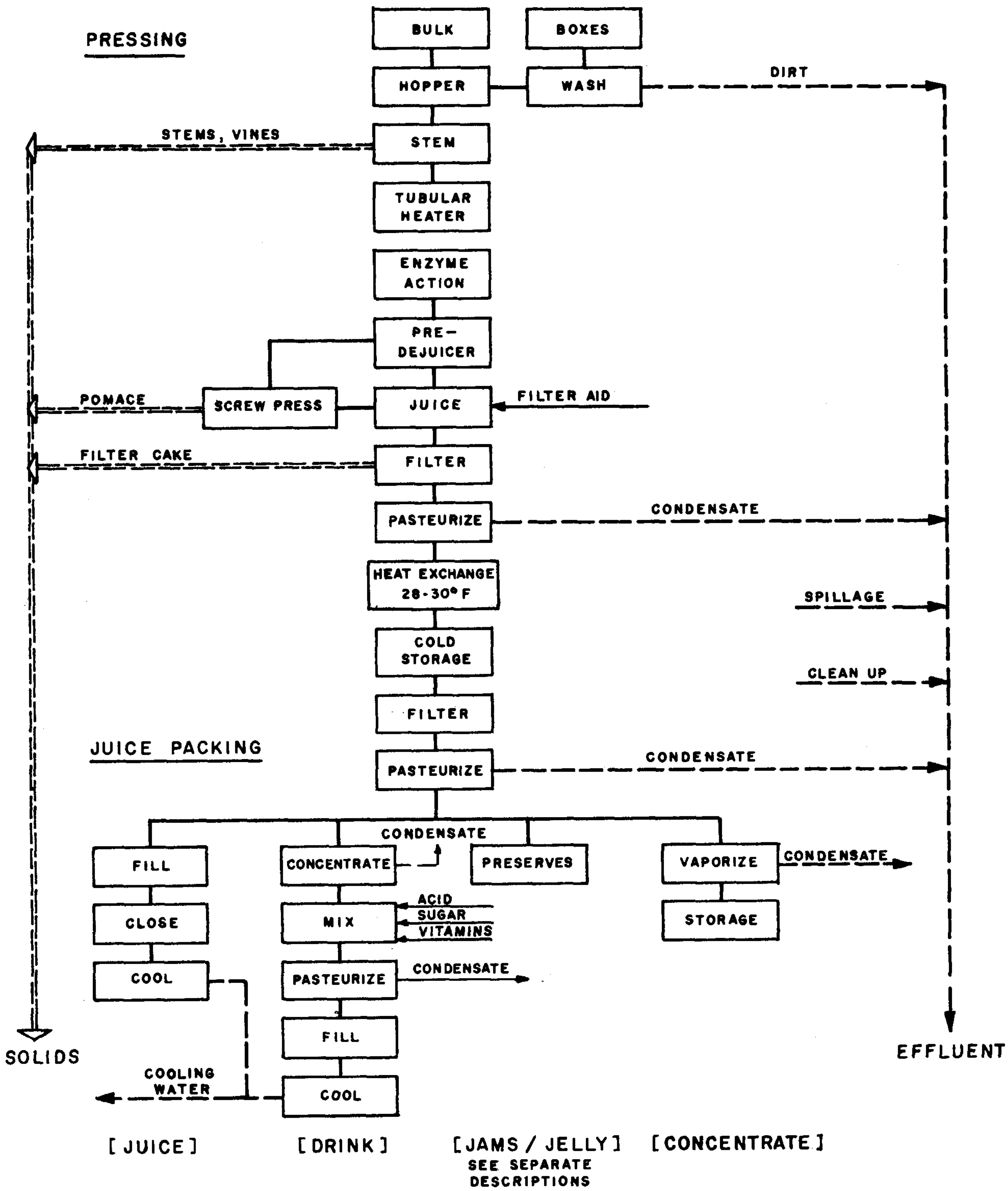
Grapes

Approximately 93 percent of the total U.S. production of grapes is processed in California, with the remainder processed primarily in New York, Washington, and Michigan. For the purposes of this study, three plants in California, one in Michigan, four in New York, and one in Pennsylvania were visited for the collection of historical data. Approximately 68 percent of all processed grapes are made into wine (covered in another study); five percent are made into juice, jam, and jelly (jam and jelly being covered as a separate category in this study); 25 percent are processed as raisins (see raisins); and two percent are canned either as a separate product or with fruit coctail.

When the grapes have reached optimum maturity, the clusters are harvested either by machine (bulk) or are hand picked and placed into 30 lb boxes. They are delivered to the plant by truck with as little delay as possible. Upon arrival at the plant, the grapes are dumped into a wash tank to remove dirt and loose debris from the grape clusters. The grapes are then fed by conveyor to the bunch breaker. The wash tank may be emptied once per shift or more. The bunch breaker mechanically breaks the grapes from the cluster. The grapes are transported by water flume which serves to both wash and transport the grapes to a mechanical cap stemmer which removes the cap stems. The stems are discarded as solid waste. Inspection is typically done by hand over an inspection belt at which time defective or blemished pieces or foreign material are removed and discarded as solid waste. The grapes are then fed into the cans and topped with hot

FIGURE 9

TYPICAL GRAPE JUICE PROCESS FLOW DIAGRAM



syrup. The cans are seamed, retorted, and cooled prior to packing and shipment.

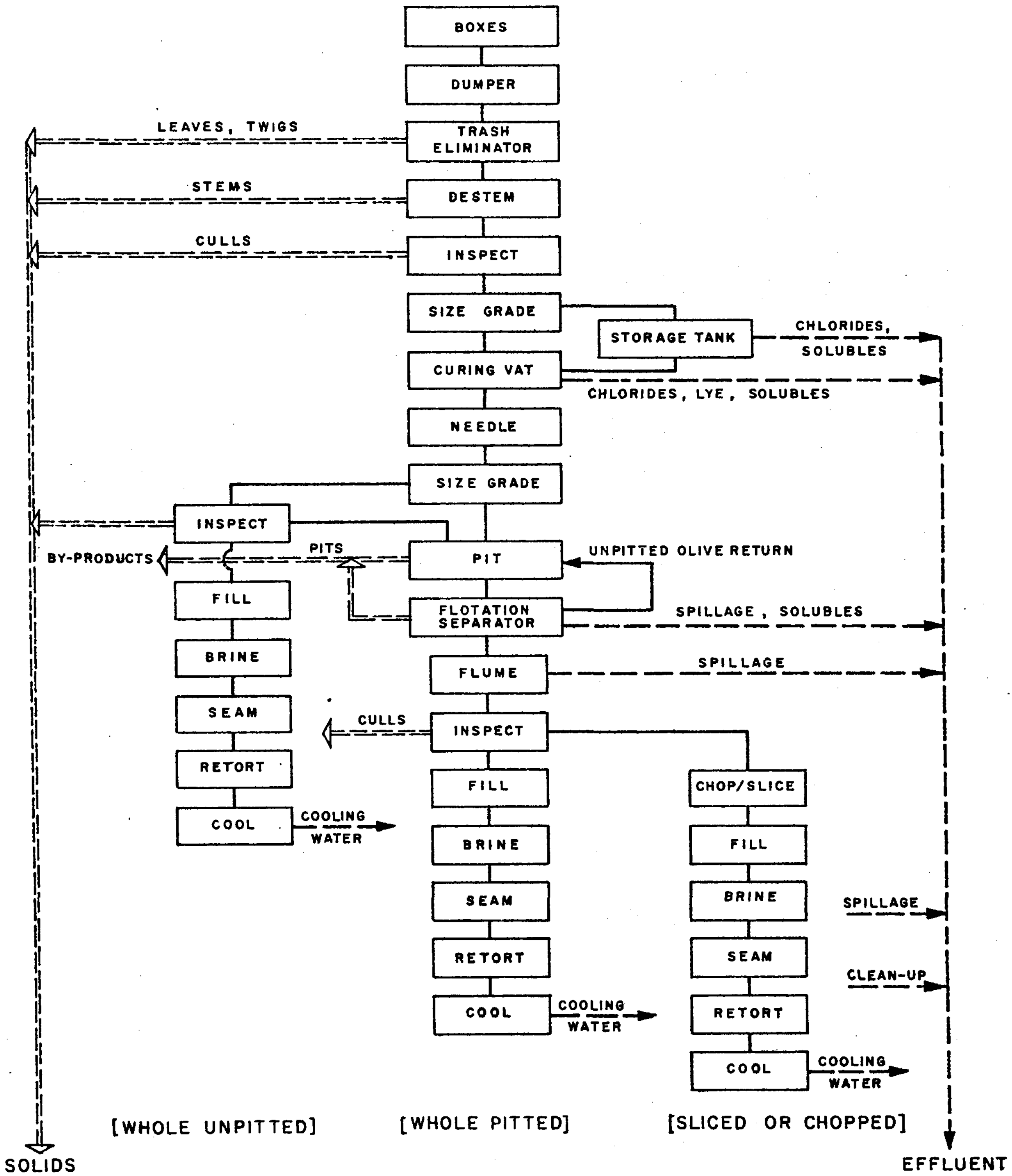
Figure 9 shows a typical grape pressing and juice packing flow diagram. If the grapes are hand harvested, they are dumped into a soak tank for a preliminary rinse. If they are mechanically harvested, they are dumped into a dry hopper or auger. Grapes from either type of harvest are then merged and are run through a stemmer to eliminate stems, vines, and other miscellaneous debris. They are flumed to a surge tank and fed from this tank directly into a tubular heater to activate the natural enzymes. After passing through the heat exchanger, they are maintained at approximately 140°-150°F until enzymatic action is judged sufficient. At this point, approximately 50 percent of the juice is available as free liquid and is separated from the unpressed grapes by means of a pre-dejuicer. The pulp, separated from the juice, is fed through a screw press which squeezes the remaining juice from the grape mass. The juice from both the pre-dejuicer and press operation is combined in a surge tank, filtered, pasteurized, and pumped through a heat exchanger to reduce the temperature to 28°-30°F. (The grape juice at this stage contains approximately 15.5 to 17 percent sugar.)

The chilled juice is pumped to storage tanks where natural or in some cases artificial means are used to settle out the fine suspended tartrates and tannins. The juice, after aging, is usually siphoned and further clarified, typically through a filter press. The juice from cold storage may be treated in several different ways. It may be directly canned as grape juice or concentrated to be used for formulated items such as drinks or jelly (covered under Jams and Jellies). In the case of grape juice, following a final filter step, the juice is pasteurized and hot filled either into cans or glass bottles. The containers are closed, washed, and cooled. Grape or grape-fruit drink is typically premixed in a batch tank at which time other ingredients such as vitamins, sugar, other concentrates, etc. are added per product formula. The batches are typically preheated, pasteurized, and hot filled as described above.

The principal wasteloading process in a grape crushing operation is cleaning. This is primarily because any spill points are minimized to conserve all possible usable juice. Collecting stems, petioles, leaves, and pieces of vine as dry waste also reduces wasteloadings. Other items such as pomace or other pulp were observed to be collected dry. Principal sources of wasteloadings during grape juice packing are typically clean-up operations and any juice or drink spillage which occurs upon filling. Can and bottle cooling water (non-product contact) contributes a significant volume to the waste stream while having a dilution effect on the wasteloadings. For the canning of grapes, both flume and can cooling water can be reused. The flume water is typically recirculated, whereas the can cooling water is normally passed through a cooling tower and chlorined

FIGURE 10

TYPICAL RIPE OLIVE PROCESS FLOW DIAGRAM



before being used as either wash make-up water or for additional cycles of cooling.

Olives

In the United States, olives for processing are grown only in California. The utilization of these olives for canning and oil is a small but substantial part of the California agricultural economy. It has been estimated that there are 32,000 acres of olives grown in California. Leading varieties include Manzanillo, Mission, and Sevillano. Some Ascolano and Barouni varieties are also grown, as well as a very small amount of minor varieties. For the purpose of this study, seven plants in California were visited for the collection of historical data. Approximately 75 percent of all olives are canned, either black or green. The remaining olives are chopped or used for oil recovery.

Figure 10 shows a typical olive process flow diagram. Olives are harvested by hand in the late fall period of midSeptember to early November, when still green, just before they would turn pink if left on the tree. If they become too ripe, they will not stand the necessary handling and preparation, and their appearance will be ruined. However, if picked too green, the oil content and nutty flavor will not be developed. Every step in the handling of the olive is done as quickly and efficiently as possible. Olives require more handling and manipulation than most tree fruit crops but are not especially prone to spoilage. They are handled either in lug boxes or larger wooden bins.

When the olives arrive at the factory, they are generally dumped into a mechanical trash eliminator, a dry operation which removes leaves, twigs, and debris. They are conveyed to a stemmer (also a dry operation) which removes stems and any remaining leaves. The olives are then inspected and graded according to size. Large and unblemished olives are canned as black or greenripe fruit. Intermediate sizes are used for Spanish-cured olives. Small and blemished fruits are used for chopped olives or oil recovery (almost all Missions because of their high oil content). There are several styles of graders used to prevent injury. The most common system consists of a series of V-shaped troughs, the different sections separated by increasing the increments by 1/16 inch. The olives are dragged along gently and when they reach the proper size, they fall through. (A second method is by the use of diverging cable type graders.) After sizing, a determination is made as to whether the fruit is to become a Spanish style, green ripe, or ripe olive. The factor determining Spanish style is size. Olives smaller than large Barouni, medium Sevillanos, petite Mission and petite Manzanillo (Ascoloni) almost always go to ripe process because of their texture and susceptibility to bruising. The determination as to style is based on production capacity of the plant since green ripe and Spanish olives must go directly to curing, but ripe olives may either go directly to curinq or be stored (minimum time of two and a half weeks to nine months).

Because processing may not keep pace with the harvest, olives destined to go for ripe processing may be stored in large tanks containing a salt brine solution. The concentration of brine used depends on the variety of olive being stored. The brine is generally four to five percent for Sevillano, Ascolano, and Barouni varieties. The concentration of the brine is gradually increased over a period of three to four weeks to a level of eight to nine percent for the smaller sized varities and seven to eight percent for the Sevillano, Ascolano, and Barouni varieties. The majority of the olives are stored in the brine for one and a half to six months. At some plants, Mission and Manzanillo varieties are stored for as long as ten months (in this case the brine concentration is increased to ten percent).

Anaerobic storage of olives has been utilized in conjunction with the storage method described above. Because of the increasing emphasis on quality control (shrivel has been virtually eliminated and pollution minimized) and a need to prevent oxygen from interacting with olives, anaerobic storaqe was developed and has been used for the last several years. The olives, after the initial cleaning and inspection, are placed in large tanks which have a gasket sealed manhole closure equipped with a liquid trap, which in turn is fitted with a transparent, removable cover. The trap walls are translucent for positive liquid level determination and control. After the tank has been filled with food product, liquid is brought up to within one inch below the manhole. The closure, with its seal and liquid trap is bolted in place. Final filling is through the liquid trap. Entrapped air is vented through solution recircualtion and product inspection ports which are built into the tank. The liquid level in the trap is raised to nine inches. As gases generate, they pass out through the liquid trap. The trap provides a semi or complete anaerobic seal and allows solution replacement of inter-cellular gases and expulsion of these gases formed in fermentation. Compensation for expansion and contraction of the liquid in the tank is through the trap. Complete anaerobiosis is obtained by floating food grade mineral oil atop the liquid in the trap.

Alternatively, the storage processes described above can be bypassed and the olives utilized directly from the field. Storage is only a means of preserving olives for processing. The curing of green and Spanish varieties is always with freshly picked fruit that has not been stored in salt brine. Curing consists of treating with dilute sodium hydroxide solutions to hydrolyze the tannic acid. If black ripe are desired, aeration is used to develop the black color. Green ripe are cured similarly to black ripe but without aeration. After curing, the caustic soda is leached from the fruit which is then canned in salt brine. Spanish-style olives are cured by a lactic acid fermentation in brine.

Ripe olives: the olives are treated with three to eight changes of dilute sodium hydroxide (lye) solutions. The first lye is usually one percent in concentration and the subsequent solutions are 1.25 percent to 1.75 percent concentration. Between applications, which usually last for an hour and a half to three hours, the olives are covered with water which is vigorously aerated by compressed air. Or the drained olives alternately are exposed to air for four to 24 hours. The object of the lye treatment of olives is to hydrolyze the bitter principle (oleuropein). The aeration at slight alkalinity oxidizes the tannins and causes the olives to develop a black color. The olives are washed with a number of changes of water until they are practically free of sodium hydroxide (pH 7.3 to 7.8). They can be alternately neutralized with sulfuric acid. The washed olives additionally are sometimes stored for one to two days in 2.5 percent brine before they are size-graded a second time and sorted.

The green ripe olives are cured by a process similar to ripe olives except they are never exposed to oxygen through aeration. Because of the texture and susceptability to bruising of the Ascoloni, few are processed as Spanish olives. (Missions because of their high oil content are also generally excluded from this process.) Sevillanos, Manzanillos, and Barounis are placed in water to cool the fruit prior to the first lye application (mainly due to the susceptability of Sevillanos and Manzanillos to lye blister). After the initial lye application (1.2 percent to 1.5 percent) has penetrated to the desired depth (usually 1/6 in. from the pit), the lye is drained. If the processor sees it necessary, the lye is re-fortified by a rapid draining of between one third and one half of the lye. If olives are not "cut" as much as normal, however, then more lye is drained from the tank. The new lye is added immediately to prevent darkening from excessive air exposure. After the lye has penetrated to the correct depth, the lye is drained. The water is turned on while there is still two or three inches of lye in the tank. The last of the lye is flushed out with water, and the tank plugs are replaced. The Spanish olives are put on a wash water change schedule to remove the excess lye. It is necessary to remove the excess lye by washing and leaching with water before the lye-treated fruit is barreled and brined for fermentation. Several factors influence the time required to wash the excess lye from the fruit: the concentration of lye in original solution; intervals between changes of wash water; size and maturity of fruit; chemical composition of wash water. The tendency at present is to shorten the washing period in order to minimize graying of olive color. Violent aeration must be avoided in filling the tanks or vats with fresh wash water, for the dissolved entrapped air may darken the olives severely. Immediately after washing, the olives are placed in barrels or left in tanks and covered with salt brine. Corn sugar (dextrose) is added to each barrel during the coopering of the barrels. The barrels are then rolled into the barrel lot (full sun exposure); the salt concentration is constantly adjusted to maintain a salt concentration of approximately 7.5 percent to 8 percent (25-30 salometer); and the olives are allowed to undergo lactic acid fermentation.

Ripe Whole Unpitted: from the curing vats, they are pumped to a needle board (minute needles perforate the olives to facilitate uptake of brine while preventing wrinkle) and then taken by belt or in bins in one of two directions. Large, well formed olives are size graded, put on a belt, and inspected; gradeouts go to the chopped olive production line. From here they are tumble filled into cans and topped with brine, usually by means of an automatic salt dispenser dropping a tablet in the can. The cans are closed in a steam flow fitted double seamer, washed, retorted, and cooled.

Ripe Whole Pitted and Chopped: olives to be canned whole but pitted are taken generally in bins, to a pitter which mechanically removes pits from the fruit. The popularity of pitted olives is increasing and at present accounts for a substantial fraction of the total production. The olives are pitted after curing and the second size grading stage. Two different makes of machines align the olives in a vertical position. A coring tube produces a loose cylindrical section of pit and flesh. A punch pin moves in from the opposite side from the coring tube to push out the pit segment. These pitting machines have a capacity of about 800 olives per minute. They are then inspected, culls removed before filling, and the same steps as above for whole pitted are followed. Sliced and chopped olives after being mechanically pitted also follow the same processes as other olives.

Green Olives (Pitted and Unitted): the processing and preserving of the various styles of green olives are the same as those mentioned above for ripe olives.

Spanish Olives: from the curing vats, the olives are washed, usually by water sprays, and after inspection and sorting, are pitted through typical pitting equipment. The olives may then be repacked in barrels for bulk sale or may be canned. Both salt brine and lactic or acetic acid are added prior to final processing. This provides a means of preservations; the cans of finished product are not retorted.

It is apparent from the above outline of olive processing methods that the spent brines and alkaline solutions constitute a considerable volume of strong wastes. It has been estimated that nine olive companies in the Central Valley used 4,300,000 lbs of sodium chloride and 740,000 lbs of sodium hydroxide to preserve 21,000 tons of olives in the 1961-62 season. Some 226 million gallons of water were discharged during these operations. Substantial quantities of sodium salts (chloride, hydroxide) are used in many food processing operations. The disposal of the saline liquid wastes from these operations, without causing water pollution, is a problem of increasing complexity. The primary difficulty in the disposal of saline liquid wastes is the non-biodegradable character of sodium chloride and sodium hydroxide.

A significant reuse of water is accomplished through the recycling of the curing water by way of the lye holding tanks (this water apparently is being exploited to its maximum potential). Of the remaining sources of daily wastewater generation - clean-up, pitting, cooling water - the first two do not offer a likely area for water reuse because of their high load qualities. Cooling water could be reused provided it passed through a cooling tower.

Peaches

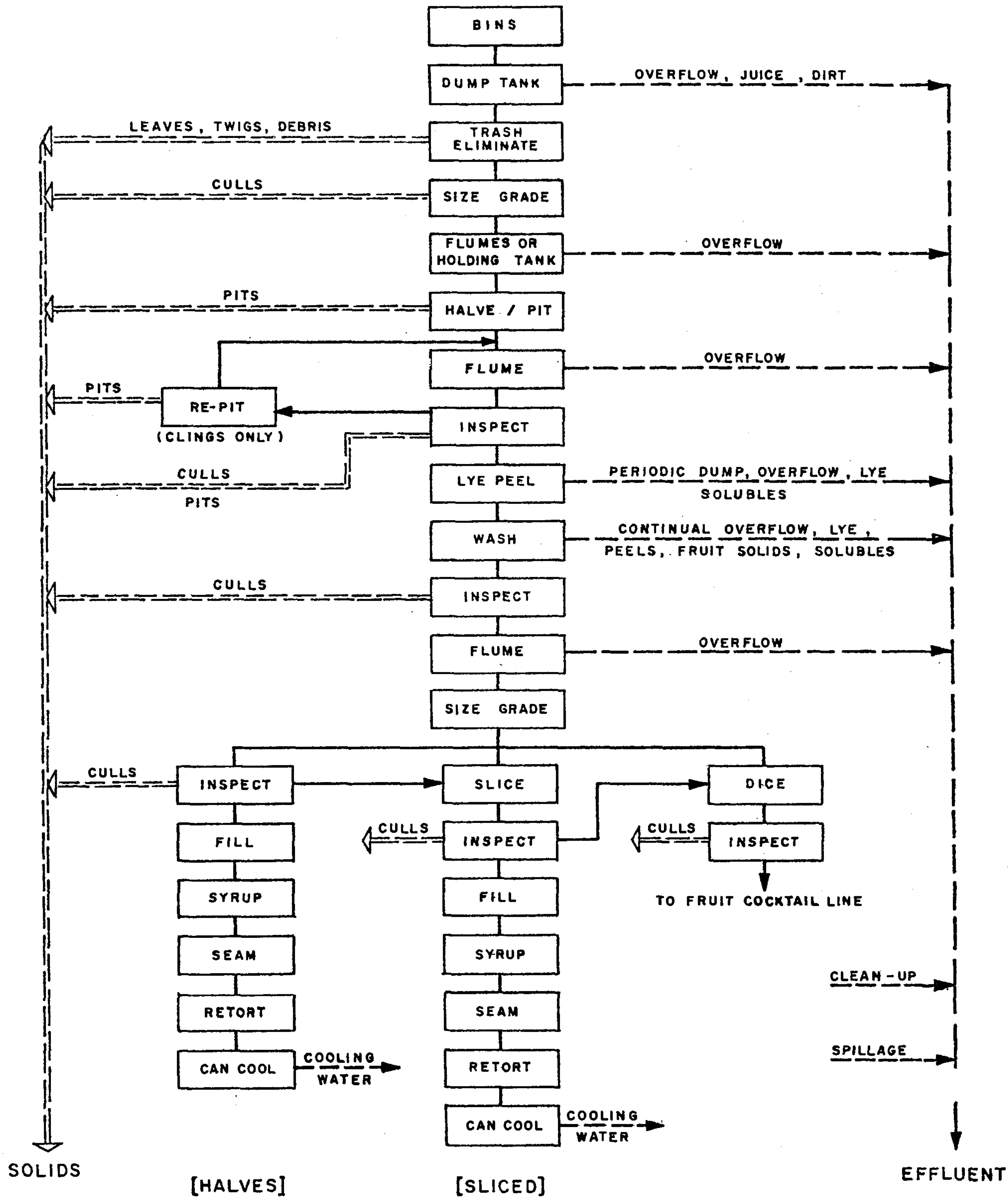
Peaches are the largest fruit pack in the United States. Nearly all U.S. production (94 percent) occurs in California, where both cling and freestone varieties are processed. Georgia, Michigan, Pennsylvania, South Carolina, Virginia, and Washington also process peaches. For the purposes of this study, thirteen plants in California, one in Washington, one in Virginia, and one in Pennsylvania were visited for the collection of historical data. In addition, a total of eighteen composite samples were collected and analyzed to verify this data. Peaches are processed in three basic styles: canned (whole, halves, diced), frozen, and dried. Over 90 percent of all peaches processed are canned, with six percent being frozen, two percent dried, and one percent made into pickles, wine, and brandy. For dried peaches, refer to separate process description of dried fruit. The main processing season runs from mid-July to mid-September.

There are two main varieties of peaches, clingstone, and free-stone, and both are essentially harvested by hand, since fruits of this type are too delicate for mechanical harvesting. Clingstones are harvested when ripe (color is generally the determining factor) and firm. Freestones are harvested several days before tree ripening because it is difficult to handle the soft, tree-ripened freestone quickly enough to avoid serious deterioration between harvesting and processing. Because all fruit on the trees does not ripen at once, several pickings are usually required. "Pickers" place peaches into lug boxes, which hold between 40 and 60 pounds of peaches. These lug boxes are then stacked on a truck and taken directly to the processor. Peaches are also delivered to the plants in larger wooden bins.

Figure 11 shows a flow diagram for a typical peach processing plant. Basic unit processes include: washing, size grading, halving/pitting, peeling, and canning. The peaches arrive at the plant in lug boxes or bins and are usually dumped into a recirculating washwater tank. This initial wash and trash removal screen remove leaves and stems and soil residues. After the initial wash, the peaches are usually, though not always, sprayed with high pressure rinses to remove final residues. Some plants use a dry scrubber with dry roller and a fine spray, wet brush defuzzer instead of a dump tank. The peaches are usually

FIGURE 11

TYPICAL CLING AND FREESTONE PEACH PROCESS FLOW DIAGRAM



transported, then, by water flumes to size graders for distribution to the various processing lines. Sorting and grading operations usually take place before and after pitting and typically, once again, after lye peeling, the main purpose of which is to sort for maturity and blemished units.

After the peaches have been washed and size graded, they enter the cutting machines where they are halved and pitted. Freestone peaches are pitted on a device similar to an apricot pitter. The fruit is cut around the circumference. The action of rolling followed by a mechanized shaker both opens the peach and shakes the pit from the peach. Holes in the shaker screen allow the pit to be dry conveyed or flumed away. Cling peaches are halved and pitted simultaneously. A rod with fitted "fins" is thrust through the peach pushing the pit into a conveyor. Pits that are fractured are automatically recycled and repitted by the machine.

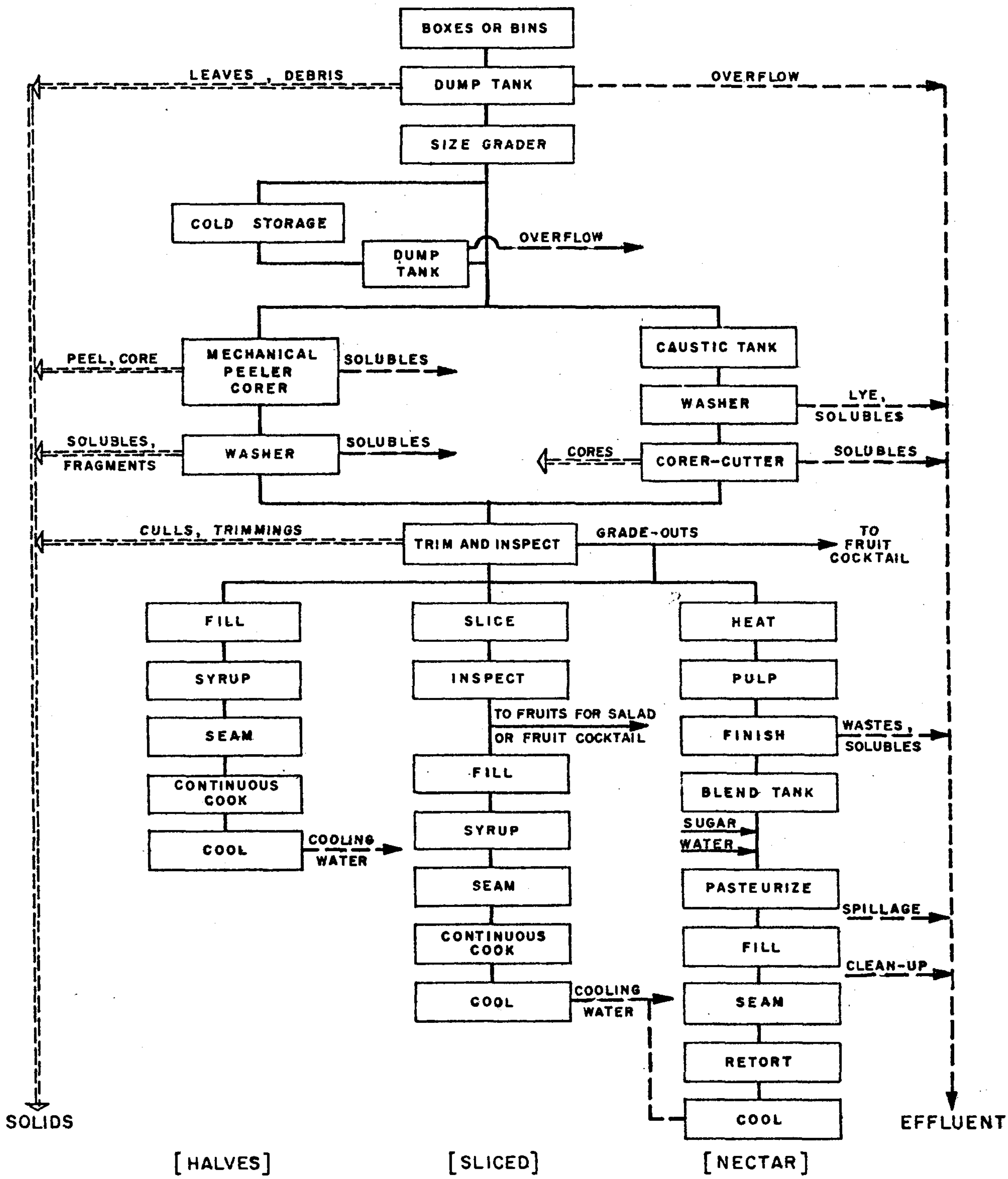
Following inspection of the pitted, halved fruit the peaches are peeled by exposure to a hot lye solution usually followed by high pressure water sprays. The peel may alternately be removed by rubber scrubber discs and the waste removed by dry conveyor. The peeled halves are then quality inspected with culls being discarded to solid waste. Size grading follows with the highest quality halves typically conveyed by flumes to filling machines. The lower quality halves (too large or small, minor blemishes) are transported to slicing or dicing operations and are then re-inspected before they are packed as sliced peaches (following the same process as for halves); or alternately sent as dices to the fruit cocktail can filling line. Peach halves are typically tumble filled into containers of various sizes, topped with hot syrup, closed with steam flow, retorted (still or continuous type) and cooled. Peach slices and fruit coctail (a mixture of diced peaches and pears, pineapple, cherries, and grapes) are similarly processed.

The significant wastewater streams include the following: overflow from dump tanks and various fluming operations located throughout a typical process line; overflow and periodic dumping of caustic peelers and wash tanks; and clean-up of spills and equipment. The initial dump tank and flume system is usually recirculating with fresh and/or reclaimed makeup and continual overflow to the gutter. This overflow usually contains fruit juices and solids, dirt, and debris. Overflows from later fluming units will contain varying amounts of soluble organics depending on their position in the process line and the condition of the fruit.

Wastewater from the lye peeler and washer is the strongest of all the waste flows. It is the major BOD and SS contributor as lye, peels, fruit pieces, and solubles are discharged to the gutter. Clean-up of spills on a continual basis and intensive end of shift equipment washdown contribute further to the total BOD and SS concentrations. Dumping of lye peelers and wash and dump tanks during clean-up operations add caustic, considerable BOD,

FIGURE 12

TYPICAL PEAR PROCESS FLOW DIAGRAM



and solids to the clean-up flow. Pollutant loadings were observed to be reduced when the peel waste was treated separately, especially in the use of "dry caustic peelers."

The major source of water for reuse in peach processing is can cooler water. After use in cooling the hot cans out of the retort, this wastewater is still relatively uncontaminated and is frequently reused directly as make-up to initial dumping and fluming operations. Alternatively, this cooling water can be passed through cooling towers and recirculated back to the can coolers. General flow rates from typical can cooler units are quite substantial, ranging from 150 to 250 gpm. Other reuse practices include continual recirculation of all dump tanks, wash tanks, and flumes with a low percentage of make-up and continued overflow to waste. Effluent from final fresh water product rinses may be reused in primary washing stages, and wastewater from the halve/pit machine is often recirculated to the preceding fluming system. A few plants have can cooling water of sufficient quality to reuse it as a major source of the plant clean-up water.

Pears

Approximately 94 percent of the total U.S. production of pears are processed in the three Pacific coast states of California, Washington, and Oregon, with almost two-thirds of the total U.S. production being processed in California. For the purposes of this study, seven plants in California, two in Washington, and four in Oregon were visited for the collection of historical data. Approximately 98 percent of all processed pears are canned; the remaining two percent are dried.

Figure 12 shows a typical pear process flow diagram. There are three varieties of pears processed in the U.S.: Bartlett, Beurre Box, and Beurre D'Anjoy. Pears do not ripen successfully on the tree and are picked green at what is called "tree maturity." This is usually determined by a pear pressure tester which measures the firmness of the pear by recording the amount of pressure required to force a plunger 5/16 in. into the pared flesh of the pear. Pears are harvested by hand because of the delicate nature of the fruit. They ripen under controlled atmosphere conditions.

Pears arrive at the plant in bins or lug boxes, at which time they are usually dumped into a recirculating washwater tank or hydro-cooled. This initial wash removes remaining leaf and stem material and soil, and cools the fruit (an energy-efficient method of removing field heat). The pears may then be transported to size graders where they are separated by size and are placed in either cold storage or in a controlled atmosphere until the desired ripeness is attained, sometimes a period of several weeks. They may alternately go to the ripening room without size grading.

Out of the ripening room, the pears are washed again and fed to the peeling machine. Peeling is accomplished with either a machine that peels, cores, and halves in one operation, or with immersion in a hot lye bath and water spray wash after which the pears are mechanically cored and halved. The advantage of mechanical peeling is the reduction in water usage and the ability to keep peels and cores out of wastewater flows, thus lowering effluent BOD and SS concentrations. However, the mechanical peeler often gives a lower yield than the caustic peeler because the knives cut off some usable fruit with the peel. After the pears are peeled, cored, and halved, they are usually inspected, trimmed, and separated by quality for halves, slices, or dices (for cocktail), or nectar. The purpose is to sort for size, maturity, and blemished units. Separations for quality are most often done by hand, while size separation is done by mechanical means. Wastes from these operations consist of whole pieces, miscellaneous organics, and juice. Manual trimming operations remove unwanted portions of the product, such as blemishes, cores, and peels.

After trimming and inspecting, the highest quality halves proceed directly to the can filling station. Pears with blemishes or smaller size fruit that are not of sufficient quality to be canned as halves are sent to the slicing line. Here they are sent through a mechanical slicing machine after which another inspection separates undesirable slices for the dicing machine and nectar line. At this stage, the halves and slices proceed through filling machines where the various sized cans are filled, topped with syrup, seamed with steam flow, sent through continuous cookers, and cooled with water sprays. The dices are combined with peach dices, pineapple, grapes, and cherries to be canned as fruit cocktail. The dices may also be combined with over-ripe and green pears not suited for halving or slicing to be canned as nectar. The over-ripe pears add flavor and high sugar content, whereas the green fruit maintains the light color of the final nectar. The fruit is initially pre-heated to break down the pectin in preparation for pulping. The fruit is pulped and finished with the resultant juice entering a blending tank where sugar, water, and pulp are added in proper amounts. The nectar is then pasteurized, filled in cans, cooked in retorts or continuous cookers, and cooled with water sprays.

The major wastewater streams in pear processing are generated in the initial dumping and fluming operation, the lye and mechanical peeling wash, the can cooling system, and clean up. The initial dump tank and flume system is continually recirculated with either fresh or reclaimed water make-up and continuous overflow to the gutter. The waste stream includes sticks, leaves, dirt, and pieces of fruit. The sytem is usually emptied once per day.

The main BOD and TSS component of the waste stream comes from the peeler and following washers. The strong solution from the peeler contains a high concentration of lye and soluble organic matter. The spray wash following the peeler is used to rinse the peel and excess lye off the fruit. This continual discharge to the gutter is the main pollutant source in the pear process. The major flow volume generated occurs in the can cooling process following retorting. Water sprays are usually used to cool the cans, often in large volumes. This flow, however, is not significantly contaminated and can be reused in preceding operations as described in the next section. Cooling water is also typically recirculated through cooling towers and reused again as cooling water. Intensive end-of-shift clean-up as well as continual equipment washdown and spill clean-up can also be a significant suspended solids and BOD source. Washers and dump tanks are usually dumped during clean-up and add further solids and soluble organics to the clean-up stream.

The major wastewater reuse is can cooler water that is collected and reused in the initial dumping and fluming operations. This supply is usually augmented with a fresh-water make-up line. Other possible reuses include recycling of water from the cores/ cutter machines to the preceding peeling and washing operations and the recirculation of water in all flumes, washes, and dump tanks.

Pickles

The preserving of cucumbers by salt and acid is called pickling. Cucumbers produced for processing in the U.S. are all processed into one of several varieties of pickles or relish. Thirteen states are major processors of cucumbers into pickles. Michigan, with seventeen percent of the total U.S. production, is the leading pickle producing state, followed by North Carolina and California, with twelve percent each. Ohio, Wisconsin, Colorado, Delaware, Indiana, Washington, South Carolina, and Virginia are the other major pickle producing states. For the purposes of this study, three plants in Delaware, two in Michigan, one in Oregon, one in Alabama, and one in Georgia were visited for the collection of historical data. In addition, a total of seven composite samples were collected and analyzed to verify this data.

Within recent years, a change has taken place in the pickle industry due to the introduction of fresh pack pickles. Prior to this development, practically all cucumbers were salted and fermented in barrels or tanks, after which they were marketed or processed and finished. There are two general types of pickles, process or salt stock pickles and fresh pack pickles. The former is defined as a cucumber cured by a fermentation process using a salt solution. These process pickles are cured either at separate salting stations used strictly for curing cucumbers or at pickle plants that cure cucumbers and also process and pack the pickles. Plants of this type and salting stations cure cucumbers, in more or less the same way, and this process is described below. Process pickles are packed year round. Fresh pack pickles are defined as essentially pickles that have been cured after packing. The fresh cucumbers are packed May to

FIGURE 13

TYPICAL FRESH PICKLE PROCESS

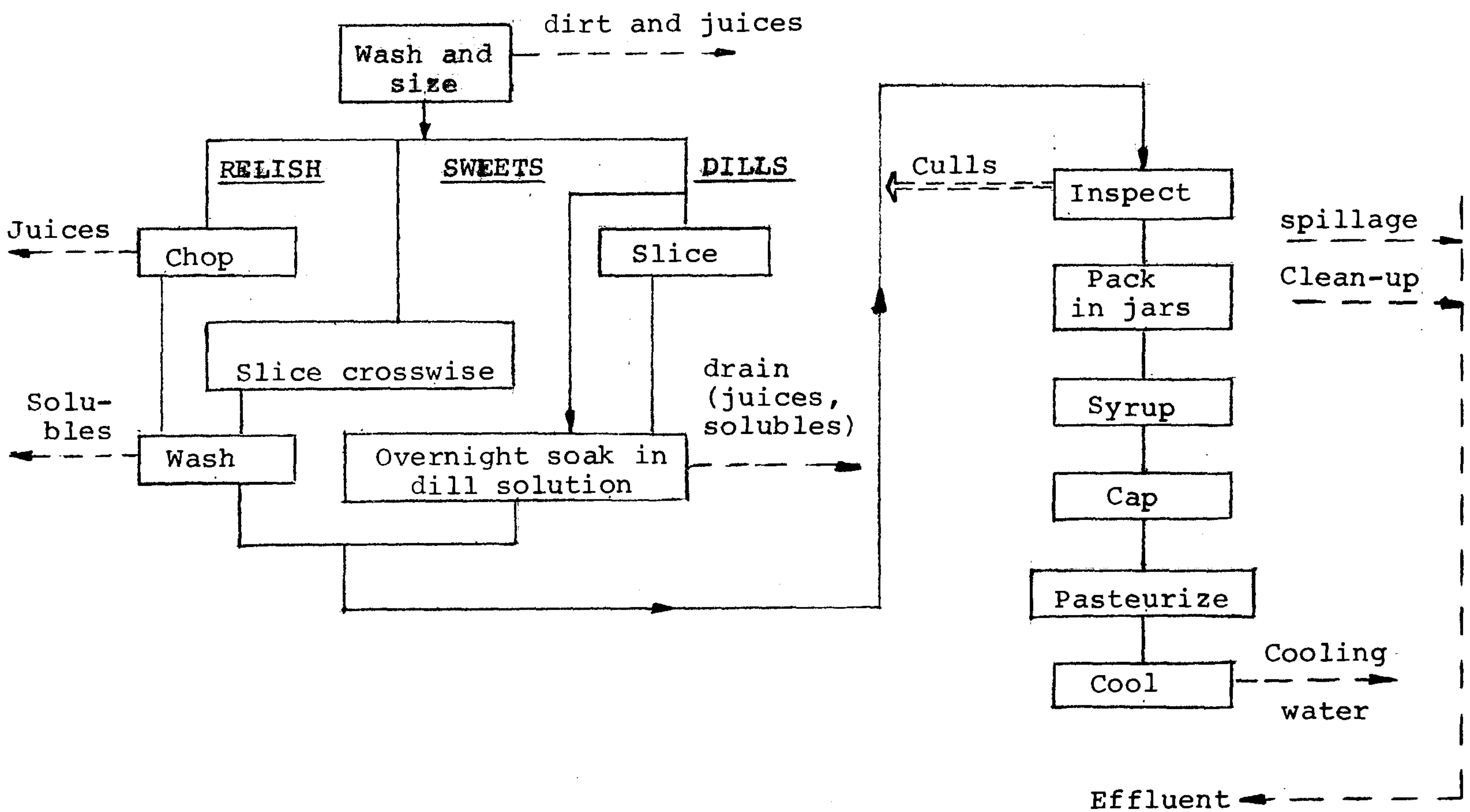
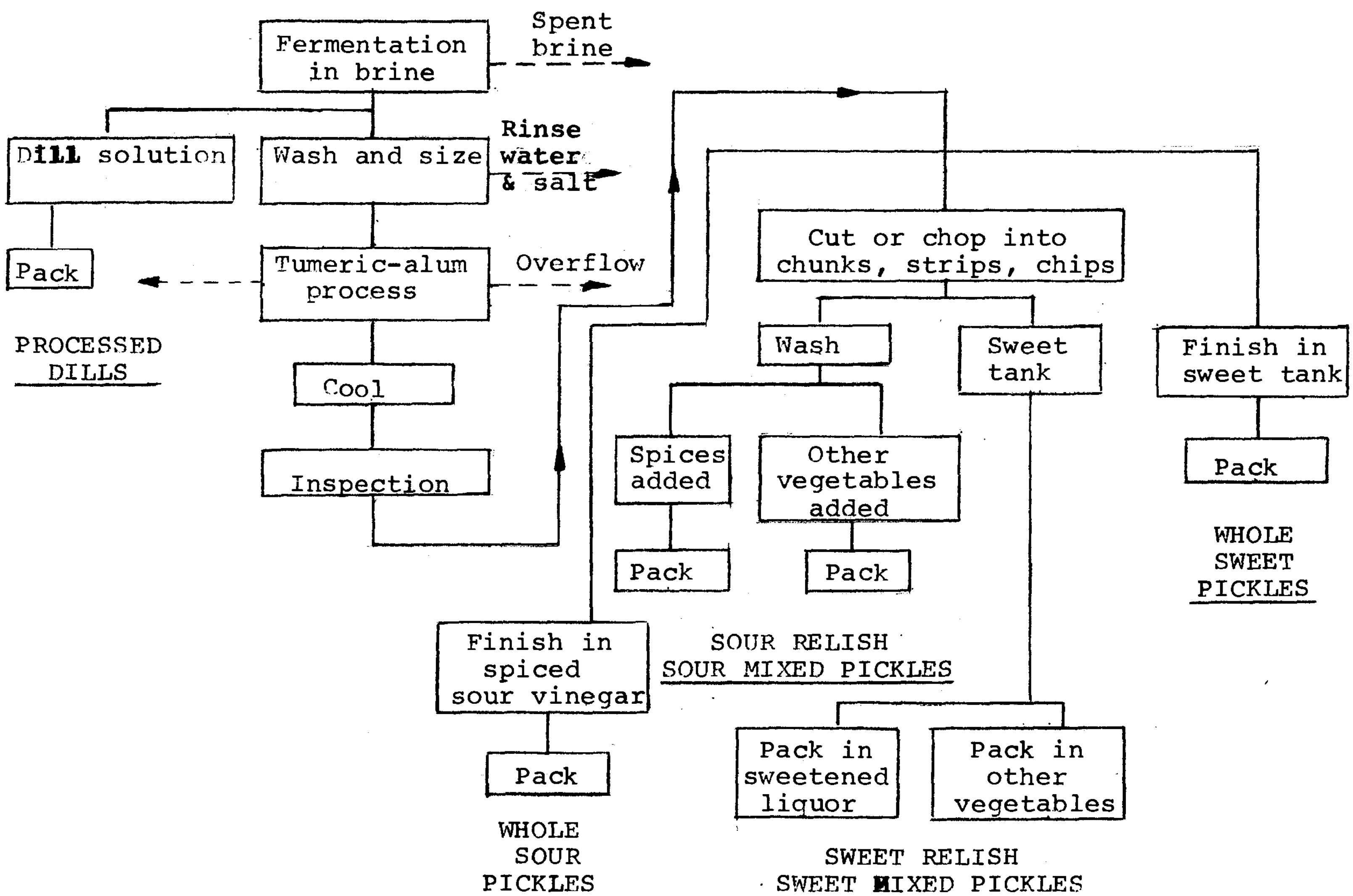


FIGURE 14

TYPICAL "PROCESSED" PICKLES PROCESS



August, in jars or cans, sealed in a brine solution, and pasteurized.

There are over 36 types of pickles belonging to the process and fresh pack pickles. These are various dills, sours, sweets, and fresh pack products. Pickles are packed whole, halved, quartered, sliced, chopped, and in spear, cube, and chunk styles. Most pickle plants manufacture both processed and fresh pack pickles and may also have their own curing tanks. Waste loads for these plants vary greatly depending on whether processed or fresh pack pickles are being processed. The process description following explains more in depth the processes for processed and fresh pack pickles.

Figures 13 and 14 show typical pickle process flow diagram. The proper selection of cucumbers is essential in obtaining satisfactory pickles. The cucumbers should be firm, sound, and free from blemishes. Cucumbers are harvested by hand and by machine. The trend is moving toward mechanized methods. These cause an additional wasteload in settleable and suspended solids because of the soil and vines also collected. The cucumbers are either delivered to salting stations or directly to processing plants as soon as possible after picking. After delivery, the pickles are unloaded dry to a flume and are washed with fresh water. The cucumbers are then mechanically sized, placed into bins, and are processed immediately or stored in coolers for no more than a few days.

Fresh pasteurized dills, sweets, and relish are made by placing fresh cucumbers in glass jars, covering them with suitable brine or syrup, and pasteurizating them. Cucumbers of a suitable size are used for making fresh sliced cucumber pickles, also called bread and butter pickles. Fresh whole dills are packed tightly into containers with the desired whole spices and covered with hot or cold dill liquor containing vinegar and salt and water. The containers are then capped, pasteurized, and promptly cooled. The process for Kosher dills and fermented or Polish or Hungarian dills is similar to other dills, but other spices, such as garlic cloves or garlic juice or onion, are added. Other fresh pack styles are sliced or chopped, washed, and then packed in liquor or syrup depending on the particular type desired. The packing operation is the same as for process pickles. The styles of fresh pack pickles have similar wasteloading characteristics. However, the dill pickles that are sliced will have a somewhat greater wasteload than whole dill pickles, and fresh pack sweets will have a somewhat greater wasteload than products packed as dills due to the drip loss of the sweet cover syrup.

Cucumbers are brined in wooden vats ranging in capacity from 200 to 1,200 bushels. The vats are filled with fifteen to twenty percent salt brine and green cucumbers graded for size or mixed, and are fitted with wooden board covers and keyed down firmly to enhance the fermentation process. Sufficient amounts of salt and brine are added throughout the operation to keep the cucumbers covered. The brine is generally recirculated by means of a pump from the bottom of the tank to the top until all salt is dissolved. The fermentation process requires a minimum of eight days, but more often three to six months is allowed. The scum which forms on the top of the tanks during fermentation is removed from time to time to avoid spoiling or softening of the pickles. The pickles are cured when the original bright green color has changed to dark olive green and the pickles are translucent and show no white spots or areas when sliced. After curing, the pickles are kept usually in the original covered tanks or vats. Scum is removed daily and sufficient brine added to keep the pickles submerged at all times. When completely and properly cured, pickles will keep satisfactorily for a year or more. If kept longer, new salt is added as needed to maintain the desirable brine concentration.

Various types of sweet pickle products are made from processed pickles by a series of operations: leaching out most of the salt with fresh water, conditioning with alum and tumeric in most cases, adding vinegar, and sweetening with sugar. The fifteen to eighteen percent salt in cured stock is reduced to about four percent by at least two changes of water. In the last change, the water may be heated to increase the rate of desalting. Whole pickles go directly into vats for impregnation with vinegar and sugar syrups, whereas pickles destined to become chips, relish, and so on are first sliced to the desired degree, usually in a rotating cutter which simultaneously cuts the pickles and sprays the pieces with a jet of water. After the "sweetening" tank, the pickles are packed into jars, covered with vinegar and syrup, capped, pasteurized, and cooled. The process for sour pickles is similar to that for the sweet pickles, except for the fact that the pickles are impregnated with a vinegar and herb mixture which contains only a small amount of sugar.

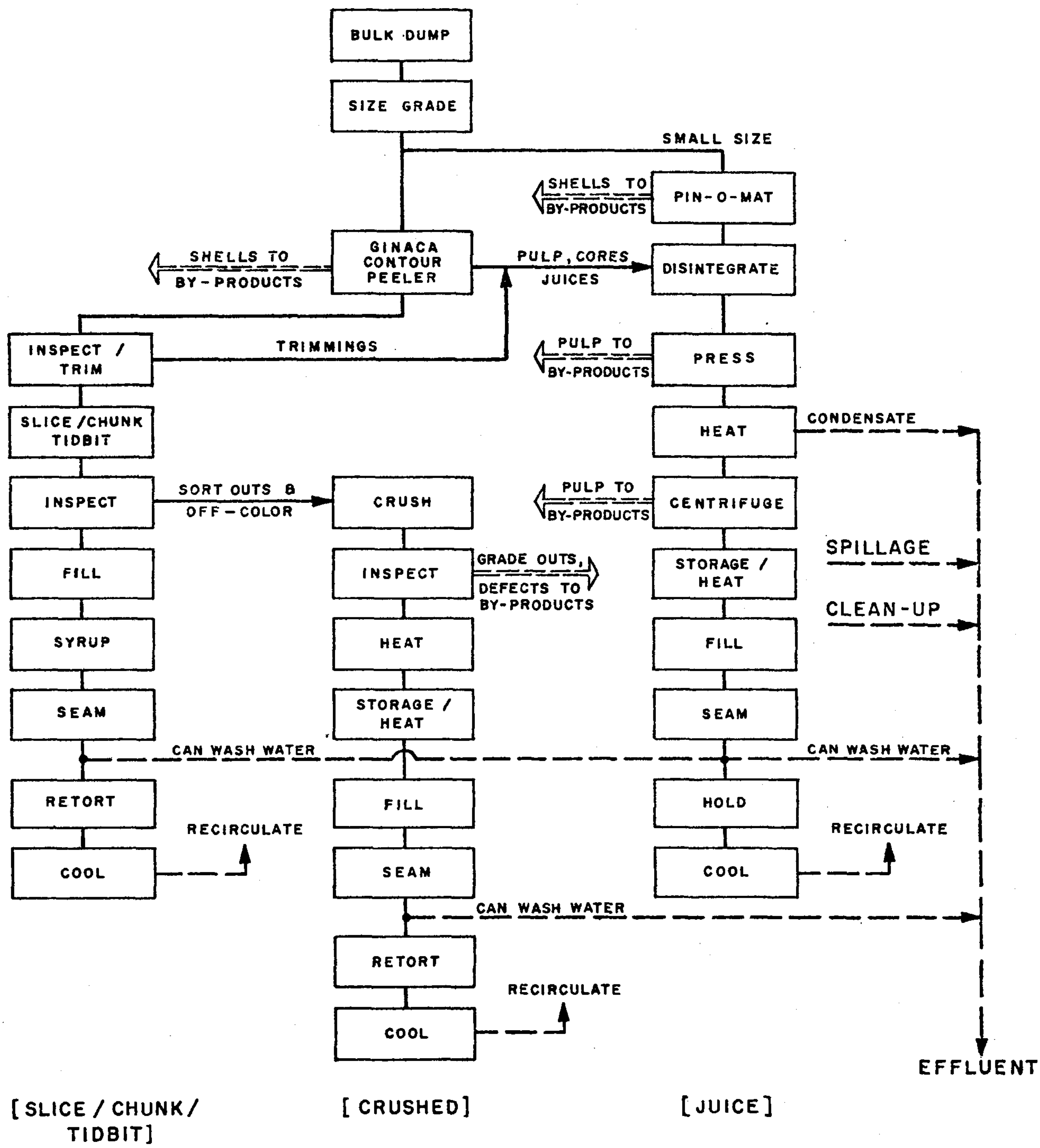
The processing of dill pickles is very similar to that for sour pickles. Dill herb is added to the brine tanks during fermentation (producing natural dill pickles) or dill-flavored vinegar is used to impregnate regularly brined pickles (producing process dill pickles). Dill pickles can vary from very large whole cucumbers to finely chopped relish. Some are sliced lengthwise. Many are sliced crosswise.

Sources of wastewater have been indicated on Figures 35 and 36. In addition to these wastes, significant amounts of water are used in conditioning the vats and in clean-up operations. Lime water from "sweetening" the tanks is dumped about once a year. Fermentation and sweetening vats are occasionally dumped and are high in wasteload concentration and salt content. Daily clean-up operations also generate a considerable amount of wastewater.

Spent brine is a major contributor to the wasteload. Brine recycling is a new technique to recover salt plus reduce wasteload. Several plants are experimenting with this operation and are currently in the pilot stages. One plant using this

FIGURE 15

TYPICAL PINEAPPLE PROCESS FLOW DIAGRAM



technique was visited, and the recycling steps are described as follows. After fermentation, the pickles are removed for further processing. The spent brine is then recycled to a fermentation holding vat where residual sugars in the brine solution are oxidized by lactobacillus bacteria. Retention time for this anerobic process is about one week. After the sugars have been consumed, the spent brine is passed through a heat exchange process. At this time, lime is added to the brine solution to adjust the pH. The spent brine is then recycled back to a salt tank where salt is added to bring the brine solution back to a 100° salometer. This recovered brine solution is then recycled back to the curing vats where the process is repeated. Recirculation of flume water is common. Cooling water is also reused in a counterflow principle, then discharged.

Pineapple

Most of the U.S. production of pineapple occurs in three Hawaiian plants, although it is also processed in Puerto Rico. Approximately two thirds of the 1,095,700 tons of pineapple produced in 1971 was canned, and the remaining one third was made into juice. The amount of processed pineapple in the U.S. has been declining the past few years because most processors have been moving their plants to the Phillippines or other foreign countries. For the purpose of this study, three pineapple plants were visited for the collection of historical data. In addition, a total of five composite samples were collected and analyzed to verify this data.

The generation of pineapple plants is started with the planting of green crowns that are removed from the mature fruit prior to the harvest. The ground is first fumigated for nematode prevention, the crown is placed in a "cutout" hole in a long narrow continous piece of plastic. The bottom part of the crown is covered with dirt, a shot of fertilizer is given, and the growth cycle is renewed. The planting is mostly done by hand, but machinery has been developed to automatically plant the crowns. Each plant yields a single fruit which matures in eighteen to twenty-four months depending upon climatic conditions. After harvest, the plant will send up a sucker which in approximately twelve to thirteen more months, will yield a second fruit (ratoon crop). This fruit is generally smaller in size than the first picking, but is still quite acceptable for processing. The plant may be further allowed to produce one more fruit (second ratoon) which in turn is usually smaller than the first ratoon. All fruit processed is of the Cayenne variety. Harvesting is a hand operation. The crowns are "snapped" from the top of the fruit and saved for planting. The mature fruit is then removed from the plant, placed on a boom (spread over several rows at a time) which feeds a bulk container, and the fruit delivered to the plant immediately thereafter.

Figure 15 shows a typical flow diagram for a pineapple plant. The pineapples are gently "rolled" from the bulk bins and are initially size graded by being passed over a series of spinning screw-rollers which both convey the pineapple and allow the smaller fruit to drop through to another conveyor. Conveyance can be accomplished by rapid moving flumes or by conveyor belts fitted with water sprays. An operator at this station equipped with TV monitoring apparatus, controls the flow of fruit into the plant. The operator views the different slice, chunk, and juice operations and varies the proportion of fruit into the plant as needed by selecting the various available sizes for processing.

The fruit can be prepared for canning in one of three different ways. The first method employed by all processors is by use of the Ginaca machine, which removes a cylinder of fruit along the long vertical axis of the pineapple. Both ends are trimmed, the inner core removed, and the cylinder is conveyed to a trimming line. Because the Ginaca machine does make an even cylindrical cut, however, there is much flesh left adhering to the shell. Another function of this machine "eradicates" this fruit which, combined with the cores and juices (from cutting), is conveyed to the beverage juice operation. The shells are conveyed by a separate system for by-product processing (see more detailed explanation below).

The second method of preparing pineapple is by use of an FMC Contour Peeler. This device, rather than remove a "cylinder" of pineapple, is designed to follow the shell curvature of the fruit, thus aiding in fruit recovery. The crown, butt ends, and cores are removed automatically to complete the trimming. Cores and shells are conveyed to by-products. The prepared fruit, however, because it is not in a shape to yield uniform diameter slices, is utilized mainly for the production of chunks and tidbits. The third processing line is a direct result of size grading. The smallest size fruit are conveyed directly to either a citromat or pin-a-mat machine that first slices the fruit in half, lengthwise, rips the flesh (cores included) from the shells and finally results in two product streams - fruit to a juice line and shells to by-products.

Once prepared by either the Ginaca or Contour Peeler, the fruit is conveyed to trimming tables where careful hand trimming with special knives is diligently performed. Blemishes such as bruises or adhering shell material are removed, and the fruit, still intact at this point, is conveyed for either slicing or chunks/tidbit sizing. Trimmings are conveyed separately to the juice line. As mentioned above, only the Ginaca lines are used for finished product slices although the chunk and tidbit pieces are sliced before being forced through a die and reduced to final desired chunk/tidbit size. The slicing is done automatically, after which a very careful inspection is made. Only the select and properly mature slices are accepted for final pack. Grade-outs and fruit of varying maturity are conveyed to the crushed line. Slices for canning are generally packed by hand into the desired can size, but automatic can packers are being successfully utilized by at least one processor. Chunks and tidbits from either the Ginaca or Contour Peeler may be filled by either a tumbler-type filler or by a revolving table-top pocket filler fitted with a brush-off device. All cans are filled to weight specifications. Once filled into cans, the fruit is topped off with varying concentrations of hot syrup (see by-product description). The cans are closed under steam flow and then retorted by either continuous pressure or atmospheric cookers. Water cooling to approximately 100°F is the final step in the process.

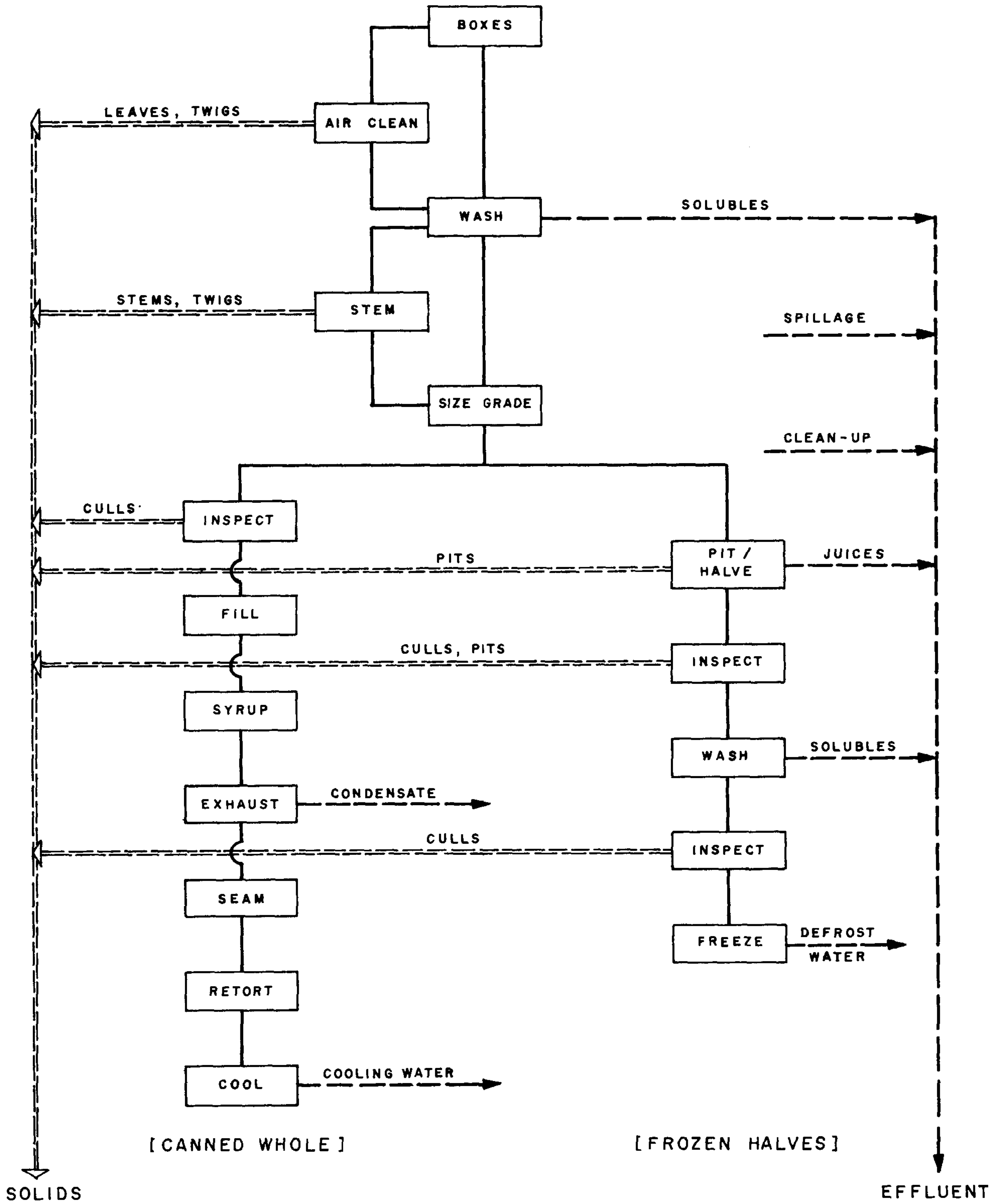
As mentioned above, the crushed line is fed from both overflow and sortouts from either the sliced or chunk lines. The entire flow is conveyed through a crusher or dicer and undergoes another inspection at which time defects are removed and transferred to either a juice line or by-product conveyer. The flow is then pasteurized and conveyed to a heated storage tank (or alternately heated in thermal screws) from which cans are filled via a piston or displacement type fitter. It should be noted that in both crushed and juice canning, the temperature of the pineapple is usually raised in two successive steps to a final fill temperature of approximately 200°F. This is done to prevent flavor degradation by rapid exposure to high temperatures. After being hot filled, the cans are sent through a continuous cooker or held for a few minutes at this temperature and water cooled, typically by a spray cooler.

The make-up flows for juice have been described in the various above sections. All fruit destined for juice is first run through a disintegrator, then through a "rough" pressing operation during which most of the fibrous material is expelled for by-products with the resulting juice being pumped to, in some cases, a finisher to further eliminate fiber, or directly after heating, to a centrifuge which eliminates remaining fibrous material. In some cases, these centrifuged solids enter the waste stream, while in others, these are saved for by-product processing. The juice is then held and concentrated to a desired brix level, heated for a second time, hot-filled, seamed, held, and cooled. Alternately, a small portion of the juice may be further concentrated, filled, closed, and frozen for juice concentrate.

Approximately 55 percent of the finished pack is utilized in a typical processing plant. This necessitates an elaborate by-products operation. The three main by-products produced are livestock bran, syrup, and alcohol. Some enzymes may also be recovered. Typically, the entire line of final grade-outs, juices, shell materials, expelled fibrous material from juice pressings, etc. are merged into one line. The entire mass is ground, heated, force pressed, or screened and fine filtered with the juice and solids going in different directions for further processing. The juice is run through a series of ion exchange media to remove various acids, gums, enzymes, etc. The syrup is then concentrated and used for the filling operations of the raw processed pineapple. Solid sugar is added as make-up whenever

FIGURE 16

TYPICAL PLUM PROCESS FLOW DIAGRAM



necessary to achieve a desired brix concentration. Alternately, the juice, after being fine filtered, can be fermented and finally distilled as 190 proof ethyl alcohol. All solid wastes generated from either process are run through kiln dryers, reduced to approximately 10 percent moisture, and sold as cattle feed.

The characterization of pineapple effluent streams can basically be divided into three types: (1) high volume, high load wastes usually consisting of fluming, washing, and clean-up water; (2) can cooling water - high volume, low load, and; (3) by-products condensor water - high volume, low load, brackish (salt) water. All three of the processors divide their wastes in at least two and sometimes three individual plant effluent streams. A major water volume variation between processors occurs at the initial washing operations depending upon whether the fruit is flumed or transported by conveyor belt. Constant floor clean-up to keep the acids from attacking the floors is practiced and generates a considerable volume from each processor. Other cannery sources include standard volume generations such as can washers, steam flow condensate, etc. The largest volume of water used in processing pineapple is that for can cooling. This is always fresh, potable, chlorinated water and in two of the canneries is recirculated and used as make-up water for the initial washing operations. Similarly, the by-products operations - specifically, the production of sugar - uses large volumes of condenser water. This water is usually taken from brackish wells and with the exception of being natural salt brine, is low load water. The principle area for reuse of water is the recirculation of can cooling water to provide make-up for initial washings.

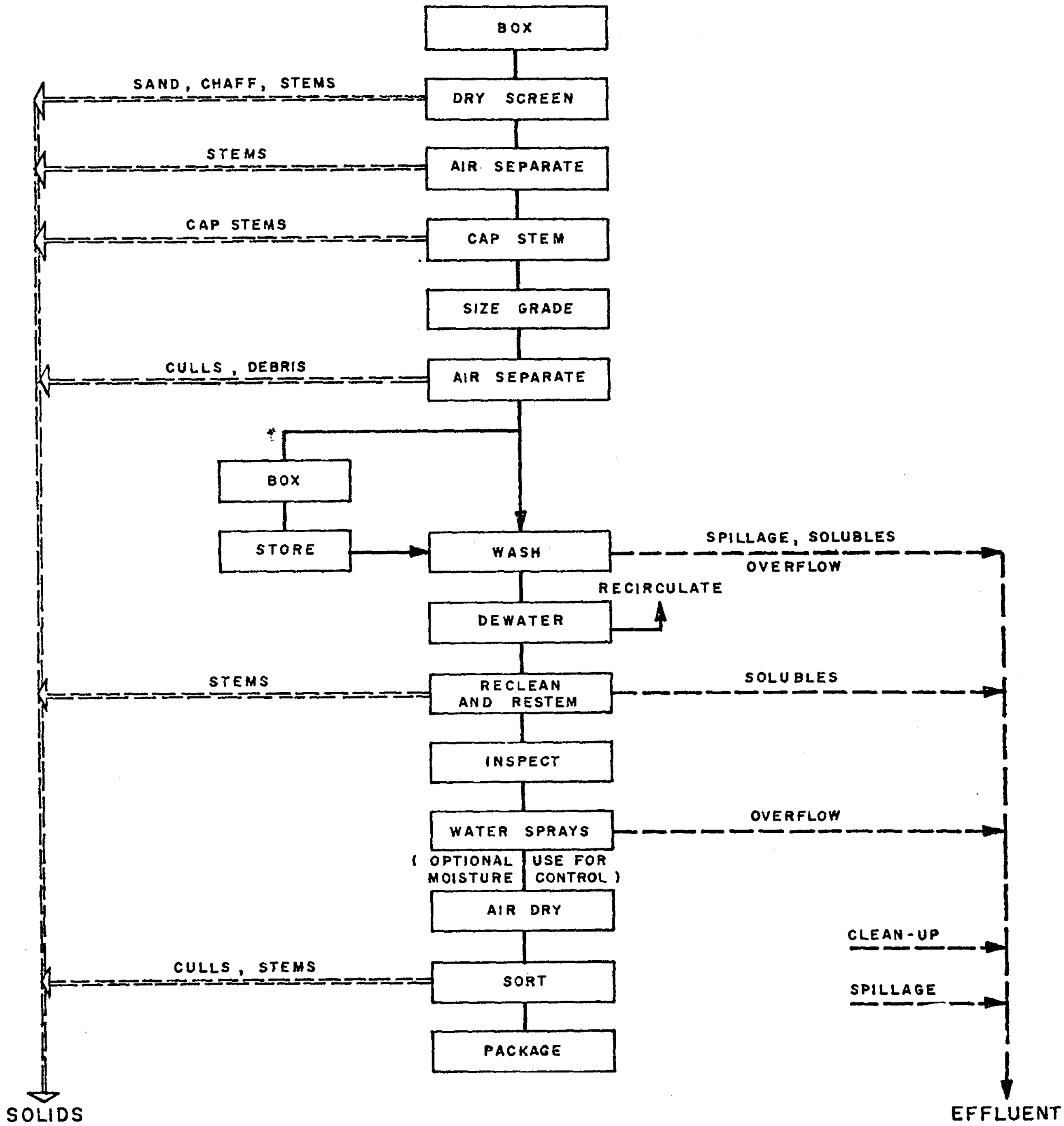
Plums

Approximately two-thirds of the total U.S. production of plums (other than prunes) is processed in Michigan, with the remainder processed primarily in Oregon and Washington. For the purposes of this study, five plants in Michigan, four in Oregon, and one in Washington were visited for the collection of historical data. Approximately 82 percent of all processed plums (other than prunes) are canned, with the remainder being frozen. Prunes are discussed as a dried fruit. Plums are usually harvested mechanically by shaking the tree; the fruit falls onto canvas and is funneled onto a conveyor and into field boxes. Plums for fancier packs are picked by hand and ripened at the plant in temperature and humidity controlled warehouses.

Figure 16 shows a flow diagram for a typical plum processing plant. Upon arrival at the plant, plums are usually dumped into a washing tank which uses a riffle board to separate the leaves, twigs, and loose dirt. The plums are usually given a high-pressure water rinse as they leave the washer. In addition to this first washing, the plums may also be air cleaned to remove leaves, twigs, and other debris. Sizing is normally accomplished

FIGURE 17

TYPICAL RAISIN PROCESS FLOW DIAGRAM



by a mechanical shaker with perforated holes. Sizing is uaually done to separate the fruit for canning whole or for distribution to the pitting line for plum halves. Plums to be pitted or canned whole are usually sent through a destemming or "eliminator" operation. This removes any adhering stems, twigs, etc. prior to either final size grading or halving. Final inspection, done by hand, separates culls and defective units from the flow of product before filling and preserving.

Plums may be either canned or frozen. Those fruits to be canned whole are tumble filled into cans, topped with hot syrup, exhausted, seamed, retorted, and cooled. The plums to be frozen are halved on a machine similar to one found on an apricot line. The fruit is cut in half by small saw blades protruding from the bottom of a shallow trough. As the fruit rolls over the trough, a slice is made around the circumference, and subsequent tumbling and shaking loosen the pit. The pit falls through openings in the shaker, and the fruit is conveyed to an inspection line where remaining pits are removed by hand. The fruit is given a final wash and inspection and is then either frozen in bulk (30 pound tins) or by IQF.

The principle wastewater generators in terms of volume are the washing and can cooling operations. With the exception of some dust and debris in the washing operation, however, this effluent is relatively weak in pollutants. Halving and pitting, on the other hand, can contribute significant strengths to the effluent streams. However, wastewater volume and subsequent loadings have been successfully reduced by replacing flumes (for pits and halved fruit) with dry conveyors. Plums are very acidic; and these juices were observed in at least one plant to require pH adjustment prior to final discharge. The principle sources of water reuse and recirculation are the can cooling waters and closed hydraulic transport systems which were observed at several of the plants. These waters can be reused provided they are chlorinated to prevent microbial growth.

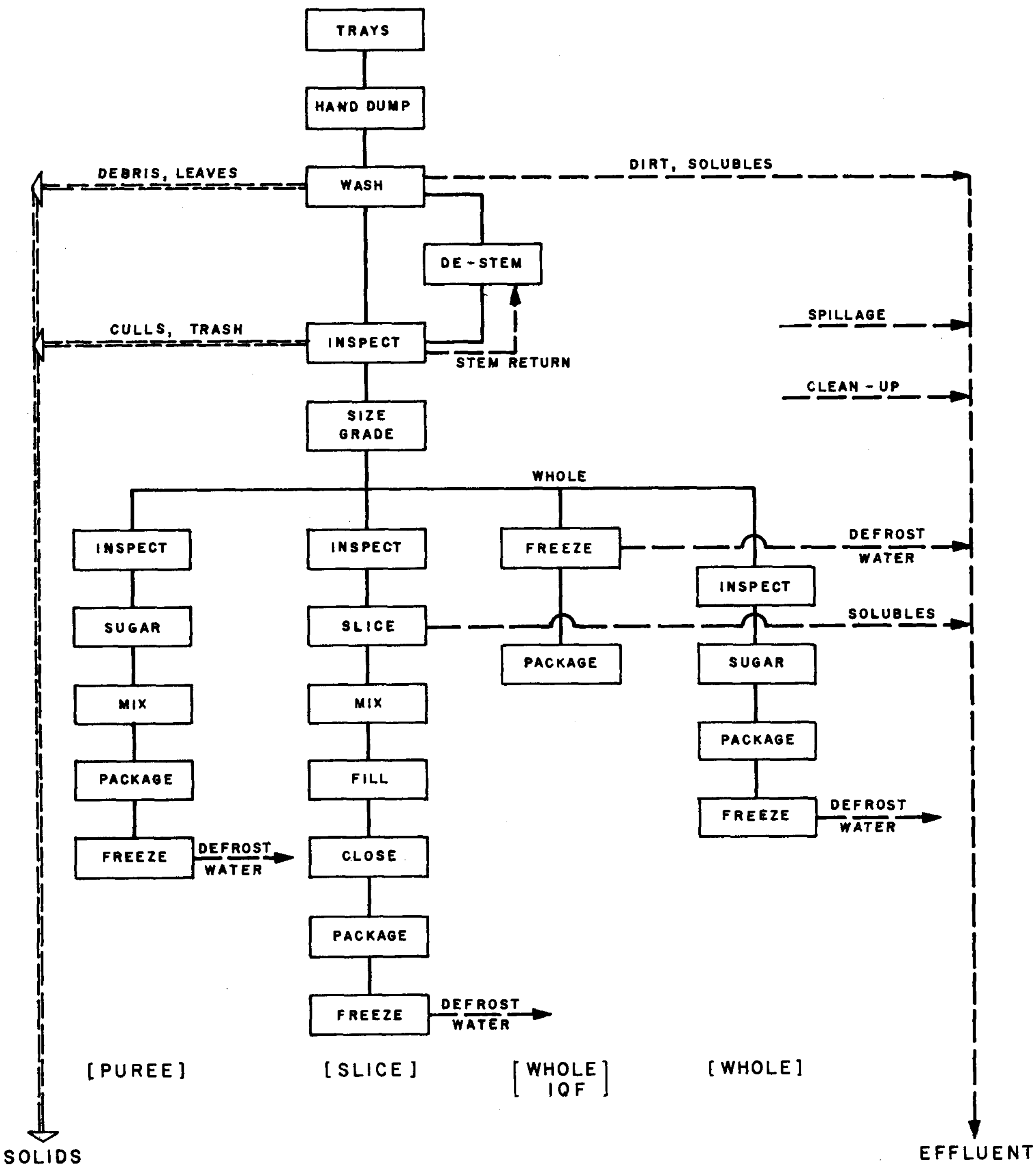
Raisins

Approximately 25 percent of the U.S. grape production is made into raisins, the great majority of which are processed in California. The proportion of grapes going to raisin production was 969,000 tons in 1973. For the purposes of this study, four plants in California were visited for the collection of historical data.

Figure 17 shows a typical raisin process flow diagram. There are several types of grapes processed into raisins; the principal varieties are Thompson Seedless and Muscate. Natural-dried raisins are hand picked (August in California) from the vine in bunches and set on paper to be dried in the sun (two to three weeks). After the raisins have dried to a moisture content of nine to twelve percent. They are loaded into "sweat" boxes and shipped to the processing plant. Golden Bleach (Thompson

FIGURE 18

TYPICAL STRAWBERRY PROCESS FLOW DIAGRAM



variety) raisins are hand picked in bunches from the vines, dipped in 0.5 percent hot lye solution for three to six seconds, sulfured for four hours, dried (sun or forced air) to a moisture content of nine to twelve percent, and stored in sweat boxes. Soda-dipped raisins are processed the same as Golden Bleach, but are not sulfured. From this point, the processing is the same as for natural-dried raisins.

Raisins are processed by a series of screenings, stemmings, and air separations. In the screenings, the raisins are blown over screens where the loose dirt and debris are removed. They are then stemmed and screened again to remove the raisins from the particles. The raisins are then blown over an air separator. The heavier berries fall through the air blast to a conveyor belt which carries them to another air separator. The process is repeated until light-weight particles, including small and inferior raisins and cap stems (the stems usually go to a cattle feed lot), are removed. Small raisins may then go to a distillery or be packed for use in cereal or bakery products.

The raisins are next washed and sent through a dewatering operation which removes the excess surface water. They then go through another stemming operation to remove residual cap stems. Following the final stemming operation, the raisin's moisture content is checked and may be raised by water sprays (to a maximum of eighteen percent). The raisins are then sorted and inspected for size and quality. The quality sort is usually by hand, and until recently the size sort has been done by hand. There is now a mechanical sorter which can handle this operation. After sorting, the fruit is mechanically packaged and stored for shipment.

Because of the requirement to maintain the fruit below a maximum moisture content of eighteen percent, the amount of water coming into contact with the fruit is kept to a minimum. As a consequence, the major steps in raisin processing are dry, and the principal sources of wastewater stem from the fruit washing and plant clean-up operations. The wash water is used in a closed loop system to pump the raisins to a second washing operation. The water from the "optional sprays for moisture control" is also recycled to the wash water tanks.

Strawberries

Strawberries are the nation's leading frozen fruit. They are grown and processed in nearly every section of the country. The leading strawberry-producing state is California, but Oregon, Washington, and Michigan are also important. For the purposes of this study, three plants in California, six in Oregon, and one in Washington were visited for the collection of historical data. In addition, a total of ten composite samples were collected and analyzed to verify this data. Because strawberries lose their fresh appearance, take on a weak neutral color, shrink, and become soft and placid when canned, almost all strawberries are either sold fresh, made into jams or preserves, or frozen. Of the strawberries produced for freezing, about 43 percent are frozen whole and 57 percent are sliced. Figure 18 shows a typical strawberry process flow diagram. Nearly all strawberries are harvested by hand into small, square, fiberboard boxes. A mechanical harvester has been used but with limited acceptance by the industry because it damages the perennial strawberry plant and is not selective to the varying maturity rates of the fruit. Stemming is typically done manually at the time of picking.

Strawberries are washed and inspected after unloading at the plant. In a typical operation, these are shaker-type washers which immerse the strawberries and gently agitate and move them across a riddle where leaves, caps, stems, berry pieces, and foreign materials are removed. Strong sprays of water then remove dirt that may cling to the berries. Some plants use a destemmer at this point to remove any adhering stems or leaves. The berries may be recycled back through the destemmer after inspection. Less frequently the washer is a shallow tank with an inclined perforated conveyor which carries the berries to overhead sprays for washing. These sprays are generally directed through screens to break their force and therefore prevent injury to the fruit. From the washer the fruit is carried by conveyor belt to an inspection belt, where culls and remaining leaves are removed. The fruit then passes through a sizing machine (riddles more often than seives to protect fruit quality) and a sorting belt where culls which have escaped previous inspection are discarded; and the best fruits are separated for whole and fancy packs.

Those strawberries graded for whole production are placed on belts, inspected, sugar-added, and frozen. They may also be taken directly from the size grader, inspected, individually quick frozen, and packaged. Those strawberries that are too large or small for whole or sliced production are usually pureed in a large "ribbon" type mixer to which sugar has been added. The agitation of all ingredients produces the desired texture. The product is then packaged and frozen.

The principal volume sources of wastewater generation are the washing and clean-up operations. Slicing and filling operations produce some juice and spillage. These go to the waste stream, but the volume is small. Clean-up operations can contribute significantly to the wasteloads because of the sugar used throughout the plant. The clean-up volumes wash these wastes directly into the main plant effluent. Wastewater reuse has been of relatively minor importance as a water conservation method. However, crate wash water as well as berry wash water have been utilized for recirculation on a limited basis.

Tomatoes

Tomato products are the leading canned vegetable items in the United States. Approximately two-thirds of the total U.S.

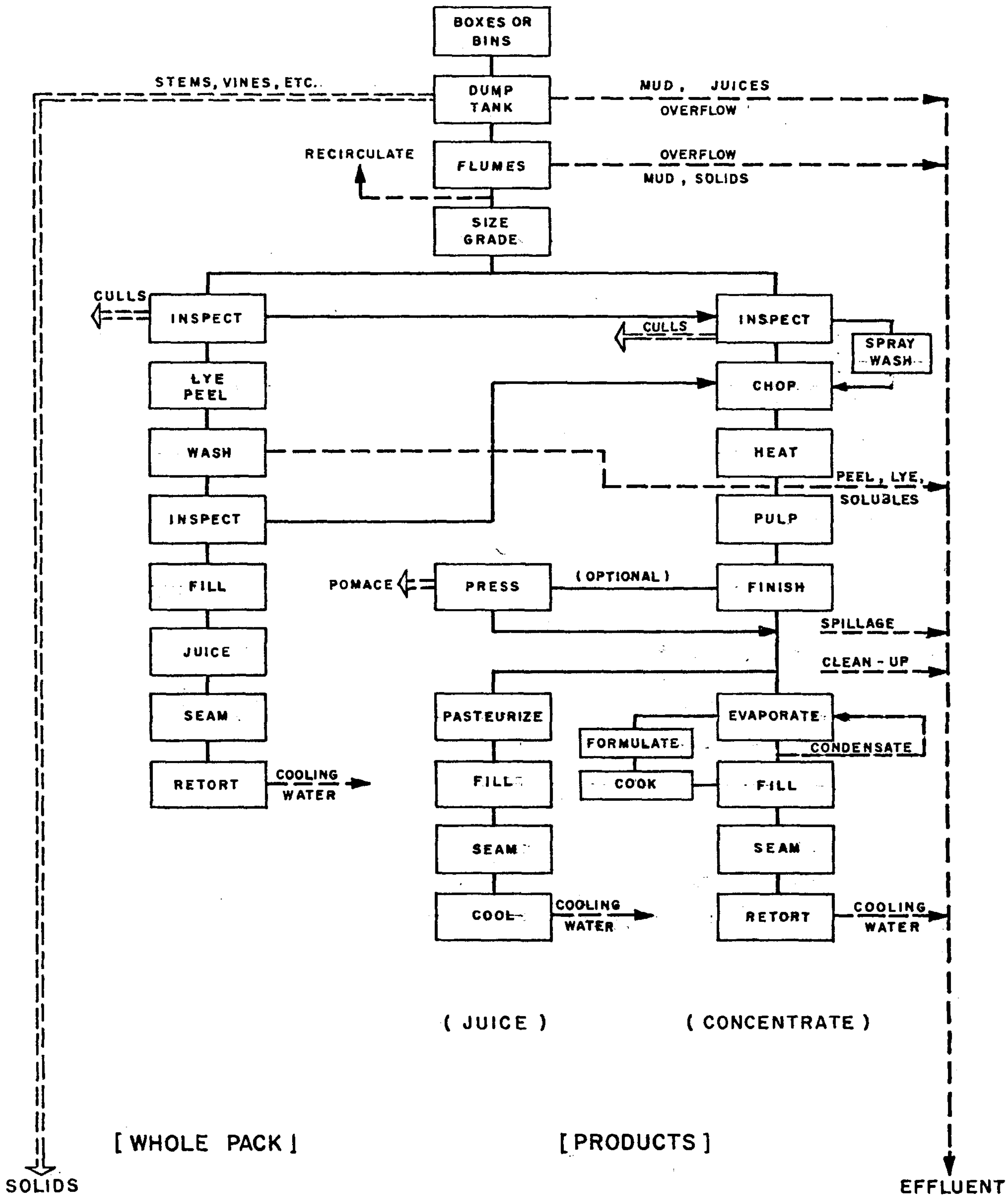
production is processed in California with the remainder processed primarily in Ohio, Indiana, New Jersey, Pennsylvania, and Michigan. For the purposes of this study, 27 plants in California, seven in Ohio, one in Iowa, eleven in Indiana, one in Illinois, one in Florida, three in Texas, one in Georgia, and one in Alabama were visited for the collection of historical data. In addition, a total of eleven composite samples were collected and analyzed to verify this data. Approximately ten percent of all processed tomatoes go into juice and ten percent go into canned whole tomatoes. The remaining 80 percent is used in the production of tomato catsup, paste, sauce, and puree.

Many varieties of tomatoes have been developed to facilitate harvesting, resist climatic conditions, and increase production yields. Field labor shortages in California led to the development of varieties that mature more uniformly and are harvested by machine with a single pass through a field. The harvester undercuts the vines, lifts the plant, separates the tomatoes from the vine, and returns the plant material to the ground. Often, a crew rides the harvester to additionally hand separate cull material. Tomatoes are loaded from the harvesters directly into wooden bins or gondolas and trucked to the processing plant. It is reported that mechanical tomato harvesting in comparison to hand picking increases the amounts of soil and organic solids included with the raw product, and results in a higher percentage of damaged tomatoes delivered to the processing plant. In those tomato growing areas outside of California, hand harvesting into lug boxes is the more prevalent harvest method. Reasons for this are generally smaller field sizes (economics), rolling terrain (topography), and unpredictable weather.

Figure 19 shows a flow diagram for a typical tomato canning plant. Separate processing lines are shown for the manufacturing of canned tomatoes, tomato juice, and other tomato products, e.g., paste, puree, catsup, etc. The tomatoes arrive at the plant in gondolas (bulk), bins (bulk), or individual lug boxes at which time they are usually dumped into a recirculating washwater tank or a combination of recirculated water flumes and dewatering screens. This initial wash removes some of the remaining leafy and stem material and most of the soil residues, seeds, and pesticide residues. After initial washing the tomatoes are sprayed with high pressure rinses to remove final residues. The U.S. Department of Agriculture, Western Regional Research Laboratory, Albany, California, in cooperation with EPA and NCA, during 1973 conducted experiments with rubber disc scrubbers as a mechanical aid to washing tomatoes at a processing plant in Hayward, California. Initial results show significant water volume savings with very little loss in washing effectiveness. The tomatoes are usually transported by water flumes from the washers to size graders where they can be separated for use in either whole-pack, juice, or sauce products. Flume transport requires large quantities of water and results in greater leaching of organics into the wastewater. Another method used

FIGURE 19

TYPICAL TOMATO PROCESS FLOW DIAGRAM



for transportation in recent years has been a combination of roller conveyors fitted with water sprays. This method has the advantage that the tomatoes are constantly rotated to facilitate sorting and cull removal. Sorting and grading operations may take place more than once in the process. The purpose is to sort for size, maturity, peel removal, and blemished units. Separations for quality are most often done by hand. Wastes from these operations consist of whole pieces, miscellaneous organics, and juice. Trimming operations remove unwanted portions of the product, such as blemishes and damaged areas. Blemish removal is done by hand and results in wastes consisting of pieces and juice.

Since canned tomatoes constitute only ten percent of the tomato pack, the remaining 90 percent is processed as described in this section. The cleaned and size separated tomatoes, as well as shape and color rejects from the "whole pack" line, are typically run through the "hot break" process. This usually consists of a chopper or disintegrator (with steam injection) for comminution, followed by exposure of the product to agitating stream coils to prevent the breakdown of pectins. The product is then normally pumped to holding tanks from which the various style consumer products are made. To make tomato juice, the product is taken from the holding tank and more completely reduced by mills, pulpers, and "finishers" to eliminate skins and seeds (pomace). The juice is then typically homogenized, deaerated, pasteurized, and "hot-filled" into various sizes and styles of containers, held for several minutes, and cooled.

The manufacturing steps for tomato paste and puree are similar to those for juice up to and including the final finishers. The macerated product, however, is then pumped to concentrators or evaporators where the desired consistency is achieved. This is usually accomplished under partial vacuum to maintain acceptable color and flavor standards. Resultant flows from the evaporation process are normally then pasteurized, hotfilled, held for several minutes, and cooled. Alternately, the product may be hot-filled, retorted and cooled. Products such as tomato sauce, catsup, and other related items are made by adding various spice formulations and additives to a puree or more concentrated form as a base. Method of processing is either pasteurization, hot-fill, hold and cool, or hot-fill retort, and cool.

The process flow for whole pack tomatoes is essentially the same as described above in terms of initial washing, sorting, and grading. The tomatoes at this point, however, are peeled usually by exposure to a heated lye (eighteen percent) solution for approximately one minute. The peels are subsequently removed by either high pressure cold water sprays or rubber scrubber discs followed by water sprays. The peeled, whole tomatoes are then typically conveyed by water flume to hand pack filling machines where the various size cans are filled, topped with hot juice, seamed, retorted, and cooled. The hot lye peeling operation is a major source of alkalinity (resulting high effluent pH), high temperatures, BOD, and suspended solids. Elimination of the peeling operation in the manufacture of tomato products other than canned is the major reason why pollutant generation from manufacture of canned tomatoes is significantly higher than from other tomato products.

The significant wastewater streams include the following: overflow from dump tanks and various fluming operations located throughout a typical process line; overflow and periodic dumping of caustic peelers and wash tanks; can cooling and condenser water; and clean-up of spills and equipment. The initial dump tank and flume system is usually recirculating with fresh and/or reclaimed makeup and continual overflow to the gutter. This overflow usually contains fruit juices and small solids, dirt and debris. Overflows from later fluming units will contain varying amounts of soluble organics depending on their position in the process line and the condition of the fruit.

Wastewater from the lye peeler and washer is the strongest of all the waste flows. It is the major BOD and SS contributor as lye, peels, fruit pieces, and solubles are discharged to the gutter. Can cooling and condenser water contribute significantly to the final volume of wastewater but are usually relatively free of contaminants. Unless a cooling tower is utilized, their major effect on the effluent is from their high temperature. It must be realized, however, that contamination with volatiles from the tomatoes results in a significant BOD load in evaporator condenser water. In addition, level control problems may result in solids carry-over from evaporators. Clean-up of spills on a continual basis and intensive end-ofshift equipment washdown contribute further to the total BOD and SS concentrations. Dumping of lye peelers and wash and dump tanks during clean-up operations adds caustic, considerable BOD, and solids to the clean-up flow. Caustic may also be used as a cleaning agent. The degree of damage to the tomatoes as received at the plant exerts considerable influence on the degree of contamination of transport and wash water. Other significant factors are time of harvest, maturity of fruit, variety of tomato, degree of field processing, and field-to-plant transport time and distance. Considerable solid waste results from the various pulping and finishing processes. This waste may either be removed dry or be transported by water. The latter results in considerable added wastewater load. In the course of products manufacturing, the use of vinegar adds substantially to the risk of BOD contamination through spillage, equipment washup, or condensation of vapors from hot processes. Additional condensers may be required for deaeration of the product or for odor control when required.

The major sources of water for reuse in tomato processing are can cooler water and condenser water. After use in cooling hot cans, the cooler wastewater is still relatively uncontaminated and is sometimes passed through cooling towers and recirculated back to the can coolers. A recycle system for condenser water, utilizing evaporation water from the tomato concentration process is also frequently used, but some fresh water make-up and waste water overflow are usually necessary. Other reuse practices include continual recirculation of all dump tanks, wash tanks, and flumes with a low percentage of make-up and continued overflow to waste. Effluent from final fresh water product rinses may be reused in primary washing stages. A few plants have can cooling water of sufficient quality to reuse as a major source of the plant clean-up water.

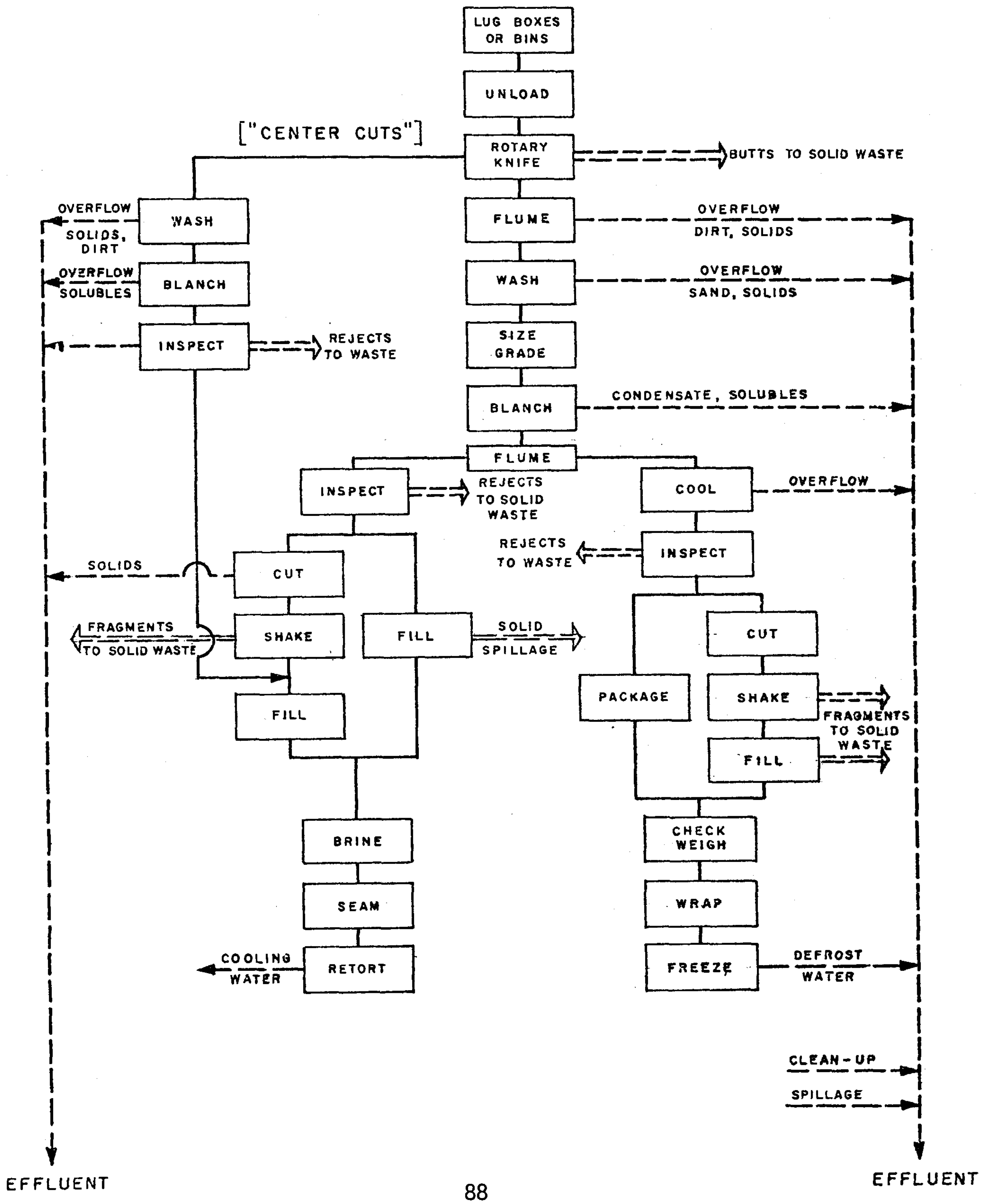
Asparagus

Asparagus processing is performed in several states, with California leading in production with 43 percent of the total pack. Other states producing a significant crop are Washington, Michigan, Illinois, New Jersey, Maryland, and Oregon. For the purposes of this study, seven plants in California, one in Delaware, one in Michigan, and three in Illinois were visited to obtain historical information. In addition, a total of six automatic composite samples were collected and analyzed to verify this data. Of the 98,500 tons of asparagus processed in 1972, 37 percent was frozen and the remaining 63 percent canned. The recent trend has been toward increased frozen asparagus production. In recent years, green asparagus has comprised 70 percent of the total pack and the white variety 30 percent. Both green and white asparagus are packed in spears, tips, and center cuts, with spears representing approximately 75 percent of the total production. The asparagus processing season runs from late March through the middle of June, thus preceding most of the large fruit and vegetable packs.

Both the white and the green varieties are harvested by hand using a long handled, sharp, chisel shaped tool. White asparagus stalks are cut off six inches below the ground just as the tips are breaking the surface of the ground. Their white color is due to the absence of chlorophyll in the cells. For the green, the stalks are allowed to grow from 4 to 6 inches above the ground and are then cut off slightly below the surface. The only difference between the "white" and "green" varieties is the time of harvest. With new beds or fields, a cutting can usually be made early in the season of the second year after planting the roots. The first year of cutting usually yields from five to seven hundred pounds per acre. The quantity will double each year for the next four years; after five years, the yield will average from six to eight thousand pounds per acre. A well-established bed which receives good cultivation and fertilization should produce profitable crops for fifteen to twenty years. Asparagus changes in structure very rapidly after it has been cut. It rapidly becomes more fibrous and takes on a bitter flavor so that it is necessary to handle it promptly. In California, where there are fields of several hundred acres each, it is customary to have a central station where the "grass" is thoroughly washed within an hour or so after removal from the ground. The white or bleached grades will stain very rapidly,

FIGURE 20

TYPICAL ASPARAGUS PROCESS FLOW DIAGRAM



and once this stain is formed, it is impossible to wash it off. This stain is not so noticeable on the green grades. The stalks are placed in lug boxes in the field with tip ends in one direction. The tips must always be carefully protected from breaking or mashing because the value of the stalk depends largely on the perfect condition of the tip. The boxes are then trucked to the factory.

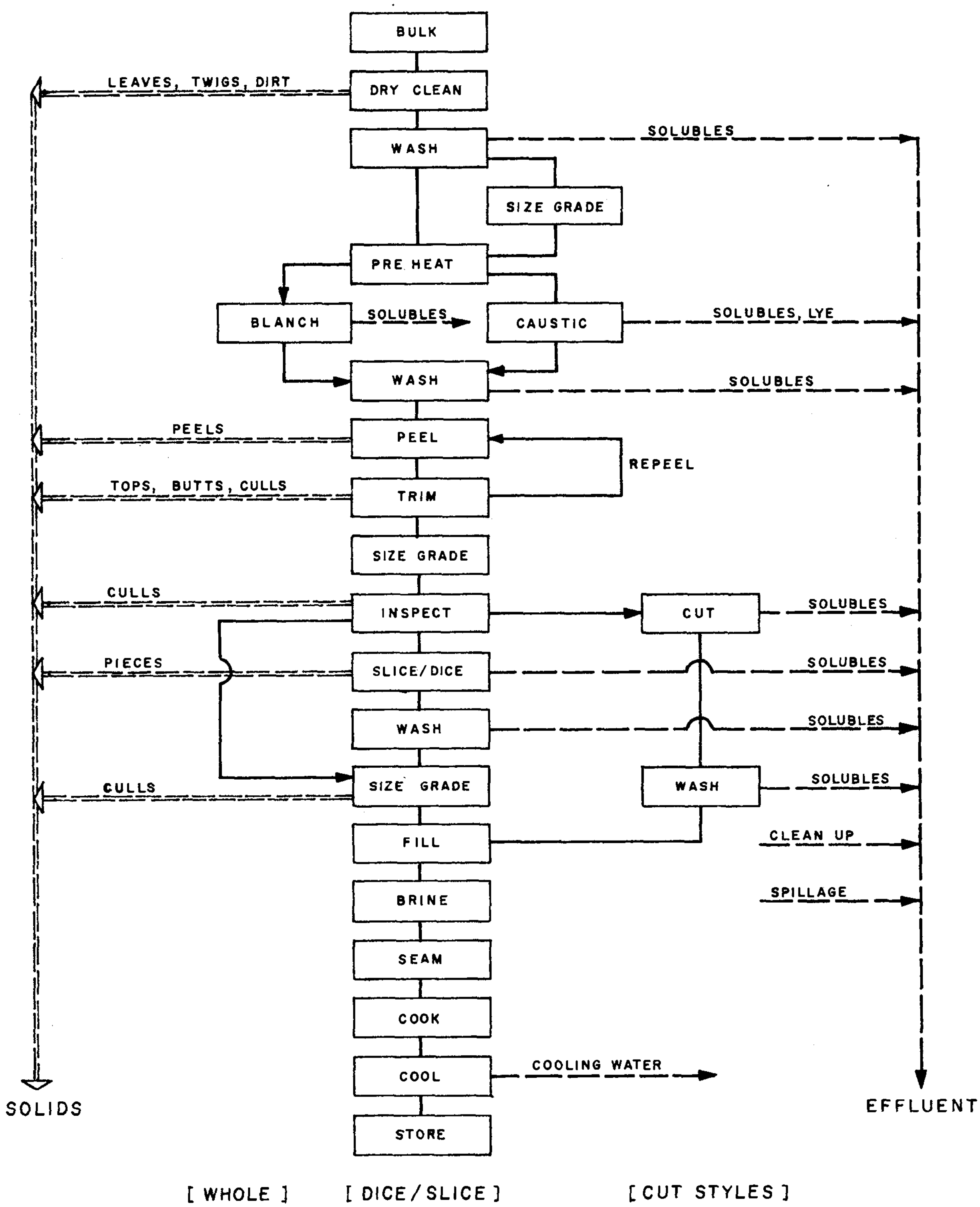
The operations for processing white and green asparagus are the same. Figure 20 shows a flow diagram of a typical asparagus canning and freezing operation producing spears, tips, and center cuts. Asparagus is either processed immediately upon arrival at the processing plant or stored in wooden lug boxes or bins under cold water sprays (additional ice packing optional) for not longer than one day. This storage at between 40° and 50°F with sufficient moisture will prevent staining, bitterness, and any increase in fibrous texture. Hydrocooling has been shown to extend 35°F cold storage of green asparagus up to one week. The asparagus spears are typically hand unloaded from the field boxes and aligned with tips all pointing the same direction on a conveyor belt to a rotary knife or band saw. This mechanical knife or saw is adjusted to make the desired cuts. The first cut removes the butt ends which are conveyed mechanically or flumed to the waste hoppers. Successive cuts separate the "center cuts" from the spears, with the center cuts flumed to another processing line.

Center cuts are flumed from the rotary knife to the washer. Washing by dipping cannot be relied upon to give satisfactory results, so spray washing of some kind is generally necessary to remove dirt and sand. Blanching is accomplished in most instances with a continuous steam or water blancher heating the asparagus to 180°F for two or three minutes. The cuts then proceed over inspection belts where rejects are removed to the gutter and solids hopper. The center cuts are blended with tips and cuts from the main spear process line (as shown in Figure 2) and then mechanically or hand filled into cans. Following the rotary knife operation, the spears usually enter a series of flumes and a spray washer similar to that used on the center cuts. It is important to ensure that all dirt and sand be removed from the tips. This can be facilitated by using hot water at 140°-150°F which causes the small leaflets in the stalk to open up, thus providing better water contact. After washing, the spears pass over conveyor belts and are either size graded mechanically or graded by hand. Grading is based on color, quality, and size. The spears then enter a continuous steam or hot water blancher where they are held at 180°F for two to three minutes. At this point, the spears can either be canned or frozen.

Those to be canned pass over inspection belts to filling conveyors where workers hand fill all cans with tips up. A selected portion of these spears enter a cutter and shaker operation before filling where tips are severed from the center cut (stalk

FIGURE 21

TYPICAL BEET PROCESS FLOW DIAGRAM



portion) and small fragments removed to waste by the shaker. These tips and cuts are joined by cuts from the initial center cut line and proceed into the automatic can filler. After the cans are filled, they pass to the briner where they are filled with a two to three percent salt solution at a temperature of 190-200°F. The hot brine should be sufficient in amount to cover the tip ends when the can is closed. If the cans are filled sufficiently hot, atmospheric closure is satisfactory. Otherwise, a steam-flow closure is used to produce a vacuum. The canned asparagus is then retorted and cooled. The asparagus spears to be frozen are flumed from the blancher to inspection. This flume acts as a cooler to prepare the product for packaging. Some of the spears proceed on conveyor belts and are hand packed, whereas others are fed through cutters and machine packaged as tips and cuts. These cartons are check weighed, wrapped, and frozen in storage.

Asparagus produces a very low waste load of all vegetables processed. The waste is very low in both BOD and SS, primarily because: (1) the plants arrive fairly clean from the field with very little dirt; (2) there is no peeling operation which is a major BOD producing operation in a cannery; (3) asparagus solids are slow to leach into wastewater streams; and, (4) dry conveyance of trimmed butts is frequently used so that a significant portion of the cutting is never exposed to water. The major wastewater flows come from the retort cooling water, freezer defrost water, initial fluming and washing operation, and the strongest waste stream from the hot water or steam blanchers. This blancher discharge is the only significant wastewater BOD component. Other waste streams result from can washing in the seamer, overflows from the brining operation, and various fresh water sprays at inspection belts. The two significant water reuse systems frequently employed in asparagus processing are: (1) continuous recirculation of initial flume and washer water (often with substantial overflow and makeup required) and, (2) reuse of retort cooling water or freezer defrost water as makeup in the initial fluming operations.

Beets

Beets, all canned, are processed in four main states: New York, Wisconsin, Oregon, and Texas. Almost 50 percent of beet production is into sliced styles. For the purposes of this study, three plants in Oregon, six in Wisconsin, and one in Washington were visited for the collection of historical data. In addition, a total of thirteen composite samples were collected and analyzed to verify this data. Figure 21 shows a typical beet process flow diagram. Beets for canning are ordinarily harvested and topped mechanically. The mechanical harvester travels along a row digging, cleaning, and topping the beets, and discharges them into a truck for transport to the cannery. Beets can be stored on cement slabs for a few days. When placed in a well ventilated warehouse, they can be stored for several months.

Prior to washing, the beets are often subjected to a dry cleaning operation (reel or shaker) to remove stems, trash, and loose dirt. The beets are then dumped or conveyed to a washer. The washing operation is done by large brush washers or rotating reel type washers. The washing opera#ion removes the majority of silt or leaves from the beets. Beets are normally size graded as many as three different times throughout the process. These sizings may be accomplished with shaker screens, parallel bars, or a combination of both. The purpose of these separations is to segregate for peel removal and product style. From the size graders, the product is blanched or preheated using water baths, belt-steamers, or atmospheric screw-steamers. After this preheating step, the vegetable is subjected to high pressure steamers or hot caustic. Peel removal may be accomplished by either high pressure water sprays or by abrasive peelers. Dry peel removal was also observed to be successful in several of the plants visited. From the peeler, the beets move along a belt for hand trimming and inspection. Soft beets are removed, and beets requiring additional peeling are sorted out and returned to the peelers. After trimming and inspection, the beets are size graded again and transported to the appropriate processing line.

Small, nearly-spherical beets are canned whole. Medium-sized beets are sliced (regular or crinkle-cut) and canned. The large and irregularly shaped beets are diced, "shoestringed," or sectioned. The cut beets are then washed, filled with a tumble type filler, topped with hot brine, seamed, cooked, and cooled. Cooking is done in retorts or continuous cookers.

The principal wastewater generators are washing, blanching, trimming, peeling, fluming, and cooling waters. Trimmed portions of beets are usually transported dry from the inspection belts, but some plants utilize flumes; this increases both waste volumes and pollutant loadings. The wet peeling processes are another major source of waste loads. Dry peeling machinery, however, is an alternative. Dry peelers use rotating discs to remove the peel from the product. The peel material is transported from the process in a semi-liquid state and may be disposed of separately from the main plant effluent. Some plants, however, use water to flume this peel material to the gutters and thereby reduce the benefit of the dry peelers. The blanching and steam peeling operations contribute significant waste load strengths to the plant effluent. In many cases, peel loss can be related to incoming product quality, and this can affect the blanching and peeling conditions.

In many plants, the dirt and debris removed by the washers goes to the wastewater stream. Some plants were observed to recirculate the washwater after settling out the mud and silt. The water, if maintained and chlorinated, can be used up to several days before discharge. Plants also utilize recycled can cooling water for the preliminary washing operation. Self-contained, internally recycled pumping water for in-plant transporting of whole and cut beets is another major source of recirculated water. The reduction of water consumption has been accomplished by the use of dry conveying and dry cleaning processes for several of the operations.

Broccoli

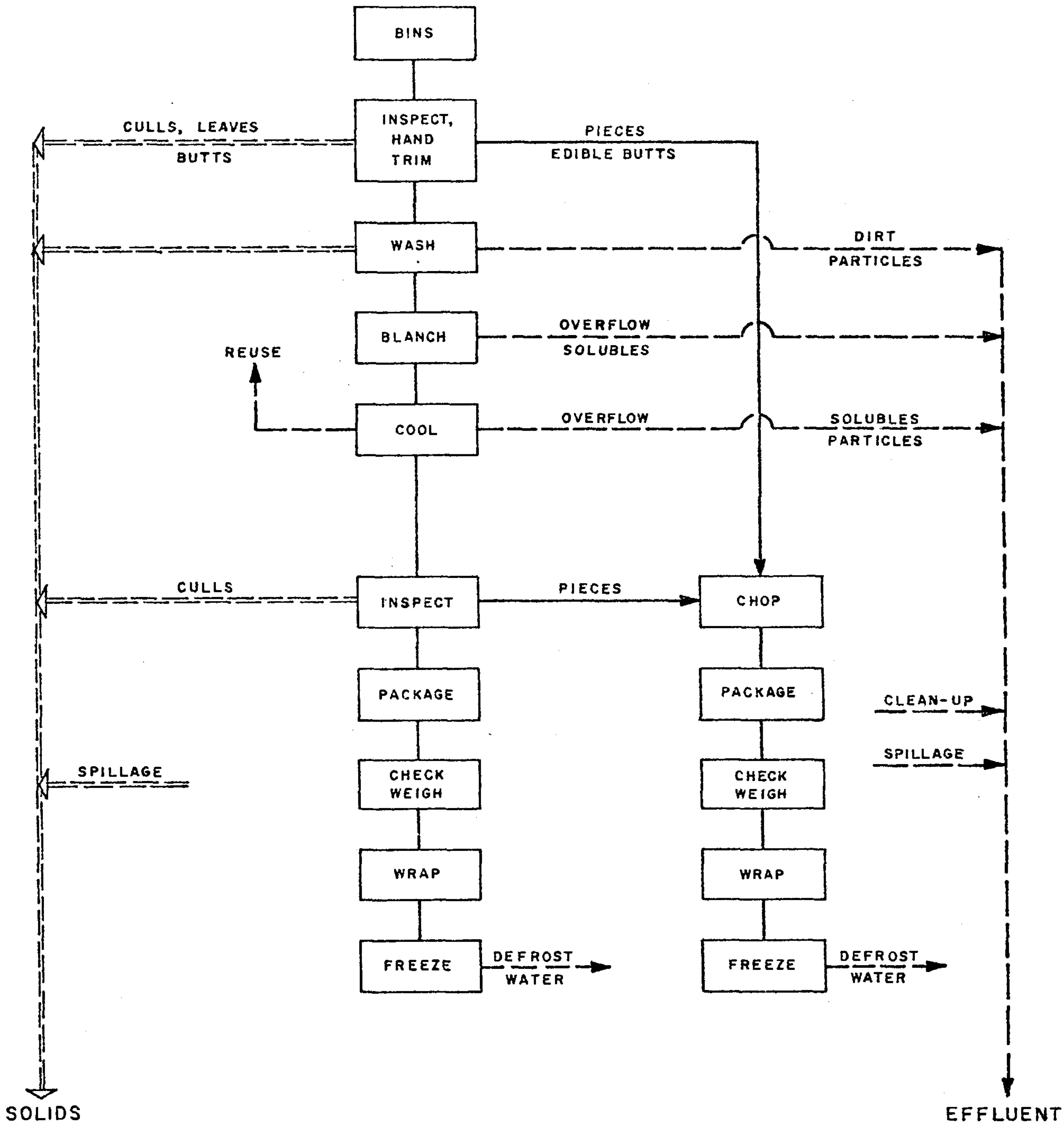
Nearly all broccoli produced for processing in the U.S. is processed frozen in California, although a small amount of broccoli freezing is done in Illinois, Oregon, and Washington. For the purposes of this study, four plants in California were visited for the collection of historical data. In addition, a total of eleven composite samples were collected and analyzed to verify this data. Most broccoli (63 percent in 1973) is frozen in spears. The rest is processed about equally as chopped broccoli and broccoli cuts. Broccoli is all hand harvested and trimmed in the field. There are generally three cuttings in each field, about one week apart, before the crop is finished. The broccoli is taken directly from the field in 700 pound bins to the processing plants. Ice may be added to prolong storage. Broccoli is generally processed the year round excluding the summer months of July, August, and September.

Figure 22 shows a flow diagram for a typical broccoli processing plant. The broccoli arrives at the processing plants in 700 pound bins and is dumped onto a conveyor belt. As the vegetable is moved along the conveyor belt, it is hand trimmed and quartered. The good stems and pieces from the trimming are saved and used in chopped broccoli. After trimming and quartering, cuts are typically dumped into a recirculating washwater tank which utilizes a highpressure spray to move the vegetable and to remove soil and pesticide residues. This process is sometimes repeated if further cleaning is required. From the washer, the broccoli is dewatered before entering either a hot water or steam blancher. Post-blanching operations usually consist of a cooling cycle (either cold water flume or cold water sprays), dewatering, and a second inspection. Further hand-trimming occurs, and the broccoli is sorted for spears and chopped fractions. The packaging of broccoli is essentially a hand operation in which the desired piece sizes are hand-packed, the boxes individually weighed, and finally conveyed to a package-wrap operation. These packages are then normally plate-frozen and freezer-stored. Alternately the chopped broccoli after inspection may be conveyed directly to an IQF freezer and automatically filled into poly-bags.

The large flow volumes generated are mainly attributable to washing and defrost water. BOD and SS levels are reasonably low due to the large amount of hand trimming. The principal BOD loadings are generated during blanching operations and vary according to method of blanch (steam or hot water). Clean-up water, sometimes containing detergents, also contributes to these waste loadings. Freezer defrost water is discharged sometimes directly to navigable streams or alternately combined with the plant effluent. The BOD loading of these defrosting waters is

FIGURE 22

TYPICAL BROCCOLI PROCESS FLOW DIAGRAM



equivalent to the BOD loadings of the individual plant's potable water supply.

Counter-current flow recycling provides the best opportunity for water reuse. Typically water is recycled from a second stage washer back to the initial wash, usually by collection from dewatering screens. Fluming water may also be recycled back through the various washing steps. Defrost water, if used, provides an excellent source of pre-blanch chilled spray or flume water. Screened final effluent discharge water has been observed to be recycled to provide in-plant gutters with a continuous water flow.

Brussels Sprouts

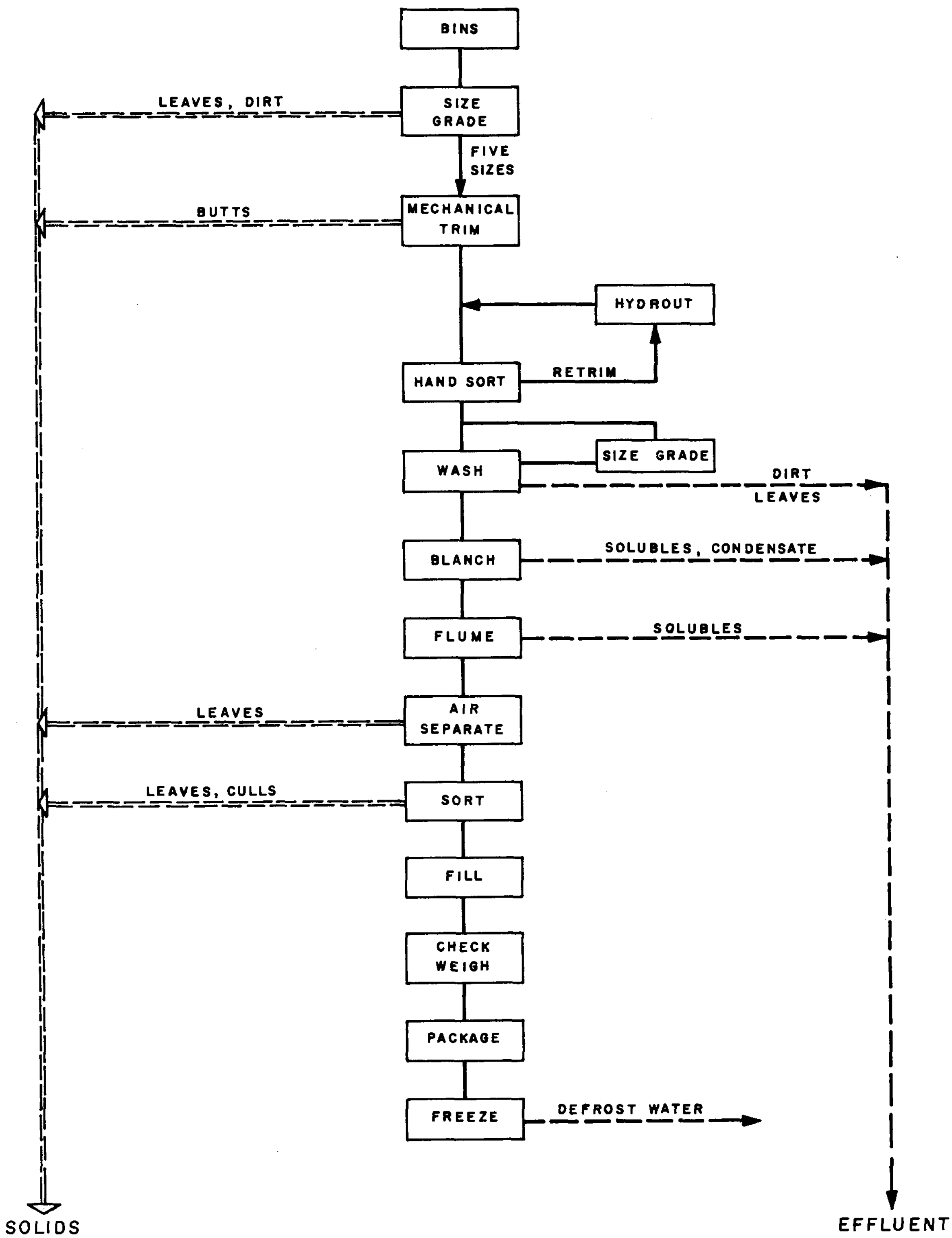
California produces approximately 95 percent of the Brussels sprouts in the United States. This production area is further limited to the immediate proximity of the Pacific Ocean strip from the shoreline inland about one-half mile, and just south of San Francisco in the Half Moon Bay and Santa Cruz areas. In this limited strip, the right combination of foggy days and mild nights is ideal for Brussels sprout growth. For the purposes of this study, two plants in California were visited for the collection of historical data. In addition, a total of five composite samples were collected and analyzed to verify this data. All Brussels sprouts for processing are frozen whole.

Figure 23 shows a typical Brussels sprouts flow diagram. Harvesting of Brussels sprouts is a hand operation. Since there is a great difference in the maturity rate of the bud units on the individual plants, it is necessary to make several passes through the field or "pick over" the plants several times to assure raw product of optimum quality. The stalks with mature buds are severed from the plant with a sharp knife and transferred to lug boxes or tote bins. The product is transported to a field or grower's station at which time the edible buds are mechanically trimmed from the stalk. The individual buds may then undergo several inspections for quality parameters prior to shipment to the processing plant. The sprouts may be iced or placed in cold storage to accomodate plant operations.

As many as five size separations are made for Brussels sprouts to control mechanical trimming, blanching conditions, and final quality and size parameters. Grading is usually done through parallel rollers so spaced that the smaller buds fall to another conveyor or processing system. Sprouts are usually mechanically trimmed to remove the butt or stalk portion of the vegetable. The trimmers are pre-set for a particular size which necessitates the size separations as mentioned above. Following this trimming, the buds are hand inspected for quality and trim removal. Those buds needing further or more complete trimming are returned to a "hydrout" line. Washing operations, following trimming, are usually done in a shallow tank fitted with overhead

FIGURE 23

TYPICAL BRUSSELS SPROUTS PROCESS FLOW DIAGRAM



high pressure sprays which provide both make-up water and an agitation to thoroughly clean the sprouts. Blanching is normally done in steam blanchers, although at least one company utilizes a hot water blanch system. These stabilizing operations are typically done in more than one blancher to accomodate the different sizes of sprouts. Blanching conditions vary depending upon the size of sprouts and type of blancher used. The sprouts are typically water-flumed to sorting belts after blanching. This cools the buds as well as providing a final wash. Air separation after fluming provides a final aspiration to remove any loose leaves. The sprouts are given a final sort and are then conveyed to a filler. Preformed boxes are filled, check-weighed, wrapped, and frozen.

The principal sources of waste loading in a typical Brussels sprouts process are the washing, blanching, and post-blanch fluming steps. These contribute the greatest concentration of wastes with the heaviest load coming from the blanchers. Initial washing and defrost water contribute the largest volumes to the waste streams with the defrost water being essentially "no-load" water. Flume water, whether pre- or post-blanch, can be recycled to provide make-up for the initial wash. The final flume operation is not continuously recirculated as this provides a final potable water wash for the sprouts. The flume water, however, can be used for make-up in previous washing steps.

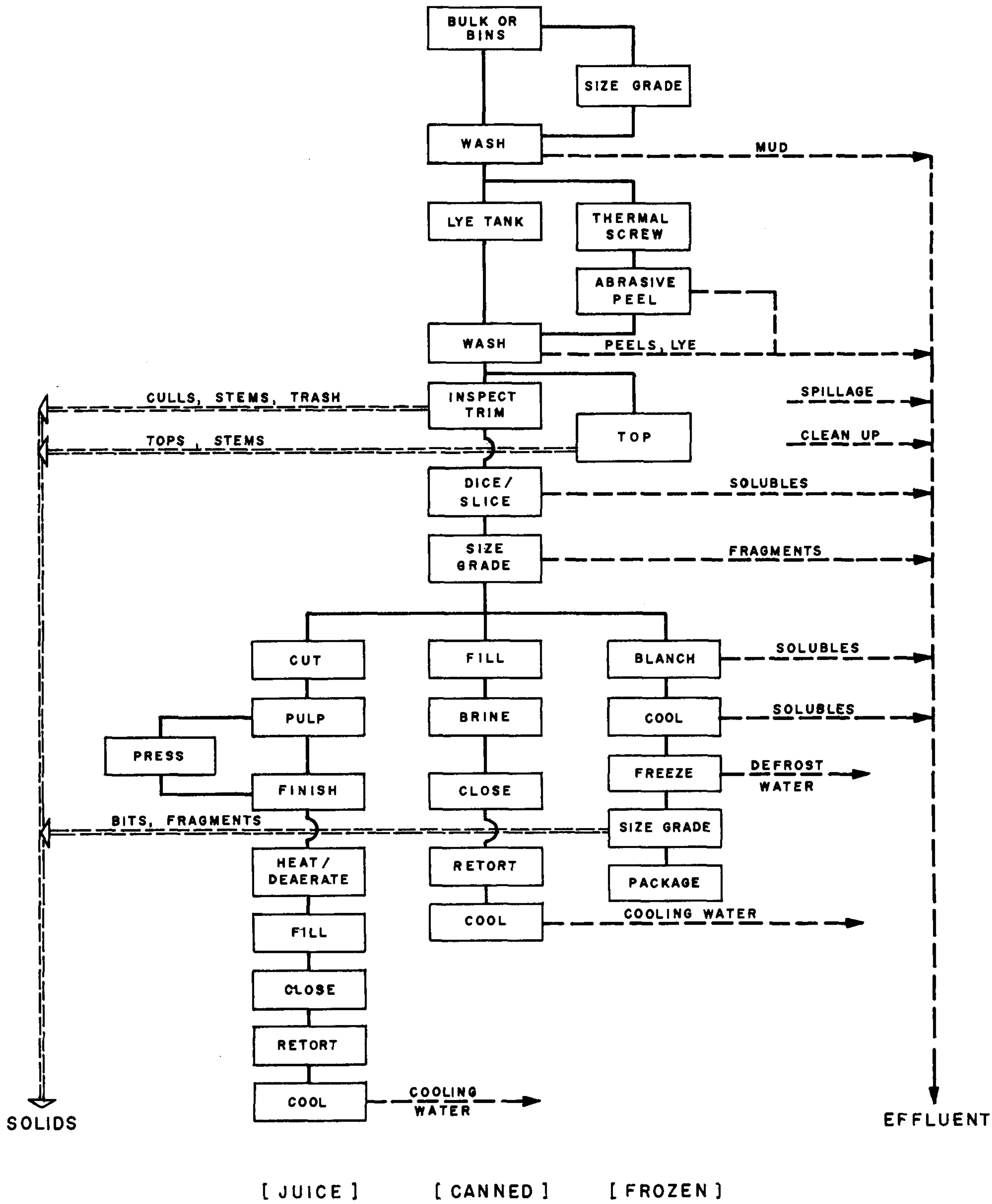
Carrots

Carrots are root vegetables canned and frozen in almost equal proportion. Carrots may also be commercially dehydrated (see separate commodity description on Dehydrated Vegetables). For the purposes of this study, ten plants in Wisconsin, four plants in Oregon, one in Iowa, two in Washington, one in California, and one in Texas were visited for the collection of historical data. In addition, a total of six composite samples were collected to verify this data. Carrots are processed in numerous styles, including diced, sliced and crinkle cut, nuggets and whole, julienne and shoestring, chunks and chips, irregular, and juice.

Figure 24 shows a typical carrot process flow diagram. Carrots are removed from the ground while a large percentage of them are still in the growing stage, before all have reached full maturity. In this way, the smaller carrots may be kept separate and processed whole, while the larger carrots are sliced or diced. Carrots for processing are usually mechanically harvested and sometimes topped in the field. The mechanical harvester travels along the row digging the carrots, cleaning and topping them, and discharges them to a truck ready for the processor. Occasionally lug boxes or baskets are used. Carrots may be held in cold storage to extend the processing season. Several types of washers may be used on carrots. These can be reel washers, soak tanks, or brush type, or any combination of the three. They are usually washed prior to lye peeling so that peel removal will be more efficient. Alternately, the carrots may run through a

FIGURE 24

TYPICAL CARROT PROCESS FLOW DIAGRAM



dry reel for dirt removal prior to a wet washing step. Size grading may be accomplished either before or after lye peeling. Gradings are usually accomplished by using parallel rollers, allowing the smaller carrots to drop through onto a separate processing line. Size gradings are also done to divide the flow of carrots for slicing and dicing. The larger diameter carrots are generally used for dicing whereas the smaller diameters are utilized for slicing or for baby wholes.

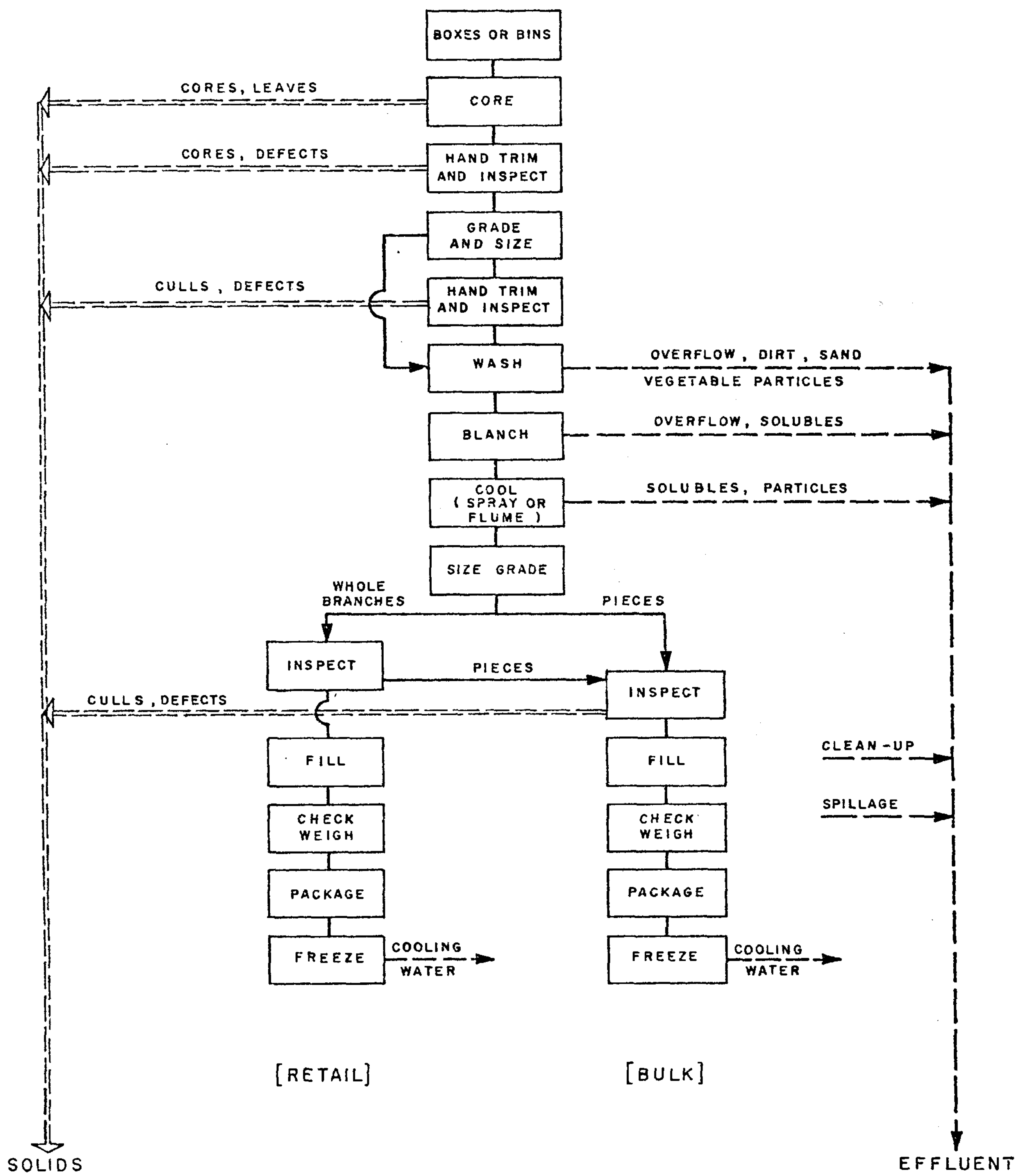
All carrots for canning and freezing are peeled. Peel removal is done either by use of lye, steam, or abrasion. The carrots are sometimes pre-heated before entering a lye bath. Typically, they are augered through a steam chamber which serves to further clean the vegetable and to soften the peel. The carrots are then immersed in hot lye for a short time. The peel at this point is very loose and can usually be removed by high pressure cold water sprays as the carrots are conveyed through a reel washer. In some cases, more solids may be removed by use of an abrasive peeler. This operation "polishes" the carrot and is typically used for the produc#ion of baby wholes. An alternative to lye peeling is a steam pre-heat, abrasive peel combination. The carrot is pre-heated in a manner similar to the above, but fed directly into an abrasive peeler. The carrots are then washed and conveyed to either an inspection table or to a dicer or slicer. Post-peeling operations usually consist of manual inspection and trimming. Defects are generally removed by hand; trimming green-tops and stems may be done by cutter blade, by hydrout, or by hand.

Canned or frozen carrots may be sliced or diced into a number of different forms. Slices may be regular or they may be crinkle-cut. Dices may be cubed or rectangular. Sliced carrots are sometimes conveyed over shaker screens to eliminate extra large slices or small bits and fragments. The sliced or diced carrots to be canned are usually moved directly from final size grading and inspection to a tumbletype filler. The containers are topped with hot brine, exhausted, closed, retorted, and cooled. Carrots to be frozen are blanched prior to packing and freezing. Blanching is usually done either by steam or water tubular type blanchers. The carrots are usually cooled after blanching, typically by water flumes or sprays. The product is then individually quick frozen, stored in bulk, and packed at a later date. After peeling, washing, and final inspection, the carrots are chopped and sent through a pulper and a finisher. Solids expelled from the pulper/finisher operation may be sent through an additional filter press operation to recover the remaining juice. The liquid is then heated, deaerated, and filled into the desired container which is closed, retorted, and cooled.

Wastewater strengths can vary considerably depending on degree of peel removal and the optional use of abrasive peelers or polishers. These peel removal waters and blancher effluents are the main contributors to both BOD and suspended solids levels. Initial washing operations were observed to generate both large

FIGURE 25

TYPICAL CAULIFLOWER PROCESS FLOW DIAGRAM



volumes of wastewater and high settleable solids levels as evidenced from the amount of mud in the effluent. Slicing and dicing operations can also contribute organics to the waste stream by generating juices and vegetable particles. Can cooling water and in-plant flumes can be recirculated and reused provided that the water is maintained and properly chlorinated. Cooling water can be recirculated to provide make-up for initial washing. Hydrocooling operations can provide make-up for flumes, the flume water being continuously recirculated and provided with a steady overflow.

Cauliflower

Cauliflower, also called "heading broccoli," is processed frozen and is very closely related botanically to regular sprouting broccoli. Approximately 80 percent of the total U.S. production of cauliflower is processed in California. For the purposes of this study, four plants in California and one in Oregon were visited for the collection of historical data. In addition, a total of ten composite samples were collected and analyzed to verify this data.

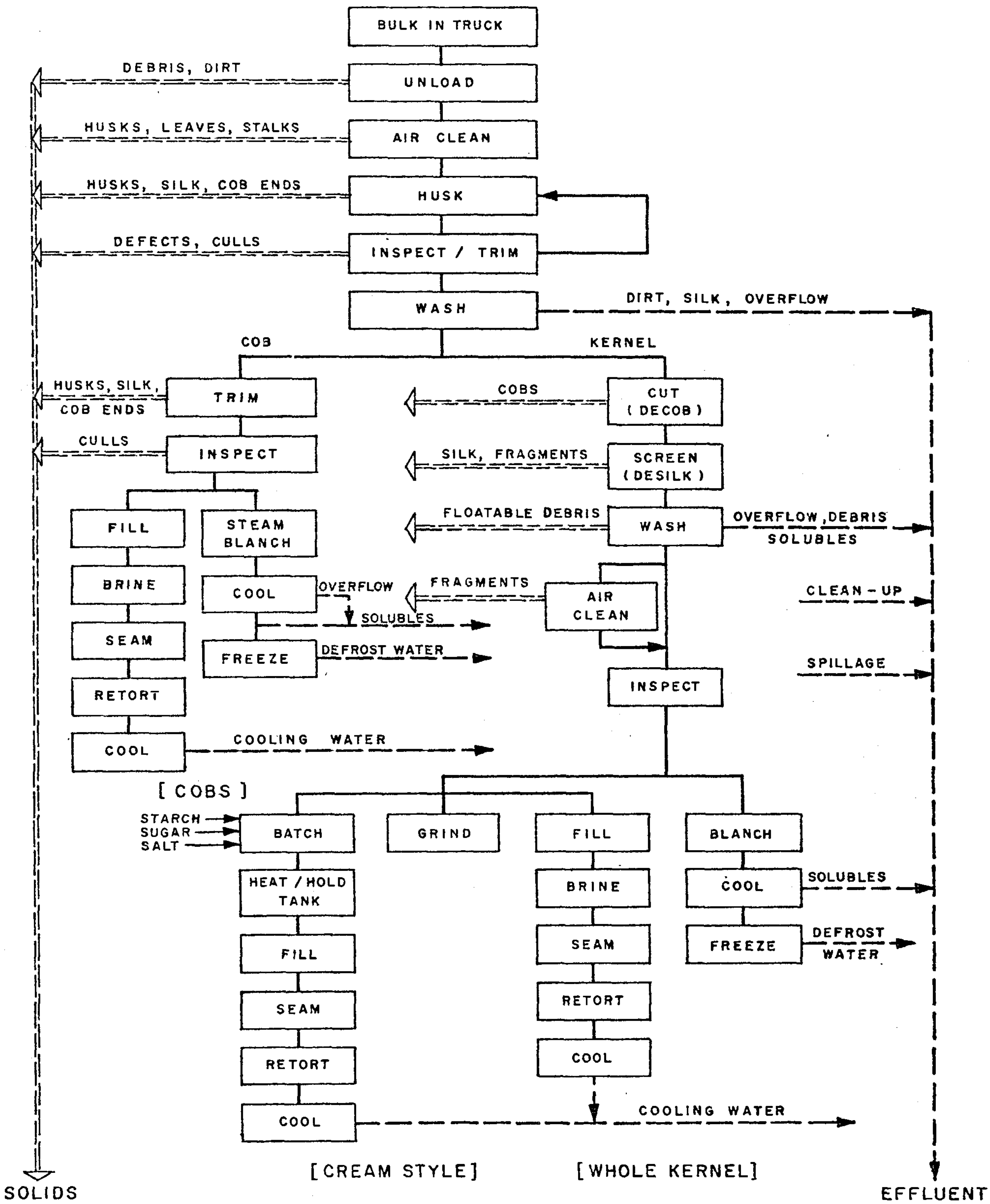
Cauliflower heads are cut from the plant with a large knife, leaving one or more whorls of leaves attached to protect the curds from dehydration and "yellowing." Before transporting to the processing plant the leaves may be further cut off just above the head, leaving a jacket of petioles and the remainder of the leaf blades. Further trimming may be done in the field to reduce transportation costs and in-plant solid wastes. Delivery to the processing plant is made either in large bins or bulk trailers. Cauliflower is reasonably hardy, but in order to maintain quality, the loads are usually chilled or iced.

Figure 25 shows a flow diagram for a typical cauliflower processing plant. In a typical processing operation, the cauliflower, after reaching the plant, is "balled" or stripped of all leaves close to the base of the curd. This is often a hand-trim operation but may be facilitated by "hydrout" machines. The large majority of wastes are generated during these trimming stages. Hand trimming usually results in a high proportion of solid waste, whereas the hydrout equipment introduces more solubles into the wastestream. After initial trimming, the heads are further reduced in size by hand trimming to the desired finished product size. After trimming, the cauliflower clusters are conveyed through a system of spray or tank washers. Salt or brine soak tanks have sometimes been included to remove insect residue. The cauliflower is then conveyed to a blancher, either a hot water or steam blancher.

Typically, however, when the cauliflower leaves the blancher, it is rapidly cooled to approximately 70°F or lower by chilled water sprays or flumes. Quick cooling after blanching stops the blanch at the desired point and is essential to preserve the color and maintain the quality of the frozen product. This flume or spray

FIGURE 26

TYPICAL CORN PROCESS FLOW DIAGRAM



cooling also serves to wash the vegetable of any adhering bleaching agent. Citric or ascorbic acid baths have been utilized to prevent discoloration or oxidation during a post-blanch hold. The cauliflower is then sometimes passed over a shaking device to remove most of the small pieces and extraneous material before being reinspected. At this point the product is conveyed to a mechanical or hand filler where it is packed into wax-treated cartons or other similar packages, which are then wrapped, sealed, weighed, and frozen. The product may also be IQF'd and stored in frozen bulk for repackaging at a later date or for packaging into plastic bags.

The main components of the liquid effluent are washwater and defrost water. The BOD and SS levels are relatively low due to the large amount of hand trimming. The principal BOD loadings are generated during blanching operations and vary according to the method of blanch (steam or hot water). Cleaning water, sometimes containing detergents, also contributes to these waste loadings. Freezer defrost water is discharged sometimes directly to navigable waters or alternately combined with the plant effluent. The BOD loadings of these defrosting waters are close to the BOD loadings of the individual plants' potable water supplies. Counter-current flow recycling provides the best opportunity for water reuse. Typically, water is recycled from a second stage washer back to the initial wash, usually by collection from dewatering screens. Fluming water may also be recycled back through the various washing steps. Defrost water, if reused, provides an excellent source of chilled spray or flume water. Screened final effluent discharge water has been observed to be recycled to provide in-plant gutters with a continuous water flow.

Corn

Corn is processed both frozen and canned in whole kernel, on-the-cob, and cream styles. It is processed mainly in ten states. The leading corn state is Minnesota, which processed about 28 percent of the U.S. corn in 1972. Wisconsin, Oregon, Illinois, Washington, Idaho, Iowa, Maryland, Pennsylvania, and Delaware are the other big corn states. For the purposes of this study, seven plants in Minnesota, two in Indiana, six in Illinois, two in Idaho, six in Oregon, four in Washington, eighteen in Wisconsin, one in Ohio, and two in Iowa were visited for the collection of historical data. Approximately 70 percent of all canned corn is canned whole kernel, both yellow and white. The remaining 30 percent is canned as cream style corn and corn-on-the-cob. Corn is frozen in whole kernel and on-the-cob varieties.

Sweet corn varieties have been developed which mature uniformly. By staggering the time of planting and the acreage, a processing plant can plan for a uniform flow of product through the plant during the season. Corn harvesting is done by large machines which mow down the stalks and remove the ears, which are then put in large trucks for transport to the plant. Due to the high amounts of sugars and starches in the corn kernels, the product must be processed soon after harvesting to prevent degradation. Most plants process the corn within 12 hours of harvest. As the corn is brought to the plant, it is weighed, then dumped on an open or covered slab.

The raw corn is transported to the processing line by a drag chain conveyor or by a front-end loader. Initially, the corn is run through a dry cleaning operation (see Figure 26), usually an air blast cleaner, which removes loose husks, silk, leaves, dirt, stalks, and other extraneous material. The clean ears then go to the huskers which are automated in most plants. Some plants use a steam wilter before the huskers to soften the husks. The husking machines consist of ridged parallel rollers which strip the husks and much of the silk from the ears without damaging the kernels. The waste material is usually transported dry to a hopper or truck (sometimes after grinding) for transport from the plant. It is used as silage, animal feed, or as a land-mulch. The husked ears are inspected and rehusked in some cases, but often go straight to some type of washer. In many plants a "desilker" washer is used, in which the ears of corn are sprayed with water while being brushed by long, cylindrical brushes parallel to the direction of product movement. Another type of washer in use is a revolving drum washer with water sprays. Increasing use of higher pressure, lower-volume sprays in this operations has reduced wastewater production.

If the plant is running corn-on-the-cob, the next operation is usually an inspection or sorting operation where good ears are picked out and trimmed in preparation for blanching. After steam blanching, the ears are cooled with water sprays and frozen in air blast freezers on trays or belts, or in liquid Freon freezers. The frozen cobs are usually stored in bulk until repacked later.

For cream style and whole kernel, the corn ears are put through a cutter, which cuts the kernels from the cob. While some are developing and using automatically fed cutting machinery, the majority of plants rely on hand labor to push the ears through the cutters. The cobs are transported dry and combined with the husk material for use as silage or feed, while the cut kernels are carried to the next operation by belt, vibrating conveyor, flume, or pump. Some plants run the cut kernels through de-cobbers and de-silker machinery to remove extraneous cob bits and silks before washing, but most plants bypass this and go directly to the washer. Most plants are using flotation type washers, in which the starch from the corn mixes with the water to produce a solution of higher specific gravity than pure water, and this solution buoys the lighter waste material to the surface, where it is carried off by the overflow. The good kernels sink to the bottom of the washer and are pumped to inspection tables. After inspection, the kernels can go three ways: whole kernel canning, whole kernel freezing, or cream-style canning.

After the inspection, the corn is transported to the fillers by pump, belt, flume, or negative air, whereupon it is filled in the cans, topped with brine, seamed, cooked in retorts or continuous cookers, cooled, and warehoused. Some plants blanch the kernels prior to filling and some use steam exhausting before seaming but these are not common. The corn to be frozen is water blanched at about 180°, then cooled by water flumes, water sprays, or air evaporative methods. It is then frozen by fluidized bed IQF, air blast, or liquid Freon freezers. Most frozen whole kernel corn is cold stored in bulk for repacking at a later time. In some cases, the product is prepared in one plant then taken to another plant for freezing.

Corn for cream style is transported to the cream style line, where part of it is put through a mill or grinder to comminute it. The resulting pasty corn material is mixed with the remaining whole kernels in a heated vat along with the salt, sugar, and other ingredients. The mixture is pumped through a "slitter" to control consistency, and is held in a large heated tank prior to filling. The cans are filled hot and seamed, then retorted and cooled.

The principal sources of wastewater generation are washers, water blanchers, wash and cooling sprays, and cooling water as well as a small amount of pumping and fluming water. The larger volumes of water are from the washing and can cooling operations. While the BOD levels are extremely low in the cooling water, they may contain significant levels in the wash water. Blanching wastes, typical for this type process, are much more concentrated as solids tend to leach rapidly from a product with the starch and sugar content of corn.

Some companies that use water blanchers (both the reel-type and pipe blanchers) do recirculate their water. However, there is a limit imposed by the need for sanitation and product quality. The input of clean fresh water is required to maintain an acceptable and clean product free from microbial growth. Thus, this modification is only a partial recirculation of the water. Air cleaners and other dry solids removal equipment are used in some operations to replace water-consuming cleaning methods. The savings are both in water consumption and in reduced waste load; however, some air cleaning devices deposit the waste material into the wastewater system, often by fluming, and this negates some of the benefits realized by dry removal. In some plants the use of cooling towers for cooling water has resulted in significant water reduction. Other sources of water reduction have been accomplished through air cooling instead of water cooling and steam or hot-air blanchers in place of water blanchers.

FIGURE 27

TYPICAL DEHYDRATED ONION PROCESS FLOW DIAGRAM

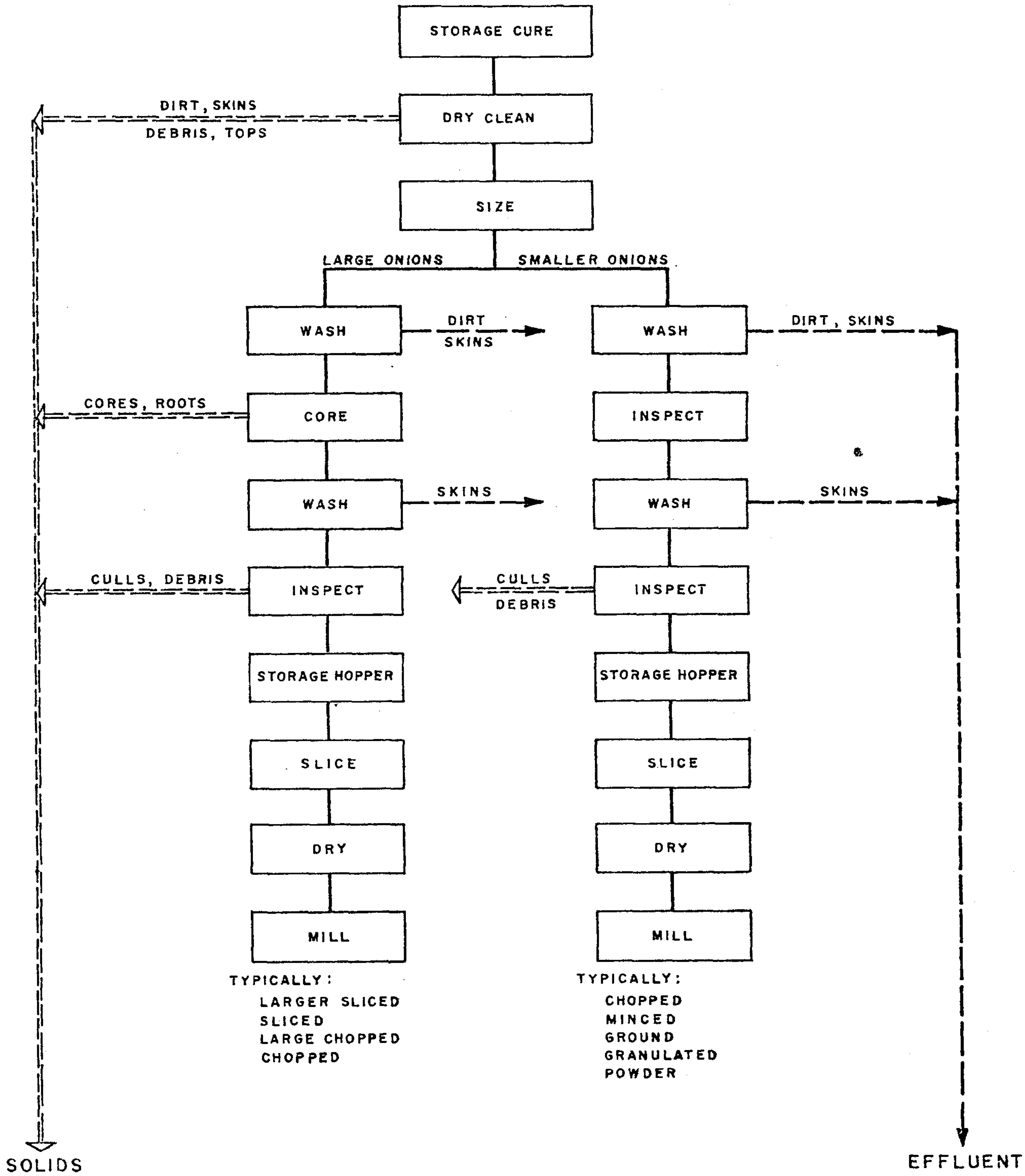
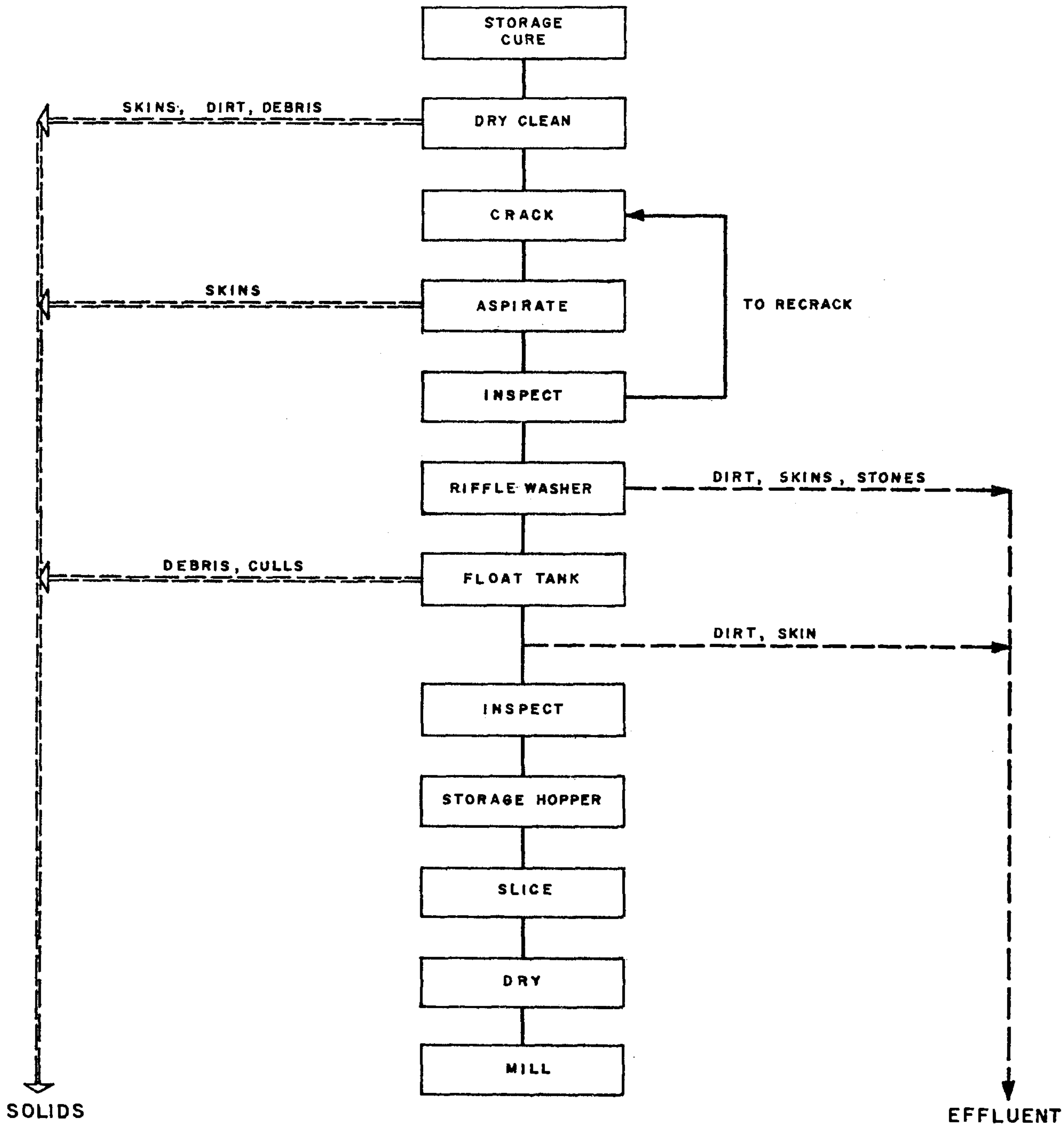


FIGURE 28

TYPICAL DEHYDRATED GARLIC PROCESS FLOW DIAGRAM



Dehydrated Onions And Garlic

There are only four onion and garlic dehydrators in the country, all of them in California. Several varieties of white onions are used for dehydration--Southport White Globes, creoles, and certain hybrids. Yellow or red onions are not dehydrated. The harvest period is from mid May in the El Centro and Blythe areas to November in the Tule Lake area. Garlic, early and late California varieties, is usually harvested from mid June until approximately the first of October. For the purposes of this study, four plants in California were field visited for the collection of historical data. In addition, a total of six composite samples were collected and analyzed to verify this data.

Onions and garlic are harvested by running a cutter blade below the bulbs. This process undercuts the root system, starving the bulb and attached green stem from further nutrients. When the tops are sufficiently wilted, a mechanical harvester picks up the bulbs, removes the green tops, screens out most of the adhering and loose dirt clods, and loads the bulbs into bulk gondola-type trailers. A labor force aboard the harvester further removes tops, defective bulbs, and dirt clods. Additional labor is sometimes used to gather those bulbs "missed" or dropped by the machinery. The bulbs are transported directly to the plant where they are screened to remove dirt and loose stems and then gently conveyed to storing bins. These bins are fitted with fans which circulate warm air through the onions (from bottom to top) in order to dry remaining tops and stems, outer layers of skin, and the bulbs themselves to prevent microbial spoilage. These storage bins can be very large (approximately 100,000 cu ft) or small individual containers (80 cu ft).

Figure 27 shows a flow diagram for a typical onion dehydrator. Cleaning is performed by both wet and dry methods. Dry cleaning is used to remove dried tops, some loose skins, and dirt. This machinery usually consists of a series of vibrating screens, parallel rollers, air aspirators, or a combination of all three. Dried tops are usually "pinched-off" by a series of rollers and, combined with the loose dirt and loose skins, are collected as dry solid waste. Wet cleaning is usually done by a series of dip or soak tanks and high-pressure water sprays. These cleaning operations are designed to remove soil, loose skins, and any other debris or contaminant which may be adhering to the external circumference of the bulbs. Hand trimming is sometimes employed to further remove tops, defective parts of bulbs, or other undesirable blemishes. The waste streams generated throughout these cleaning operations normally contain high levels of fine silt, dirt, and loose skins which can either be settled or screened from the final waste effluent.

Figure 28 shows a typical dehydrated garlic flow diagram. Garlic normally contains more dirt than onions, and dry cleaning is essential. This normally involves a series of rollers or screens which both screen the dirt and aspirate the skins from the bulbs. A cracking operation is included which breaks the bulbs into individual cloves. It is the cloves which are eventually sliced and dried into a finished product. The cloves are given a visual inspection (culls, trash, and foreign debris removed) and conveyed through a riffle washer, the purpose of which is to wash the individual cloves and separate them from small rocks and any adhering dirt. They then enter a flotation tank where they are immersed in water. The good cloves sink, whereas defective (dry) cloves and loose skin float and are skimmed off as solid waste.

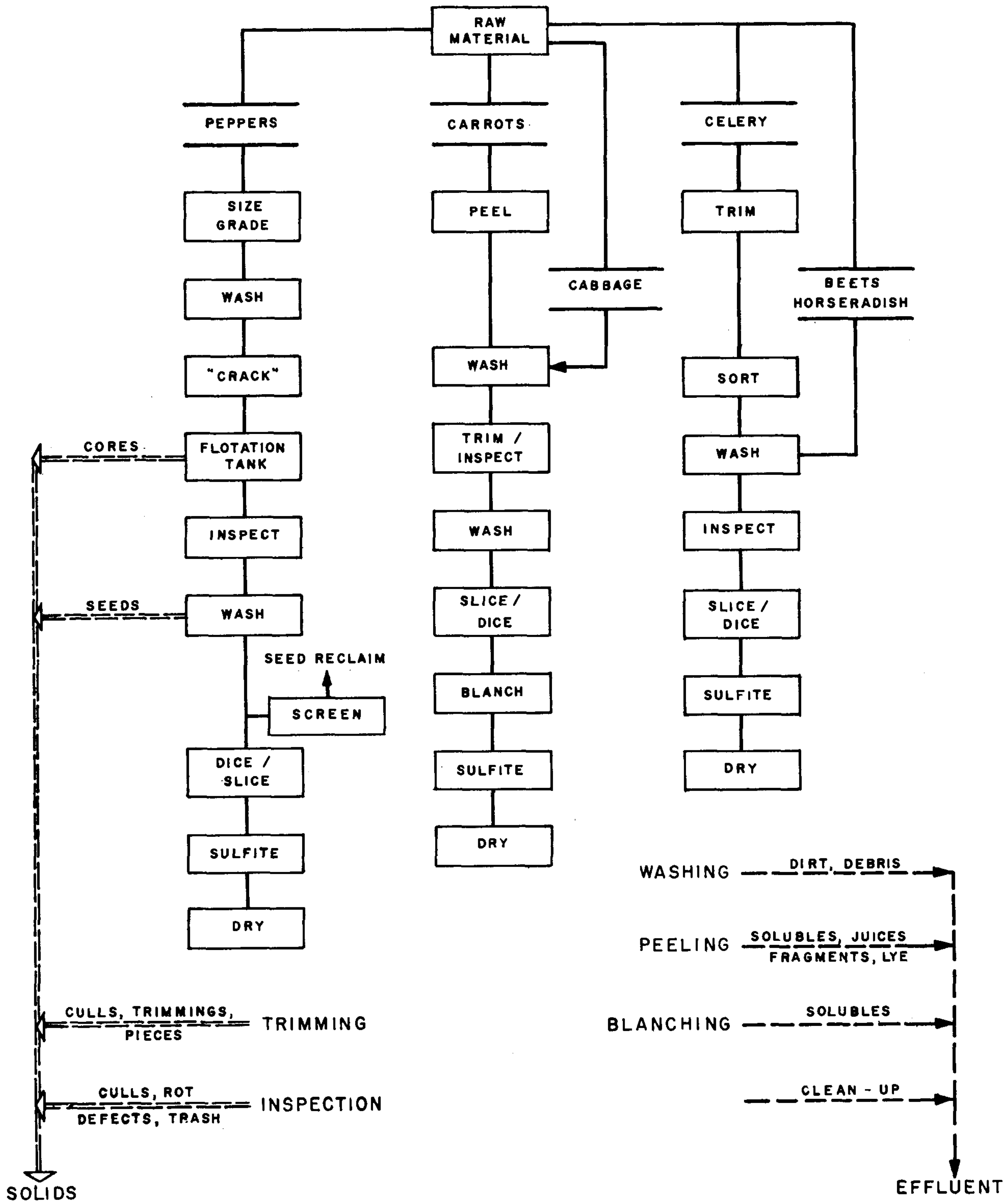
Onions may be size graded as a part of the dry cleaning operations, or they may be size and quality sorted after wet washing. In some cases, the larger onions are separated from the main stream and used primarily for the generation of the larger piece sizes--i.e., large sliced, sliced, and large chopped fractions. These bulbs normally are cored by a "hydrout" operation which removes the root and root-crown from the bulb. These particles of waste then usually become part of the waste stream. Conveying throughout these operations is usually facilitated by inclined augers, flumes, or belts. Gentle handling, however, is necessary throughout all operations to prevent bruising of the bulbs.

Following grading, sorting, and washing, the onion bulbs or garlic cloves are conveyed to specially designed machines which slice the whole bulbs and cloves into thin layers. These layers are then transferred by belt or vibratory conveyor to a continuous belt dryer. Continuous belt dryers are the most commonly used method for dehydration. They are usually long and multi-staged with baffled chambers which blow heated and sometimes desiccated air from over and under the bed-depth of the raw slices. Residence time in this type of dryer is usually ten to twenty hours, resulting in a product that has a finished moisture content of no greater than 4.25 percent for onions or 6.0 percent for garlic. Alternately, the onion and garlic slices may be taken from the final stage of drying at slightly higher moisture and reduced to the desired moisture content by "bin drying." These are unit processes in which a metal bin (approximately 80 cu ft) is fitted with wheels and a port-opening designed to accept a heated and desiccated air flow which further dehydrates the slices to the desired moisture levels. After dehydration the dried slices are usually screened, milled, aspirated, separated, and ground in various mechanical combinations to achieve the final desired piece size.

The main volume of water generated for a typical dehydrator occurs throughout the various washing operations. These are characterized by high settleable solids and screenable solid wastes (loose skins). The strength of these streams is usually low (approximately 200-300 ppm BOD), but the settleable solids are high enough (typically 200-400 ppm) so that mud settling tanks are a necessary pretreatment before final discharge. In general, these plants run a 24-hour day, seven day a week

FIGURE 29

TYPICAL DEHYDRATED VEGETABLE PROCESS FLOW DIAGRAM



production schedule. Cleanup wastes are generated throughout the production day and are usually of high volume to low concentration. The slicing operations, because of the extreme sharpness and frequent changing of blades, generate very little solubles into the wastewaters. The major wastewater reuse in the dehydration process is recirculated wash water. Another major reuse is the recycling of flume water by counter-current flow to prior washing stages.

Dehydrated Vegetables

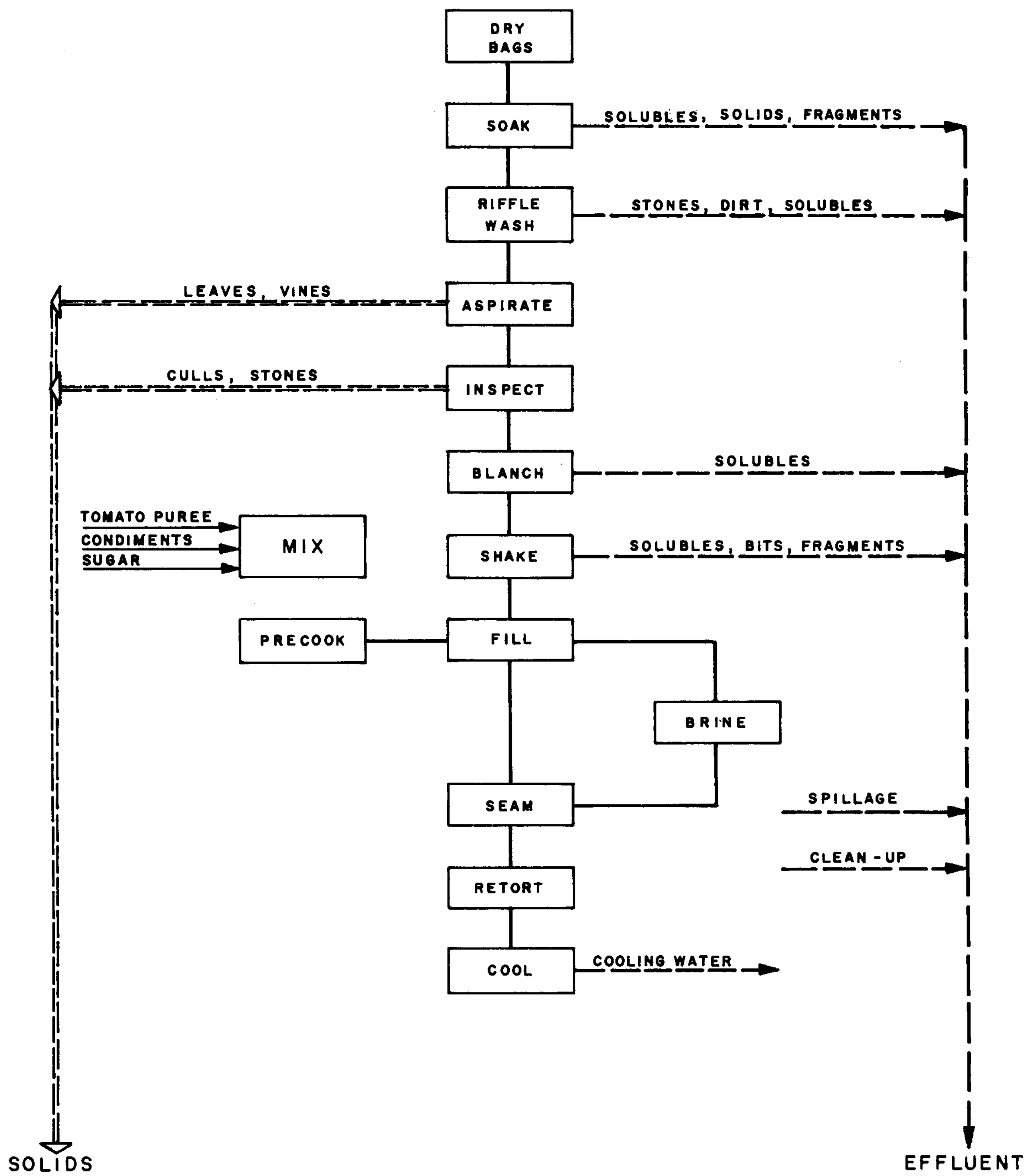
Dehydrated vegetables are an important and significant portion of the food industry. Vegetables commonly dehydrated include beets, cabbage, carrots, parsley, chili pepper, horseradish, onion, and garlic (see separate commodity descriptions), bell peppers, turnips, parsnips, and celery. Additionally, other vegetables such as asparagus, tomatoes, green beans, spinach, and green onion tops may be dehydrated upon commercial demand. These items are commonly used as ingredients for various canned specialties, baby food, and soup (canned or dried) formulations. Virtually all dehydrated vegetables are processed in California. For the purposes of this report, three plants in California were visited for the collection of historical data.

Figure 29 shows a typical dehydrated vegetable operation. Almost all of the crops are dehydrated fresh from the field although some items such as green beans may be dehydrated from the frozen state. For more detail on harvesting of the individual commodities, refer to the specific commodity descriptions. Similarly, the various washing, sorting, grading, and peeling operations are virtually identical to those as detailed in the individual commodity descriptions (except celery and bell peppers). Other notable exceptions to standard operating conditions are: cabbage is blanched prior to drying; beets are not peeled - all dehydrated beets are sold as dried, ground powder; and parsley is dried in a specially designed hot-air tower for a short time prior to discharge to a more conventional drier for final moisture equalization.

Celery - Celery is delivered to the plant in bulk fresh from the field. The butt and leaf ends are trimmed by mechanical circular saws. The butts go to solid waste, and the leaf (known as stalk and leaf) can be processed on another line. The leaf portion is sometimes trimmed in the field. Following trimming, the inner yellow stalks are hand separated and are typically discarded. The celery stalks are then washed in immersion type or spray type washers and conveyed directly to slicers or dicers. The cut fractions are sprayed with a sulfite solution (to preserve color integrity) and fed in a steady stream to continuous belt driers. The dried product may be further dried in forced-air bin driers or may be packed directly into bulk containers. Repacking into specific customer containers is usually done at a later date. "Stalk and leaf" is processed identically to the stalk.

FIGURE 30

TYPICAL CANNED DRY BEAN PROCESS FLOW DIAGRAM



Bell Peppers - Bell peppers are hand picked and delivered to the plant in large wooden bins. Bell peppers change color and solids content as they mature on the plant. The first portion of the harvest results in the prime green bell pepper. As the season grows longer, peppers remaining on the vine begin to develop yellow and yellow-orange stripes and blotches. Reaching full maturity, they develop an intense red color. Typically, then, bell peppers are run as three distinct products: green, mixed, and red. The peppers may initially undergo a size separation in order to facilitate cracking of the pods and later core separation. Grading is usually done by parallel rollers, the smaller vegetables dripping to another processing line. The peppers are then usually washed in immersion or spray type washers and conveyed to a "popper" or "cracker." This can be a device consisting of two closely spaced belts moving in the same direction (one over the other to pull the peppers in and "crack" them) or it may be two revolving wheels, between which the peppers fall and are "popped." Separation of pods and cores is usually accomplished by means of flotation. The very light and buoyant core floats while the flesh of the pepper is more dense and sinks. The cores are skimmed and go to solid waste. Inspection for defects and hand-sorting of remaining attached cores is then accomplished prior to a final wash to remove the remaining bits of core and seeds. The peppers are diced, sliced, or cut into desired piece size, sprayed with sulfite solution, and dried on a continuous belt drier. Final moisture can be achieved in the main drier or by bin drying. Packing is usually done in bulk, though the peppers may be repacked into smaller packages at a later date.

Carrots - Carrots are size graded, inspected, washed, trimmed, and peeled almost exactly as covered in the carrot commodity description. After final inspection and wash, they are conveyed to a dicer or slicer, blanched usually in a steam blancher, sprayed with sulfite, and dried and packaged in a similar manner to celery and bell peppers. The processing of carrots was observed to be greatly facilitated with the use of field-topped carrots.

Wastewater generations are typical of those separate commodities. Waste loadings from these operations usually consist of dirt (especially carrots and beets) with a consequent high level of settleable solids. In some cases, mud settling tanks or mud cyclones were observed. Peeling and/or slicing and dicing operations generate the highest levels of BOD, COD, and suspended solids. These steams usually consist of organic juices, peelings, lye, and solubles. Evaporated water is discharged directly to the atmosphere. Water reuse, with the exception of some in-plant flumes, is minimal.

Dry Beans

Dry beans are the sixth ranked dried or dehydrated food in the United States. The prinicpal varieties used for canning are pinto, kidney, navy, and great northern beans. For the purposes of this study, one plant in Maine, one in Pennsylvania, one in California, two in New York, one in Wisconsin, one in Illinois, one in Indiana, and one in Iowa were visited for the collection of historical data. In addition, one composite sample was collected and analyzed to verify this data. Figure 30 shows a process flow diagram for dry bean processing. The beans, previously dried, are typically stored in 100 pound sacks in clean, dry warehouses. If proper precautions are taken to prevent moisture and insect infestation, dried beans may be stored for long periods of time (one year or longer).

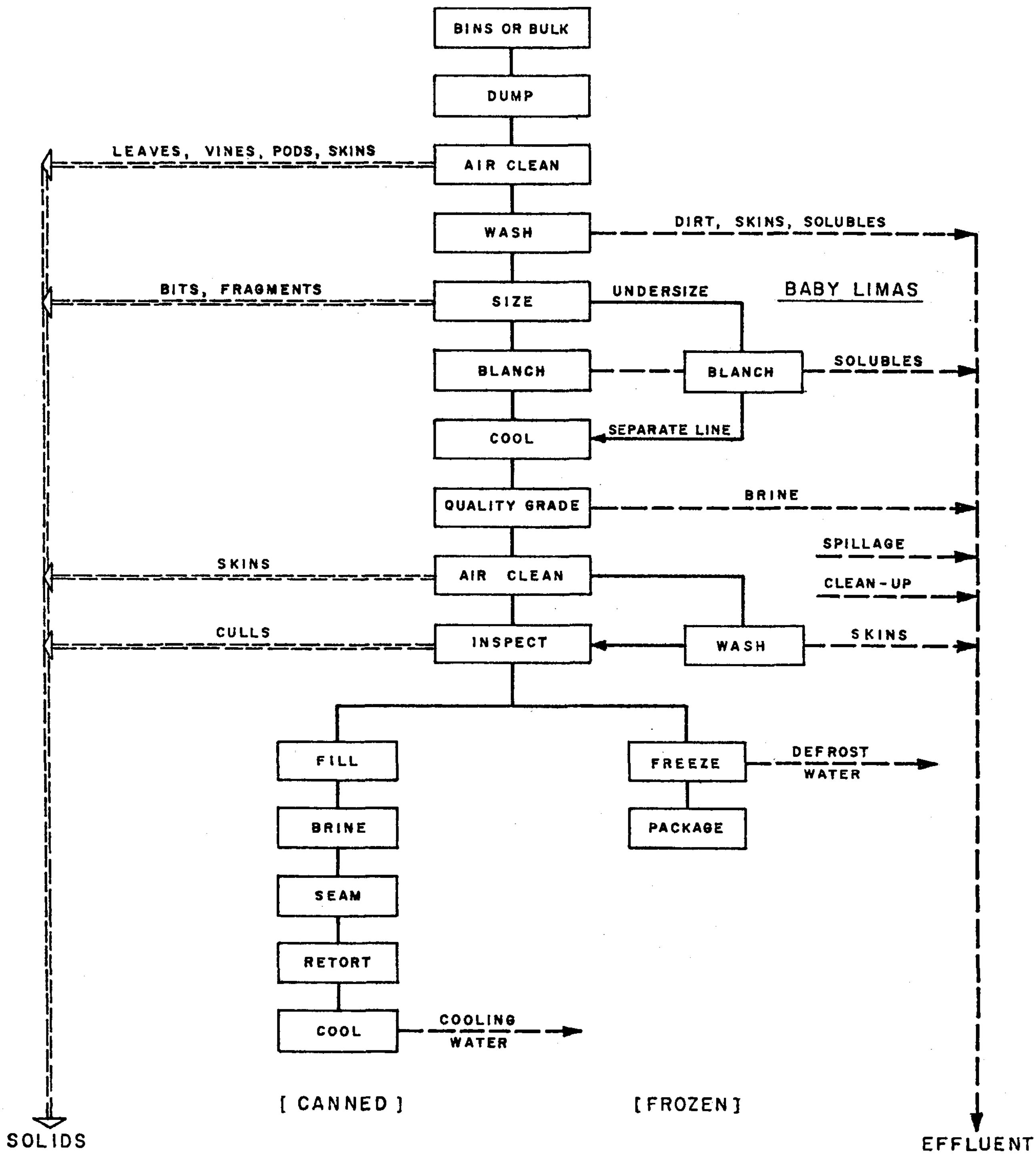
The dry beans are delivered to the processing plant in 100 pound sacks which are emptied into soak tanks and allowed to soak for approximately four to twelve hours. In order to make the beans palatable, the natural moisture content of the dry bean (between nine and twenty percent) must be raised. The soaking is usually done in shallow, non-corrosive metal, fiber-glass, or enamel-lined tanks. Depending on the climate, water hardness, and initial moisture content of the beans, the times involved in soaking will vary. However, if the moisture level is raised too high, splitting of the bean's skin will result. With beans which are soaked properly, 100 pounds of dry beans should produce 185-190 pounds after a ten hour soak. The beans may be dry cleaned prior to the soaking and cleaning operation. Regardless of the initial washing steps utilized the beans are flumed over riffles to remove small stones and other dense material. The beans are passed over an inspection belt where defective pieces, stones, and foreign material are removed. Air aspiration is sometimes used to remove lighter material.

After the beans have been soaked and destoned, they are blanched. Dry beans are blanched at varying times and temperatures depending on the variety processed. The time may vary from three to twelve minutes, and the temperature may be varied from 180° to 210° F. Blanching is normally done in hot water screw-blanchers. The beans are dewatered and conveyed from the blanchers to shaker screens which separate out skins and shriveled, broken, and undersized beans while cooling the good product with water sprays. The rejection of defective beans is usually facilitated by manual inspection and elimination of undesirable beans.

The principal sources of wastewater generation are the soaking, destoning, blanching, fluming, spraying, and can cooling waters. The soaking and post-blanch water sprays produce low volume waste but of high-strength BOD value. Blanching, while of low volume, is responsible for the high concentrations of oxygen demanding wastes and dissolved solids. The riffle washer accounts for approximately 80 percent of the processing wastewater (excluding retort cooling water) but is relatively low in BOD or total solids concentrations. Flume water for transport of the beans from the soak tank or to the filler is often a closed loop system and is continuously recirculated. Conventional cooling waters

FIGURE 31

TYPICAL LIMA BEAN PROCESS FLOW DIAGRAM



can be reused with the water passing through a cooling tower prior to its recycling.

Lima Beans

Approximately 53 percent of the total U.S. Production of lima beans is processed in California with the remainder processed primarily in Delaware, Wisconsin, Washington, and Maryland. For the purpose of this study, one plant in California, four in Delaware, one in Idaho, three in Illinois, and three in Wisconsin were visited for the collection of historical data. In addition, a total of ten composite samples were collected and analyzed to verify this data. Approximately 76 percent of all processed lima beans are frozen, with the remainder being canned.

Lima beans are usually harvested by a mobile viner which cuts the vine, threshes the beans from the vine, returns the vine to the field, and deposits the beans directly into bulk trucks for transport to the plant. Figure 31 shows a flow diagram for a typical lima bean processing plant. Upon arrival at the plant, the beans usually are fed into a shaker and air cleaner which removes leaves, chaff, dirt, vines, and pods. The beans are then given a thorough washing. A few processors use froth flotation cleaners, which remove loose skins, cracked lima beans, and undesirable extraneous vegetable material. Where froth flotation cleaners are used, the lima beans are first immersed in a treater solution of deodorized oil which prepares them for the selective bubble-attachment in the froth emulsion. The lima beans, after being pre-treated, are dropped into a separation tank filled with an emulsion (oil-in-water and a detergent). Extraneous material floats and is carried off via a discharge pipe. The beans are given a fresh water rinse with highpressure sprays after they pass through the flotation cleaner.

Sorting and grading usually occur two or three different times in a typical lima bean operation. An initial size grading is usually performed by a vibrating mechanical shaker. Post-blanching quality grading, accomplished by brine separators, divides the beans into several maturity grades at which time the beans can either be separated in bins or can be run simultaneously on several processing lines. The beans undergo a hand inspection after quality grading to remove insect damage, decay, and other undesirable pieces. Lima beans are blanched to inactivate enzymes. The type of blancher commonly used is the hot water rotary type, although some pipe blanchers and steam blanchers are used. The beans are rapidly cooled to approximately 70° F immediately upon release from the blancher to stop the blanch and to preserve the color and maintain the quality of the product.

Brine flotation graders are utilized quite extensively to separate lima beans for tenderness and maturity. Many processors pass the beans through separators installed in tandem. The brine is adjusted in the first separator to separate a maximum of starchy white beans. The portion containing only green or tender beans continues through the processing line while the more mature beans pass through the second separator containing a more concentrated brine. The final separation yields mostly green beans, although some white wrinkled beans may remain with the green beans. Brine flotation graders do not always completely separate lima beans into the various degrees of tenderness and maturity. Neither do they greatly assist in the removal of loose skins or split beans. Beans are sprayed with high-pressure water sprays to remove adhering brine. They are sometimes passed through a revolving wire reel that removes most of the splits, loose skins, and extraneous material before going over a hand-picking belt. After hand-picking, the beans are usually either conveyed to a filler where they are filled into cartons for freezing in a blast freezer, or conveyed through an IQF freezer, and then packed dry frozen. The canning process is virtually identical to the freezing process prior to the filling operation. The cans are initially filled mechanically with lima beans, then topped with hot brine and water until overflow. The cans are washed, retorted, cooled, and ready for packaging.

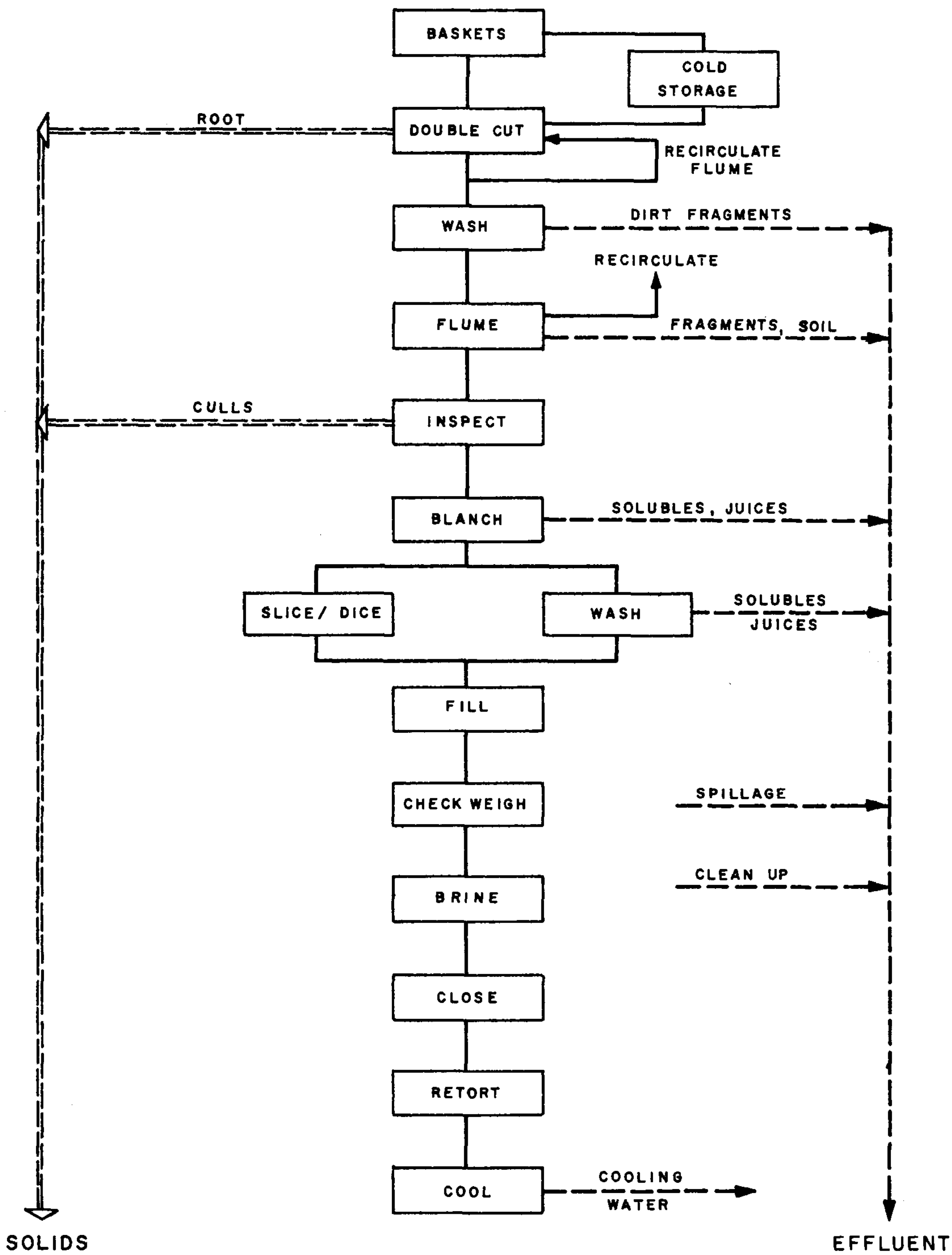
The process steps that are primary contributors to the wasteload are washers, flotation cleaners, hot water blanchers, quality graders, and clean-up operations. Dumping of blanchers, washers, and size graders contributes substantially in high BOD and suspended solids concentrations. Cooling waters are high in volume but relatively free from contaminants and are sometimes discharged from the plant without treatment. When froth flotation cleaners are used. the oil solution is recirculated. However, some spillage occurs. The fresh water rinse discharges small amounts of detergent and oils left on the beans after the separation tank. Clean-up operations vary in frequency from weekly to continuous operations. Since the concentrations in wasteload are not high, clean-up generally does not adversely affect treatment facilities. Waters used for fluming are generally recirculated; however, spillage or leakage is unavoidable. Principal reuses of water are typically those of recirculating fluming or cooling water per standard countercurrent practices. Some plants were observed to have replaced fluming operations with dry-belt conveyors which would both lower water consumption and pollutant levels.

Mushrooms

Mushrooms are processed canned, frozen, or dehydrated. Approximately two-thirds of the total U.S. production is processed in Pennsylvania, with the remainder scattered through a number of states, including New York, Ohio, Michigan, and California. For the purposes of this study, five plants in Pennsylvania, one in Michigan, one in California, and one in Oregon were visited for the collection of historical data. In addition, a total of five composite samples were collected and analyzed to verify this data. Production is heaviest between the months of October and May, inclusive. Harvesting is light during

FIGURE 32

TYPICAL MUSHROOM PROCESS FLOW DIAGRAM



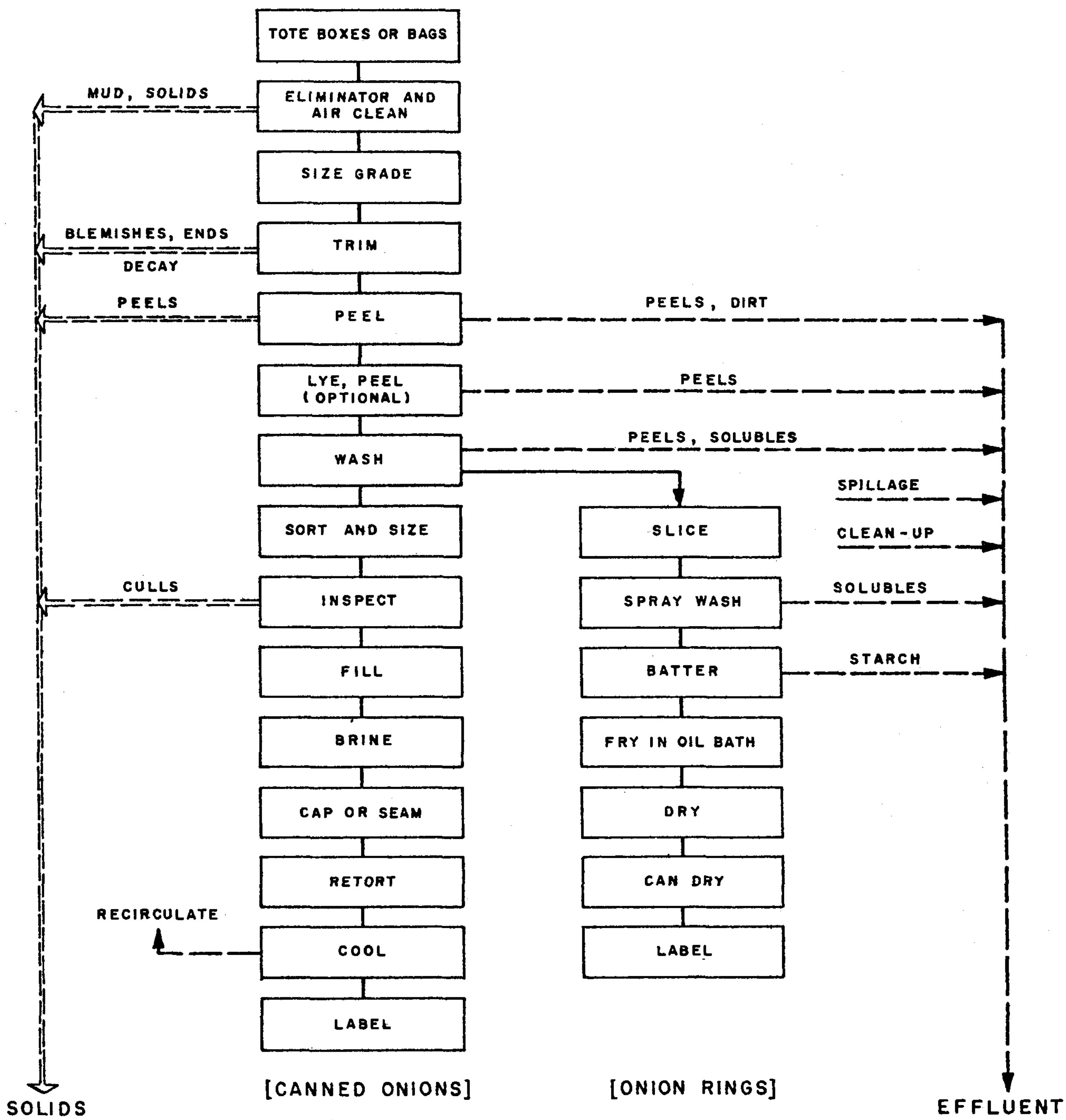
warm weather months. Many growers maintain production during the summer by means of air conditioning.

Figure 32 shows a typical mushroom process flow diagram. Mushrooms are grown best in a cool, moist place. Many producers grow mushrooms in special buildings built for this purpose, although in some areas caves and abandoned mines are used. Most canners grow a portion of their own mushrooms; in some cases this is 100 percent. Mushrooms are pulled from the beds with roots attached before the "veil" or membrane breaks open and exposes "gills." The mushrooms may be delivered to the plant either with or without roots attached. Pulled mushrooms generate a higher wasteload due to the discarded roots and attached soil. In the latter case, the roots are cut from the mushrooms in the growing houses by the harvesters. In either case, they are placed in baskets holding ten lbs or more for delivery to the plant. Freshly harvested mushrooms with the root portion attached will remain fresh longer than if the root portion has been removed. Mushrooms frequently grow in clusters which may contain three or more mushrooms.

Mushrooms deteriorate rapidly after picking; the veils tend to open, and the mushrooms become discolored and wilted. They should be delivered to the cannery promptly after picking. When mushrooms cannot be processed immediately after delivery to the cannery, they are usually placed in a refrigerated room at a temperature of 36° to 37°F until needed. Mushrooms must be handled carefully at all times to avoid bruising, which results in dark discolored areas. The baskets of mushrooms are taken to the cutting line for removal of root stubs and stems. In most plants the cutting operation is performed by manually loaded mechanical cutters, although some plants still cut by hand. The stems generally undergo two cuttings, the first to remove the root portion followed by the second which gives the stem a uniform length. In the case of whole mushrooms, the remaining stem is left one-fourth to one-half in. long. For button style mushrooms, the second cut is made just below the veil. In both cases, the root portion is carried away as solid waste with the cut stems from the second cutting operation saved to be processed in the "stems and pieces" style. After cutting, both the caps and stems are thoroughly washed. This removes the clinging bits of casing soil or other dirt. The mushrooms at some point pass over one or more inspection belts where blemished mushrooms may be trimmed or sorted out. Misshapened, blemished, trimmed, and broken mushrooms are sorted out and placed with other mushroom material for the stems and pieces style. For example, mushrooms with partially opened veils may be processed in the stems and pieces style or may be added to the buttons or whole mushrooms intended for one of the sliced styles. The mushrooms are size graded into holding tanks by a revolving drum sizer, either submerged in water (mushrooms float into water-filled holding tanks) or overhead (mushrooms fall into water-filled holding tanks). The buttons may be separated into as many as twelve

FIGURE 33

TYPICAL CANNED OR JARRED WHOLE ONIONS AND ONION RING PROCESS FLOW DIAGRAM



different sizes. The larger sizes are generally sliced, and the smaller sizes are packed as buttons.

Mushrooms are washed before blanching then flumed or dry conveyed from the holding tanks to the blancher. In addition to deactivating enzymes, blanching also shrinks the mushrooms as much as 30 to 40 percent, which is needed to meet the drain weight requirements. Most mushrooms are blanched by immersion in water at a temperature near boiling. An alternate method, however, is to pass the mushrooms through a continuous steam blancher where they are exposed to live steam for a period of two to eight minutes. Water blanching produces a better product in terms of yield, pack, and color. Since copper, steel, or iron tend to discolor mushrooms, blanchers are fabricated of other non-corrosive metal such as stainless steel. A spray rinse may follow the blancher operation. Mushrooms intended for slicing are generally sliced after blanching; however, slicing may be performed before blanching if they are to be frozen. The mushrooms are generally passed through a mechanical slicer with knives that cut them into slices of a predetermined thickness. A shaker screen for certain styles removes the small end and broken pieces to be used in other styles.

Mushrooms are generally filled into the can by tumble fillers. The cans pass through the center of a rotating cylinder that lifts and drops the mushrooms into the can. Mushrooms that miss fall back into the water in the bottom of the drum. Volumetric fillers and hand pack fillers are also used. After filling, the cans are check weighed, and the fill is adjusted if necessary. A salt tablet is normally added, and the containers are moved under taps of hot water, the temperature of which is greater than 200°F. The taps are adjusted to fill to overflowing. A hot brine solution and briner filler is sometimes used instead of the water and salt tablet to eliminate the brine overflow. This is only practiced, however, where fill rates are high. It is generally unnecessary to use an exhaust on the filled containers since a sufficiently high vacuum is obtained by the addition of hot water. After closure, the containers are washed, retorted, and cooled.

The major contributors of wastewater are flume overflow; blanching wash and rinse wastes; holding tank filling and brining; and retort and cooling waters. Blancher water has the highest wasteload concentration in BOD and dissolved solids. This water is occasionally used as filling juice in the final pack. Continuous and end-of-shift clean-up operations contribute high volumes and wasteloads, along with pieces of mushrooms and other organic wastes. Flume water is typically recycled in several unit process steps. Cooling water may be recycled for further cooling purposes or can be used as make up in initial washings or flumes.

Onions, Canned

Canned onions are packed by relavively few packers, although the annual pack increases each year as the product becomes better known and more widely distributed. The principal producing areas are Pennsylvania, New York, Delaware, Oregon, and California. For the purposes of this study, two plants in Pennsylvania, one in New York, and one in Delaware were visited for the collection of historical data. Yellow globe onions, a commerical term applied to several different varieties and strains of onions, are preferred by most processors.

Figure 33 shows a typical canned onion process flow diagram. The customary period at which to harvest onions for canning is in the fall when the tops have begun to turn greenish yellow. Usually the crop is dug by a hoe or an implement which turns the ground exposing the onions to the surface. After they have been taken from the ground, the onions are placed in windrows or piles in the field, where they remain until the tops are completely dry. After curing sufficiently, the tops are cut or pulled off close to the bulbs. The onions are then placed in storage or shipped. They are usually delivered to the cannery in sacks or crates and are stored until used. Well-cured onions will keep for several months if stored in a well-ventilized place. In some areas they must be enclosed to protect against freezing.

Generally the onions are emptied from sacks onto a belt conveyor carrying them to a sizer which eliminates over- and under-sized onions. From the sizer the onions are placed in buckets or pans on a "merry-go-round" or "lazy susan" sorting table where ends of the onions are trimmed, and onions possessing rot, decay, or other serious defects are discarded. From the sorting table a variety of peelers may be used. Carborundum abrasive, rubber abrasive, and flame peelers are the most popular. In some cases, a continuous lye peeler is used, containing a three to ten percent lye solution. The strength depends upon the variety and character of the onions. This further loosens the outer scales of the onion bulb. When a lye peeler is used, a closely controlled check is necessary to assure complete removal of the lye solution from the onion bulbs. The hot lye peeling operation results in effluent high in BOD, suspended solids, and alkalinity, unless a low water usage scrubber is utilized.

Following peeling, the onions pass through a rotary screen washer where adhering portions of the outer loosened scales are washed off under a strong spray of water. After washing, the onions are moved by conveyor belt to an inspection table where blemished onions are removed. At this time the good onions are normally separated into three size classifications: tiny, small, and medium. Each processor has his own particular sizing operation. However, most onions exceeding 1 1/2 in. in diameter and those with a diameter of less than 5/8 in. are not used for canning. As the onions come from the sizer they are conveyed onto a final inspection table where loosened scales, loose centers, blemished units, or excessively discolored onions are removed. The onions are then filled into cans or glass jars, and a sufficient amount of hot brine is added for a proper fill. Brine spillage contributes to the wasteload. After the cans or jars are filled, they are quickly closed, sealed, and still retorted in metal baskets. After sufficient time is allowed for the retort, cooling water is slowly added to the retort in the case of jars, or a cooling tank may be used for cans. Cooling tank water is generally recycled and dumped once a day or week depending upon the plant operation.

The process for canned fried onions is essentially the same as the process for canned onions from delivery through the washer. The onions are then sliced mechanically into rings and spray washed. The rings are then covered with batter, fried in an oil bath then air dried. Onion rings are then canned dry.

The process components contributing substantially to the wastewater are the following: Overflow from fluming operations located between the trimmer and peeler(s); overflow and periodic dumping of lye peelers and wash tanks; spillage and overflow of brine from filling operations; retort, condensing, and cooling water; and clean-up of spills and equipment. Flume overflow contains soil and organic solubles but the volume of water loss is minimal in most cases. Cooling and retort waters are large in volume but relatively free from contaminants except for occasional breakage of jars and brine removed from the surface of the cans or jars.

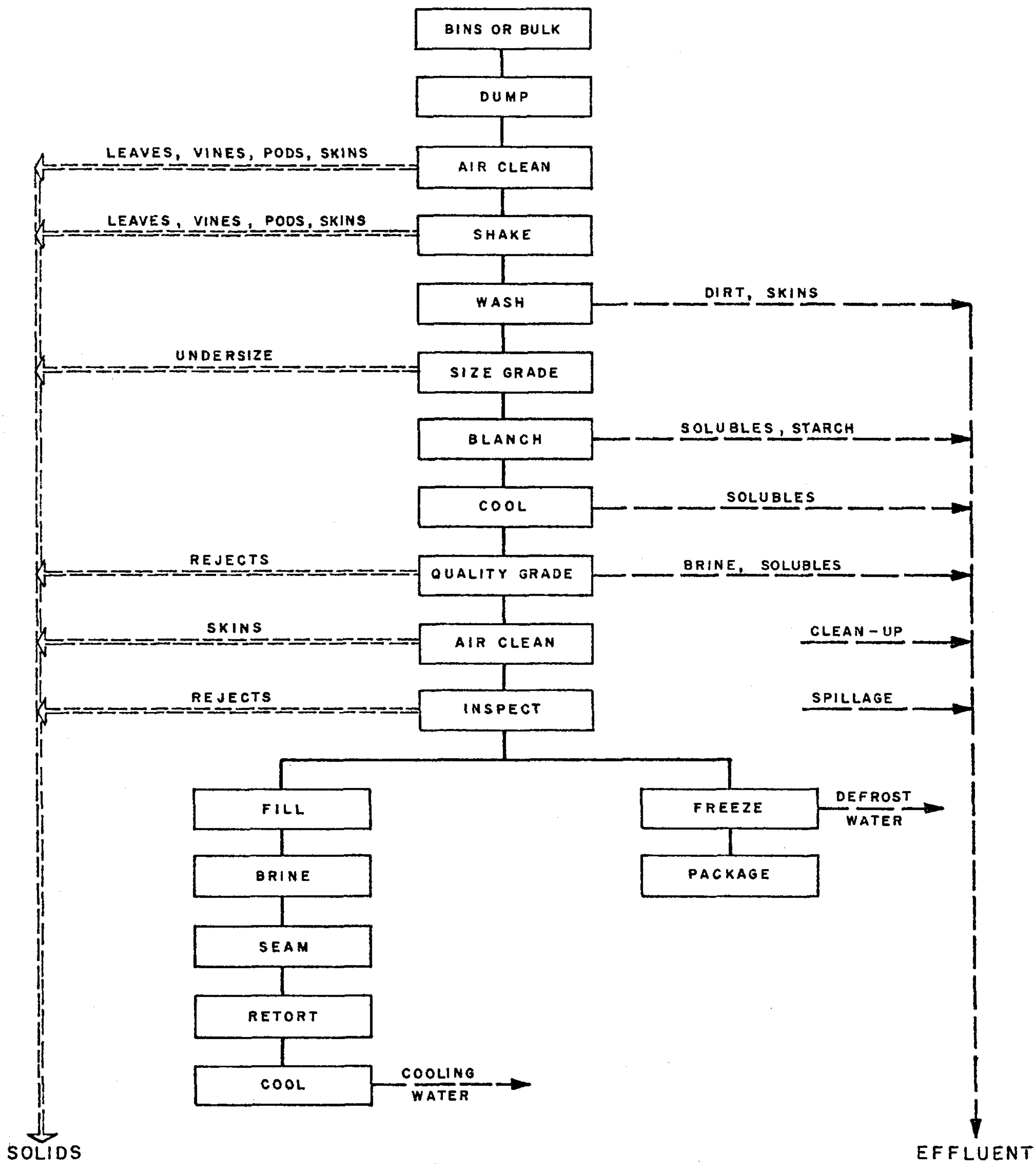
Wastewater from the peelers, especially the lye peelers and washers contributes the strongest wasteload. It has the highest BOD and suspended solids concentrations as well as onion pieces and solubles. Cleanup of spills on a continued basis and end of shift equipment washdown also contribute to the total wasteload. Dumping of washers and peelers during clean-up adds a considerable amount of BOD and solids to the clean-up flow. Fluming and cooling waters are normally recycled. Continuous recirculation of peeler and wash water with makeup water are other practices also used.

Peas

Approximately 49 percent of the total U.S. production of peas is processed in Wisconsin and Washington, with the remainder primarily in Minnesota, Oregon, Idaho, California, Delaware, and Maryland. During the peak processing season typical freezing and canning plants may operate two ten hour shifts seven days per week, with an average production of ten to fifteen tons per hour. Such intensive production is necessary to insure that the peas are processed at the proper stage of maturity. The processing season usually runs from June through July in the midwest and from mid-June to mid-August in the west. For the purposes of this study four plants in California, two plants in Wisconsin, four in Oregon, one in Pennsylvania, two in Idaho, four in

FIGURE 34

TYPICAL PEA PROCESS FLOW DIAGRAM



Illinois, nine in Washington, one in Michigan, two in New York, two in Delaware, and five in Minnesota were visited for the collection of historical data. In addition, a total of nine composite samples were collected and analyzed to verify this data. Figure 34 shows a typical pea process flow diagram. Peas are usually harvested mechanically by a mobile viner which picks up the vine from windrows, threshes out the pea pods, and shells the peas. The vines, trash, and pods are returned to the earth to be plowed under. The peas are directly bulk-loaded into trucks for shipment to the plant.

The initial operation separates extraneous material from the peas by means of an updraft air cleaner. This extraneous material is either collected in bins or carried away by water into the gutter. The peas may also be passed over a scalper to insure further removal of pods, vines, etc. The washing process is accomplished in three stages: first, a tank or reel washer, second, a flotation washer, and third, a final fresh water rinse. The initial washer often uses reclaimed or recycled water to rinse the product prior to pumping or fluming to a flotation washer. This latter wash affects further removal of soil residues and extraneous material by passing the product through a bath of water, in which the extraneous material floats to the top and is carried away in the overflow. Some plants use a "froth" washer in addition, instead of the flotation washer. This device uses a mineral oil plus air injection to create turbulence which further cleanses the peas. The peas are then flumed or pumped to a mechanical sorting operator for separation into various sizes. Flumes and/or pumps are the preferred method of transport between unit processes in order to maintain product quality. Such a system can require large amounts of water; however, a considerable water savings is often realized by using recirculated water or water from another operation. Negative air systems are also replacing water transport in many plants where practicable.

Blanching is typically done in reel or tube type blanchers. The blanching operation requires a substantial supply of fresh water, except where steam blanching is utilized, to replenish the blanching water, and to rapidly cool the peas. Under carefully controlled conditions, some water reuse can be practiced, providing in-plant chlorination is effective. The blanchers are a potential fertile source of bacterial contamination, and are cleaned frequently. Steam blanching is also practiced and is desirable in reducing waste generation since less solubles, particularly sugar, are leached from the peas. However, uniformity of blanch is more difficult using steam. Cooling is normally done in flumes or air coolers while the peas are being carried to the quality grader. In many plants the blanched peas are cooled by using spray devices such as a spray reel or vibrating screen with overhead spray.

The blanched product is dewatered after the cooling process and separated into two grades. This separation is effected by passing the product through a brine solution; and due to a difference in specific gravity, the less mature, tender peas float, whereas the more mature, starchy peas sink. The peas may then be passed through an air cleaner and subsequently to the inspection belt. Extraneous material from the air cleaner and sort-outs from the inspection belt are either collected dry or washed in the gutter for later separation by screening. Peas to be frozen are conveyed by pump, flume, or negative air to the freezer, which is usually an individual quick freeze (IQF) type. Frozen peas may then be immediately packaged in various style containers or held in bulk in cold storage for repacking during the off season. A single plant may process peas by both canning and freezing. Usually, if both methods of preservation are available, the more mature peas are held exclusively for canning, while the less mature peas are favored for freezing. The canning process consists of filling various sized containers, topping off the container with brine, and then cooking in either retorts or continuous cookers.

The largest volumes of water generated throughout a typical pea processing operation are attributable to washing and can cooling. The wash waters usually contain dissolved solids and dirt whereas the can cooling water has had no product contact and can be reused elsewhere. Hot water blanchers contribute significantly to plant effluents. These streams, however, are usually characterized by low flow with high BOD levels. Condensate from steam blanchers produce even a more concentrated load (but lower flow) than a hot water blancher. Maturity separation, usually by means of flotation through a salt brine, results in some chloride addition to a plant's waste stream. Spillage, however, is usually minimal so that chloride levels are not a significant pollutant.

As in most canneries, reuse or recycling of can cooling water can be a major contributor to reduced water consumption. This water can be utilized for initial washing operations, gutter flushings, boiler makeup, etc. Various other processing steps may be incorporated to conserve on water usage or may reduce pollutant levels.

1. Use of steam blanchers rather than hot water blanchers.
2. Dry size graders instead of hydro-graders.
3. Use of dry belt conveyors and/or negative air for transport rather than fluming.
4. Utilization of air transport methods for dry cleaning.
5. Filtering of salt brine. This can reduce both water and waste loads.

Pimentos

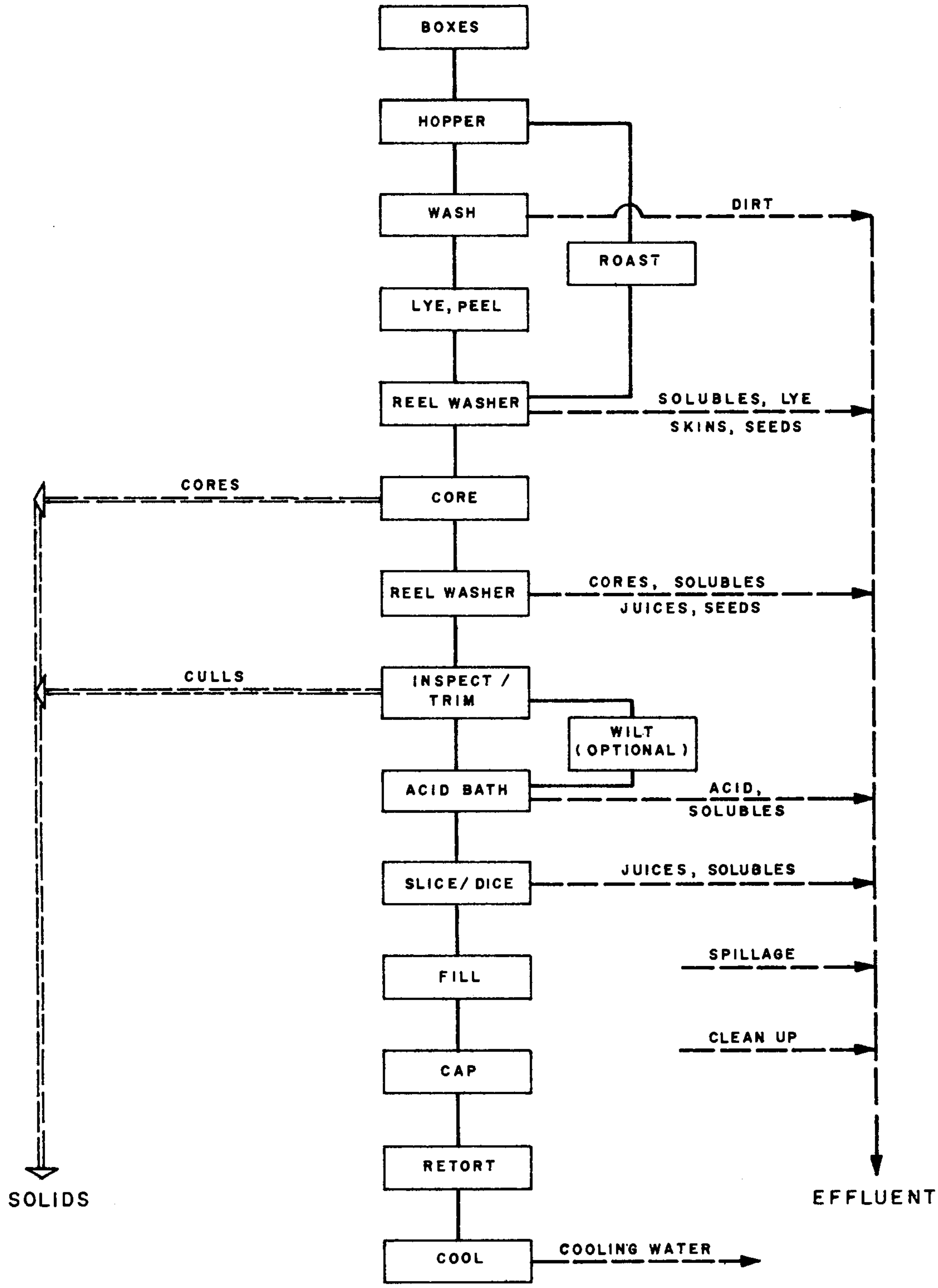
The production and processing of pimentos takes place primarily in the states of Georgia, Alabama, and Tennessee, with approximately 15,000 acres of pimento fields under cultivation each year. Lesser amounts are grown in California, the Carolinas, and Texas. The size of individual fields in the southern states range from one to twenty acres. Since considerable hand labor is involved in processing, the pimento industry provides an important source of income for many laborers. The pimento variety of the red sweet pepper (Capsicum Annum) is a smooth, heart-shaped pod covered with a hard wax peel. The flesh of the pimento is deep red in color and has a mild, sweet taste when the pod is ripe. The pimento pods do not have the deep creases and lobes which are characteristic of other red peppers and sweet green peppers. The predominant variety of pimento grown is the Truehart Perfection. Pimentos are generally used as seasoning or garnishing agents in combination with other vegetables or fruits. Therefore, the majority of packs are in small glass jars. For established uses in cheeses, lunch meat, and stuffed olives, large cans and five gallon containers are packed. Industrial sources estimate that at least 75 percent of the total pimento pack was processed in four plants in Georgia. The common styles are whole pods, strips, pieces, and dices.

While pimento harvesting has historically been accomplished by hand labor, a mechanical harvester has recently been designed and constructed, and the first commercial prototype of the harvester is currently being tested in Georgia. In the meantime, manual harvesting continues to be the common commercial practice. Since only fully ripened pimentos are picked, each field is harvested several times during each season. The pimentos are transported in small trucks to receiving stations where they are packed in field boxes and hauled to the processing plant by trailers. These boxes are then stored at the plant for use within three days.

Figure 35 shows a typical flow diagram for pimento processing. A preliminary wash is applied to the pimentos prior to lye peeling. This is usually a reel washer to remove surface dirt and assorted debris. Pimentos to be roasted are not washed prior to peel removal. An initial inspection done upon receiving is sometimes used to separate the larger pods for seed production. Pimentos are roasted in rotating metal cylinders approximately eighteen feet long and 20 inches in diameter. Each cylinder is inclined at about fifteen degrees from the horizontal. A jet flame from natural gas or fuel oil is blown through the cylinder, and the pods are allowed to roll through the flame. The pods, black from charring of the peel, emerge at the lower end of the cylinder. They are then conveyed to a reel washer which removes the charred peel by the abrasive action of the reel and water spray within the reel.

FIGURE 35

TYPICAL PIMENTO PROCESS FLOW DIAGRAM



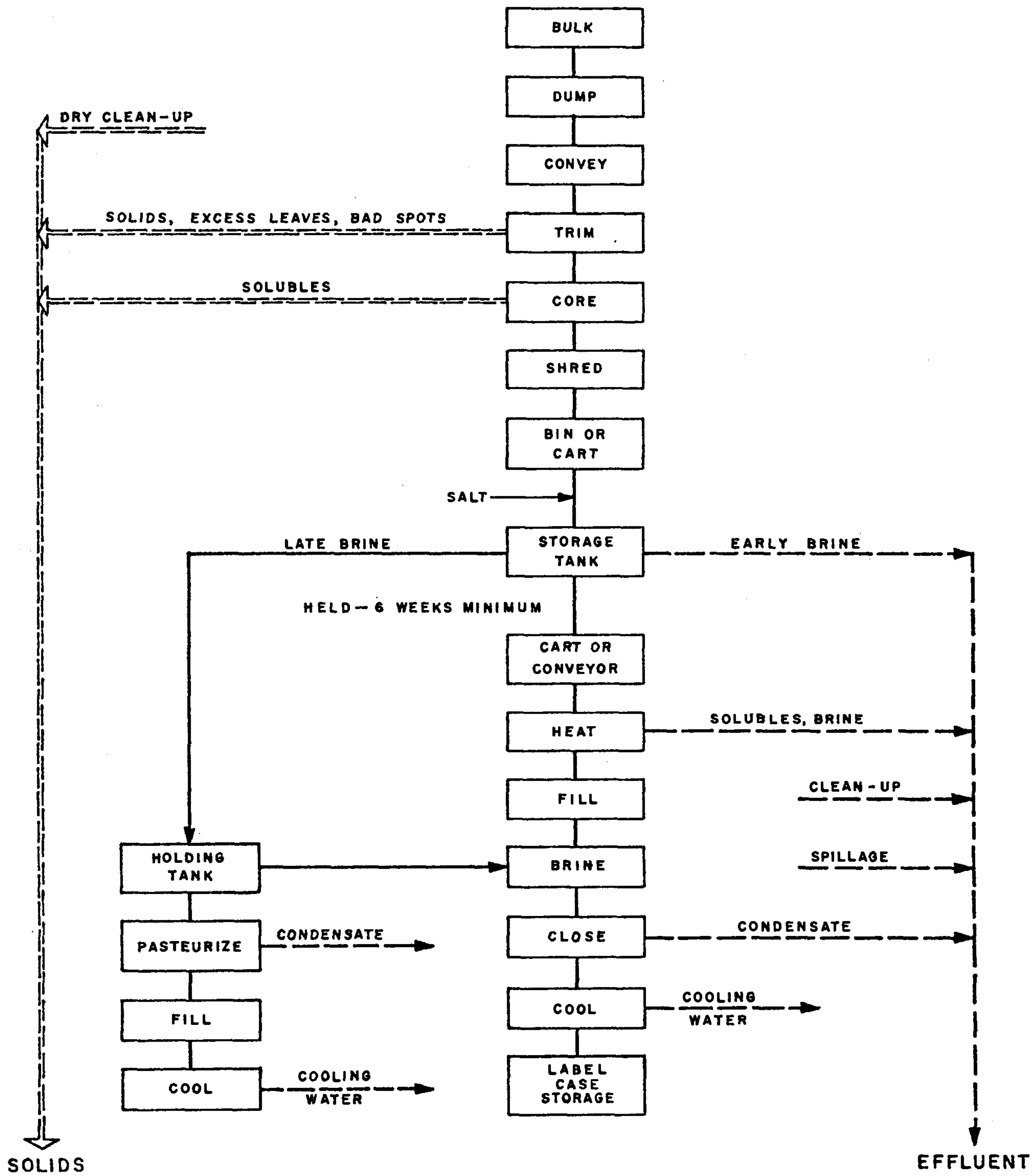
Pimentos may also be peeled by lye. After an initial wash, they are exposed to a sixteen to eighteen percent sodium hydroxide solution at approximately 99°C. The lye coated product then enters a pressurized steam vessel where the peel is loosened further. The peel is then removed by the abrasive action of a reel washer. Cores may be removed either by mechanical coring (using a rotating mechanized knife) or by crushing the pods between two belts. If mechanical coring is used, then a large employee force is needed to hand remove the cores from the crushed product. On the other hand, use of "belt-like" crusher and subsequent flotation removal of cores was observed to greatly reduce labor at no sacrifice to core removal. Hand inspection and trimming is still necessary following these steps to remove final traces of core and charred material. The fruit is then thoroughly washed in reel washers to remove any traces of seeds, char, or core prior to canning. After peeling, coring, and trimming, an optional practice is wilting of the fruit in a steam bath to soften the flesh for packing. The fruit may go directly into a citric acid bath or through a reel washer prior to the bath. The purpose of the bath is to reduce the final pH of the canned pimento to approximately 4.5.

The whole pods are generally packed into small containers by hand and into large containers by machine. Sliced, diced, and pieced styles are cut and packed by machine. If the product was cored by crushing, it is packed by machine, since only diced and cut styles can be produced from the crushed fruit. The final pH of the pimentos is the dictating factor as to final processing steps. They may either be held at pasteurizing temperatures or may have to be retorted to insure commercial sterility. During packing the containers are usually drained of excess liquid in order to insure a tight pack of the can or jar. The containers are cooled in canals or by cold water sprays.

A comparison was made by Bough (Ref. 1) of roasting versus lye peeling for generation of wastes and quality of canned products. The two main advantages of lye as compared to flame peeling were reported to be the reduction of trim labor and consumption costs. One plant in the study reported a savings of forty to fifty thousand cubic ft of natural gas per year by using lye peeling in place of flame roasting. Bough (Ref. 1) reports that the effluent from the roasting process contains 69 percent of the total suspended solids load, 37 percent of the COD load, and 30 percent of the BOD load in 18 percent of the total wastewater flow. The study on the pressurized lye application system showed that 73 percent of the total suspened solids, 61 percent of the COD, and 39 percent of the BOD load resulted from the peel removal operation. The reel washer employed for core removal is also a contributing source of pollutants. Bough (Ref. 1) reported that this wash was found to contain a high concentration of dissolved solids (1,472 mg/l) due to the large amount of soluble materials washed from the cores of the pimento pods. Cooling water, if sufficiently free of contaminants, can be recycled to the initial washing operation. Some of the final

FIGURE 36

TYPICAL SAUERKRAUT PROCESS FLOW DIAGRAM



wash water may also be recirculated to the initial washings if relatively free of contaminants.

Sauerkraut

Approximately two-thirds of the total U.S. production of sauerkraut is processed in New York and Wisconsin, with the remainder scattered over several states. For the purposes of this study, three plants in New York, two in Oregon, one in Wisconsin, one in Michigan, one in Indiana, one in Idaho, and one in Texas were visited for the collection of historical data. In addition, a total of four composite samples were collected and analyzed to verify this data. Cabbage for sauerkraut is most often harvested by machine. The heads are cut from the standing stump and lifted into trailers by a series of conveyors and elevators. Processors prefer a clean-cut, undamaged head free from excess leaves. Usually two wrapper leaves are retained for shipment to processing plants.

Figure 36 shows a flow diagram for a typical sauerkraut processing plant. Some plants are cutting and fermentation operations alone. In this case, the sauerkraut and spent brine are later shipped to canning facilities. The heads of cabbage are dumped onto a conveyor belt which carries them past the trimming station where portions of stems and heavy green outer leaves are removed by hand; cutting of blemished or discolored portions is also done by hand. Heads of cabbage are cored before shredding. The heads are placed under a rapidly moving auger with small horizontal blades. The blades cut the core into very fine pieces which are not objectionable in the finished product. Approximately 25 percent of the initial weight of cabbage is lost as solid waste in the trimming and coring operations. The range loss of weight between over-the-scales tonnage and packed quantities is 25 to 40 percent. The heads of cabbage are cut into shreds by curved knives set into a rapidly revolving disc about three ft in diameter. The blades are usually set to cut shreds 1/32 to 1/4 in. in thickness. Chopped sauerkraut is prepared by means of a mill which cuts the cabbage into pieces of varying degress of fineness.

Sauerkraut tanks are normally constructed of cypress wood, fiber glass, other materials, or a combination of materials. The tanks are usually placed in groups of ten or more, depending on the size of the plant and number of shredding and packing lines in operation during the season. The tanks are usually sized to hold from 20 to 100 tons of chopped or shredded cabbage. Each tank is provided with an opening in the bottom to drain off the juice when necessary. A small opening may be provided in the side of the tank for sampling juice to determine the progress of fermentation. The shredded cabbage from the cutter is conveyed by belt into a buggy for transport to fermentation vats at a few traditional plants. It is more commonly moved, however, by conveyor or positive air systems. Two to three lbs of salt per 100 lbs of cabbage is applied evenly as the shreds are distributed in the vat. Juice is released from the cabbage almost immediately after addition of the salt. To assure a maximum fill of cabbage into a vat, much of this "early brine" may be withdrawn from the vat and discarded during or shortly after the filling. This early brine is a major source of liquid waste in the cutting and fermentation processes. When the tank is full, heavy planks or wood sections cut to fit the inside of the tank may be placed on the cabbage and weighted down or may be held in place by a screw press. Another method is to seal the tank with a plastic lid covered with about two feet of water. This prevents air from getting to the sauerkraut.

A number of different kinds of bacteria, yeasts, and mold spores are present in or on the cabbage as it comes from the field, ready to develop when conditions are favorable. The addition of salt to the shredded or chopped cabbage inhibits the growth of many of the undesirable organisms. The juice drawn from the shredded cabbage by the salt helps to create a condition favoring the growth of lactic acid bacteria. Fermentation is considered complete when the tritratable acidity, expressed as lactic acid, has reached 1.5 percent and the shreds are fully cured. The time required for fermentation varies with the temperature and can be as short as 20 days but normally ranges from four to eight weeks. Sauerkraut which has been cured rapidly and then canned promptly will usually be lighter in color than when it is slowly fermented and packed after holding in tanks for long periods. Sauerkraut darker in color or produced from longer fermentation periods is higher in quality.

The acidity of the sauerkraut should be determined by means of laboratory tests to assure a properly cured product before the tank is opened. When the fermentation process has been completed, the sauerkraut is removed from the vats and packaged. Many times several vats are ready for packing at approximately the same time; therefore, some must be held until the packing operations can handle the sauerkraut. The sauerkraut may be held in the vats for up to two years without spoilage. The tank should not be disturbed until the sauerkraut is to be removed. Once opened, the tank is usually emptied without delay. The excess juice is drained off by means of a tap in the bottom of the tank. In most cases this juice is retained for use as fill brine in canning or for sale as sauerkraut juice. This "late brine" is extremely high in BOD, COD, and suspended solids. When discarded, it represents an important source of liquid waste.

The sauerkraut is usually mechanically filled into cans after heating to about 180° to 185°F. This eliminates the need for exhausting the cans. If sauerkraut is handfilled, then the cans need to be exhausted with steam. After filling, the cans are passed under a flow of hot brine containing two to three percent salt. This may be the late brine obtained from the fermentation vats or new brine. Care is usually taken not to overfill the cans; however, some spillage is unavoidable. After brining, the cans are seamed, retorted, rinsed, and cooled before packing and shipment.

Sauerkraut processing involves two distinct operations: first, cutting and fermentation; and second, the canning operation. The first occurs immediately after harvesting and lasts for a few months. The canning operation can last all year round but is sometimes subdued during cutting season. Because of the unpredictable time lag and overlap of these two operations, estimating total wasteloads per total quantity of cabbage or sauerkraut would be more accurate if analyzed separately; i.e., relating raw commodity to the wasteload generated by cutting and fermentation and relating quantity of final product to the canning operation.

The highest wastewater loading in terms of organic discharges results from the fermentation process of the vats. Early brine is high in wasteload concentrations; BOD may easily be as high as 20,000 mg/l. The volume released varies depending on the individual plant and the market demand for sauerkraut. Later brine is the highest in wasteload concentrations; BOD may be as high as 40,000 mg/l or more. The volume discharged as waste is also variable depending on the individual plant operations and the market demand for sauerkraut juice.

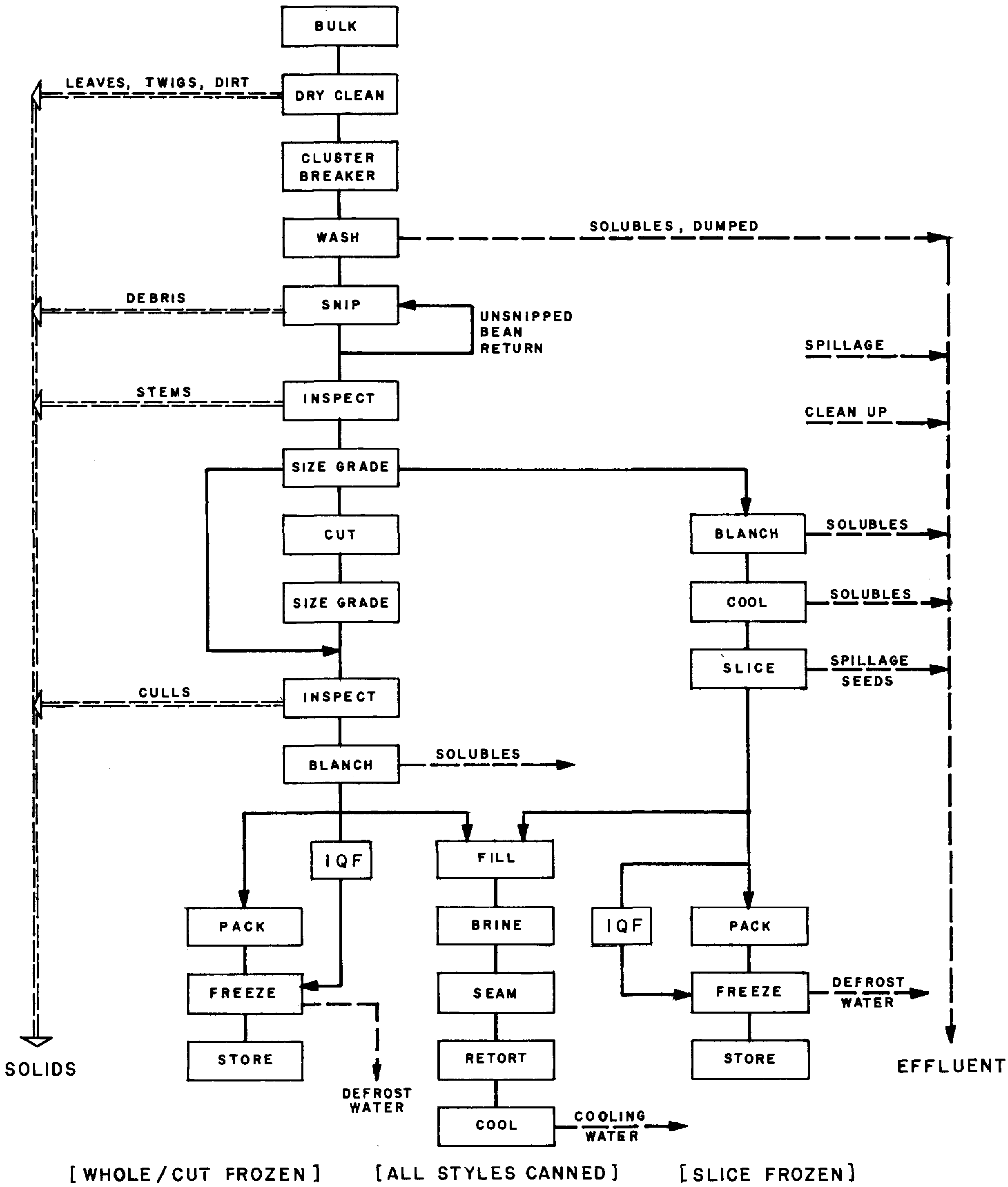
After the vats are emptied they must be prepared to be filled again next season. Wooden vats must be kept filled with soak water to prevent shrinkage and collapse until ready for use. Soak water is discharged and is low in wasteload concentrations but high in volume, the largest discharge. Fiber glass lined vats and vats of other materials, such as concrete, are becoming more popular because soak water is not needed for conditioning, yielding less water usage and less wasteload. Before being filled with cabbage, all vats are washed with water. The wastewater is of greater strength than soak water, but the volume is low. Vat wash water, therefore, is not a significant waste source. Cutting and transporting cabbage are dry operations, and clean-up is generally accomplished with brooms and shovels. Cutting and coring equipment are washed at regular intervals.

Snap Beans

Snap beans include green, Italian (or Romano), and wax beans. This category also includes "string" beans, although snap beans no longer have the "string." Approximately 58 percent of the total U.S. production is processed in Oregon, Wisconsin, and New York, with the remainder scattered throughout a number of states in small percentages. For the purposes of this study, eleven plants in Oregon, two in Washington, ten in Wisconsin, one in Idaho, and one in Michigan were visited for the collection of historical data. In addition, a toal of six composite samples were collected and analyzed to verify this data. Approximately 77 percent of all processed snap beans are canned, and the ramining 23 percent are frozen.

FIGURE 37

TYPICAL SNAP BEAN PROCESS FLOW DIAGRAM



Snap beans consist of two varieties: bush beans which are grown close to the ground for ease of mechanical harvesting, and pole beans which grow to a height of four to five feet and are harvested by hand. The mechanical harvesting of bush beans is done by a mobile viner, which pulls the vine, strips the beans from the vine, and returns the vine to the ground. Pole beans, which are harvested by hand, demand a higher price, due to the superior quality of raw product. Bush beans are bulk-loaded into trucks for transport to the plant, whereas pole beans are generally loaded in tote boxes of approximately 1,000-2,000 lbs and transported to the plant. Bush beans mature uniformly and are harvested all at once. Pole beans continuously produce mature beans over several weeks, so they are picked several times per season.

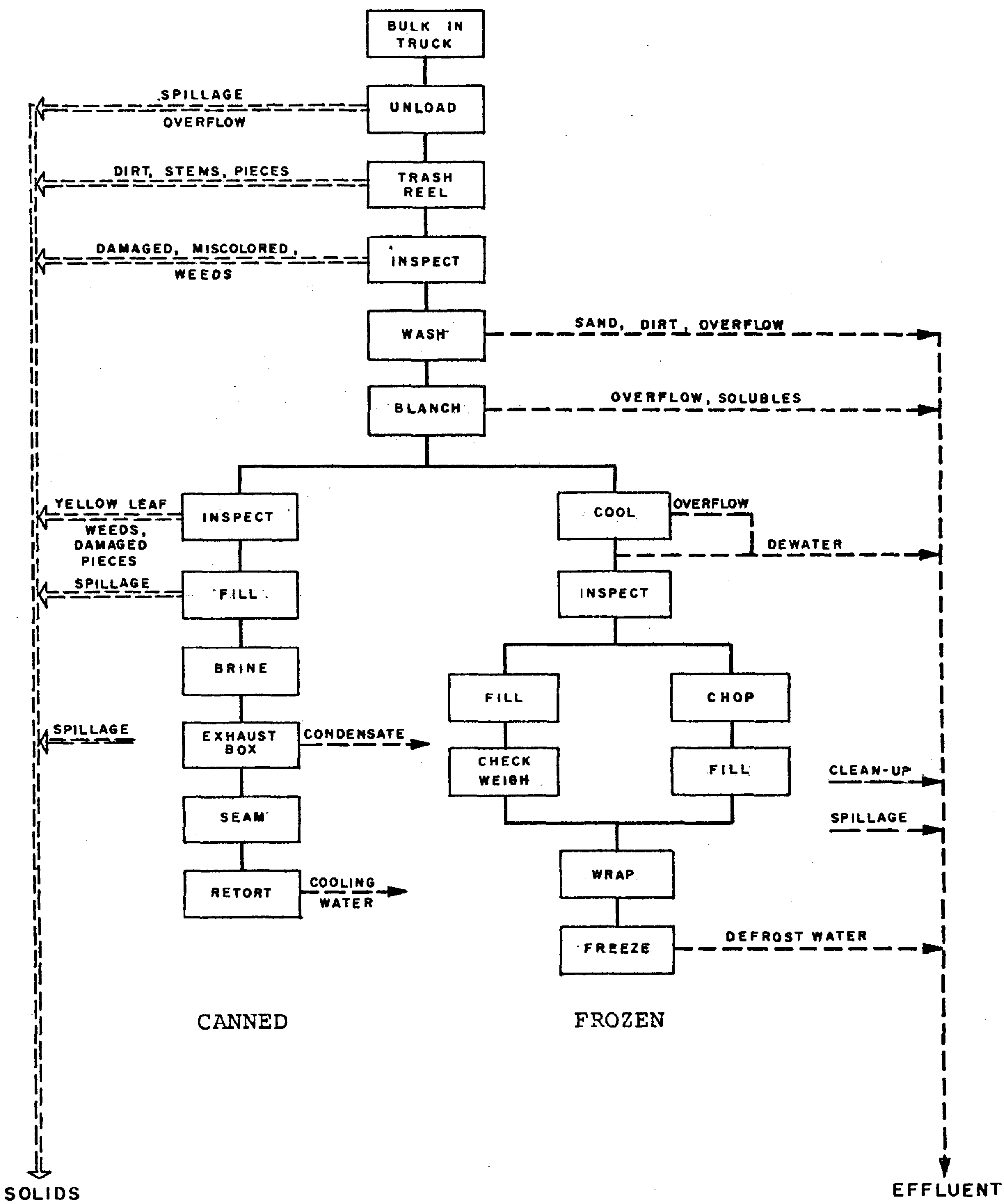
Figure 37 shows a flow diagram for a typical snap bean processing plant. The beans are normally sent through a series of vibrating shaker screens to separate pieces of vine, stones, and dirt clods. They are then winnowed in an air blast to remove leaves and other light trash. The beans are next sent through a cluster breaker, which mechanically breaks apart clusters of beans. The beans can then either be sent to another air blast or directly to the washers. The beans are usually washed on a belt type washer but may also be washed by either tank or immersion type methods. Wastes from the cleaning and washing operations include silt, pods, rocks, and bean pieces.

Sorting and grading operations are used extensively in snap bean processing. The beans are most often graded by size at several points in the process line. The first size grading segregates the beans by diameter and length using rotating reels with various sized openings. At other points, rotating reel "sieve graders" are used, and in some cases, a series of vibrating plates with perforations of specific sizes are used. These latter two are used to size grade the beans after cutting. Sorting is done by hand on inspection belts. The beans are fed into a mechanical snipper which removes the ends of the beans. The beans then progress to an unsnippedbean remover where unsnipped beans are recirculated back through the snippers. Snipped beans advance to inspection lines. The snipped ends from the beans and other debris are usually removed from the beans at the re-snipper; however, screens can also be utilized for this step in the processing.

Beans for whole pack processing (the smallest beans) are usually blanched in a water blancher and, in some plants, cooled in water. For canning, the beans are filled into the cans, topped with brine, seamed, retorted, and cooled. Some plants use steam exhaust boxes before seaming. For freezing, the whole beans are usually packed into containers and frozen by plate freezers. The mid-sized beans are prepared as cuts, either straight or angled. The whole beans are run through mechanical cutters, and are then size graded and inspected. Following a water blanch, the beans to be canned are filled into cans, which are then seamed, cooked,

FIGURE 38

TYPICAL SPINACH PROCESS FLOW DIAGRAM



and cooled. Beans to be frozen are cooled after blanching, then frozen in air blast, fluidized bed, or Freon freezers. Sliced beans are processed in the same manner as whole beans except that the beans are sliced lengthwise after blanching and cooling.

The largest wastewater volumes generated in a typical snap bean operation are those attributable to washing and cooling. Although the cooling water is generally very low in BOD and suspended solids, the wash waters and effluents from slicing operations can contribute significantly to pollutant levels. Overflow from hot water blanchers and condensate drippings from steam blanchers usually contain the strongest waste loadings. The various fluming, cooling, and pump recirculation stations throughout a typical plant also contribute in both volume and pollutant levels because of their continous product contact and overflows.

The use of dry cleaning methods has been observed to reduce effluent volumes. Fluming and recirculation pumps also have been successfully utilized to conserve process water. Cooling water, properly maintained, can be reused either for more cycles of cooling or can be reused for initial washing and cleaning operations.

Spinach

Spinach and leafy greens (included are turnip, mustard, and collard greens and kale) are important canned and frozen vegetables. Approximately 57 percent of the U.S. spinach production and a small proportion of the U.S. leafy green production are processed in California. The remainder of these crops are processed in the south, primarily in Arkansas, Oklahoma, Georgia, and Florida. For the purposes of this study, thirteen plants in California, two in Wisconsin, two in Virginia, two in Oklahoma, one in Alabama, one in Flordia, two in Georgia, and two in Arkansas were visited for the collection of historical data. In addition, a total of five composite samples were collected and analyzed to verify this data. Approximately 53 percent of the spinach for processing is frozen, and 47 percent is canned. With greens, the inverse proportion is more accurate: approximately 56 percent canned and 44 percent frozen.

Figure 38 shows a typical process flow diagram for spinach and leafy greens. Leafy green crops grow comparatively quickly and are generally grown twice a year: the first vegetable crop in early spring as well as a fall crop in September or October. These are usually harvested by a mowing machine which loads the greens directly into trucks for transport to the processing plant. An alternative method involves cutting the greens with a cutter bar machine and then elevating them into small trucks which in turn unload the greens onto a conveyor belt which loads a semi-trailer. In Flordia and Georgia, it is a common practice to place crushed ice among the greens to keep them cool and fresh during transport. More than one harvest can often be made in the same field. The crops are transported directly from the field in bulk trucks or bins. They are usually then taken directly from the fields to the processor. They can, however, be shipped in bins and iced for longer storage prior to processing.

The raw product is slowly proportioned by hand - the use of rakes or pitchforks facilitates the unloading - onto a conveyor belt which feeds a dry-reel roller. The tumbling action of the reel fluffs the spinach, which in turn loosens adhering sand and dirt. The loose soil and other debris are eliminated through the outer openings and collected as dry waste. In Florida and Georgia, where crushed ice is layered between the transported greens, the dry reel generates a waste effluent containing soil and debris. This effluent is commonly screened to remove solids, and the liquid effluent is discharged to the process effluent. An inspection usually follows dry cleaning at which time debris, weeds, off-color (yellow), and insect damaged pieces are removed by hand. The wet cleaning operations vary considerably from one plant to another. Washings can be accomplished by paddle washers, dip or dunk tank-type washers, or sprays. Typically, the plants employ a combination of these into two or three stage washing operations. Another option used to affect washing effectiveness has been the use of either cold, warm, or hot water in any of the various wet-cleaning stages. Fresh water is continually added to the washers by overhead nozzles to replace water discharged from the washer. The waste effluent from the washers may either be dumped intermittently or discharged continuously either from the bottom of the washer, or from natural overflow. Dewatering chains or conveyors are frequently used for transport between the above mentioned washes and also as a transport to the blancher. Each plant employs its own process conditions for blanching which are greatly influenced by product loading, speed of related equipment, use of heated wash water, and type of blanchers (hot water or steam).

After blanching, the spinach is conveyed either by water flume, belt, or chain conveyor to a final inspection table. Fluming, an aid to cooling, is predominant in the freezers. Trapped water, however, between the layers of the leafy greens can create some problems for freezing, so that in several observed cases, rubber inner-tube type "wringers" were used to effectively dewater the product before inspection and packaging. The final inspection mentioned above is typically done in combination with canning. Defective pieces are discarded while the remainder of acceptable grade material is generally hand-packed into the desired container size and individually check weighed. This is a critical step in as much as the retorting that follows is greatly dependent upon the "drained weight" contents of the container. Alternately, for another variety of pack, the greens may be passed through a cutter to reduce piece size and be filled on a more automated canning line. These still undergo a check weighing process. Once filled, the cans are topped with brine solution, passed through an exhaust box (to expel headspace gases), seamed (under steam flow if an exhaust box is not used), washed, retorted, cooled, and conveyed to warehouse storage. Preparations for freezing and canning are essentially identical up to and including the final inspection. The product, however, may be packed as either whole leaf or chopped. Whole leaf is basically a hand-pack operation in which the leaves are manually placed into pre-waxed boxes and weighed prior to box closing and wrapping. The chopped product, however, is the result of diverting some of the main stream of product through a high speed "chopper" and subsequently pumping the flowable mass to a piston or displacement type filler. The boxes are then automatically filled, check weighed, closed, wrapped, and frozen.

Excluding can cooling and defrost water, the largest volumes of water generated in a typical leafy green processing operation are from the various washing and dewatering stages. It was reported that 73 percent of a plant's wastewater (exclusive of cooling or defrost water) is generated during washings, and these washings were responsible for 37 and 50 percent of the BOD and COD respectively. The most concentrated wastes occur at the blanchers either in terms of spillage (hot water blanch) or condensate (steam blanch). Other sources of waste volumes generated are from water flumes, exhaust box condensate, can washers, and brine spillage. Clean-up operations vary from plant to plant and are generally similar with the exception of spinach processors. Because raw spinach has a high natural concentration of oxalic acid, resultant washings and blanching steps leave hard mineral deposits of calcium oxalate. Subsequent acid cleanings or manual buffing to remove these deposits can result in higher than normal COD or SS levels. Reference to wet sampling of plant SP05 (Figure 48) shows that the last two SS results (April 15 and April 20) were much higher than normal due to manual oxalate removal during clean-up hours.

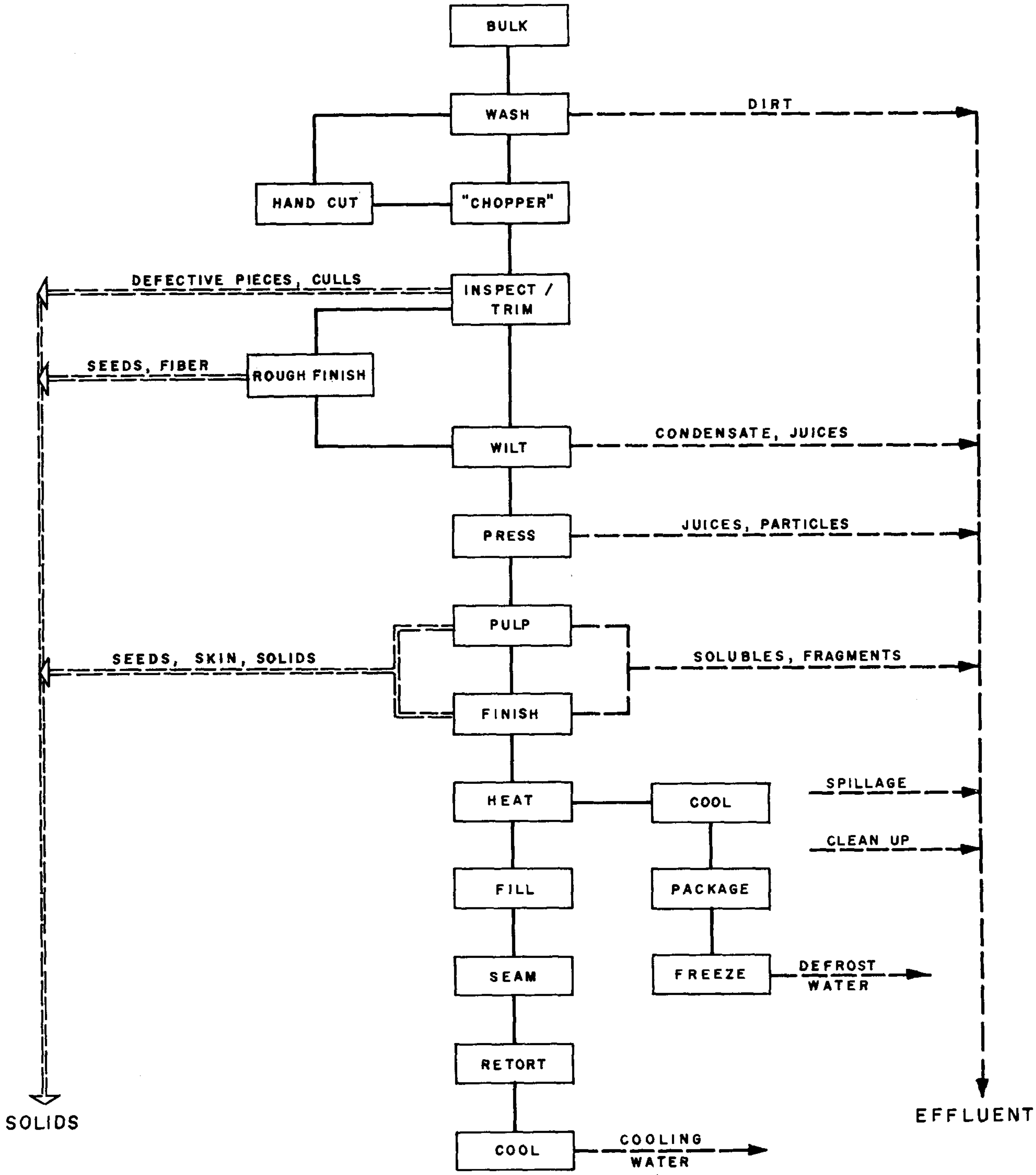
The various stages of washing lend themselves to recirculation by countercurrent flow. Many plants were observed to collect water from dewatering belts and to recirculate it back to the first washing stages. Flume water throughout various stages of plant operations was also observed to provide make-up for initial washes. Cooling tower water from canning operations was observed at some canneries to be either recycled for further can cooling operations or pumped back to first washing stages as make-up water. One plant utilized a portion of their screened waste effluent to provide constant flume-flow for all in-plant drain canals.

Squash

Squash and pumpkin combined are the thirteenth ranked canned vegetable commodity. The two commodites, which from the botanist's viewpoint are separate, are virtually indistinquishable to the food processor. The term pumpkin is generally applied to the late maturing or fall vining varieties, and the term squash generally applies to the bush and summer varieties. Both pumpkin and squash are members of the same genus; however,

FIGURE 39

TYPICAL PUMPKIN/SQUASH PROCESS FLOW DIAGRAM



they do not include "summer squash" or zucchini. In most plants the processing is identical; frozen varieties are usually labeled squash and canned varieties pumpkin, although the content need not differ to any great extent. In the ensuing discussion where the word pumpkin is used, it applies to both pumpkin and squash. For the purpose of this study, three plants in Illinois, three in Oregon, and one in California were visited for the collection of historical data.

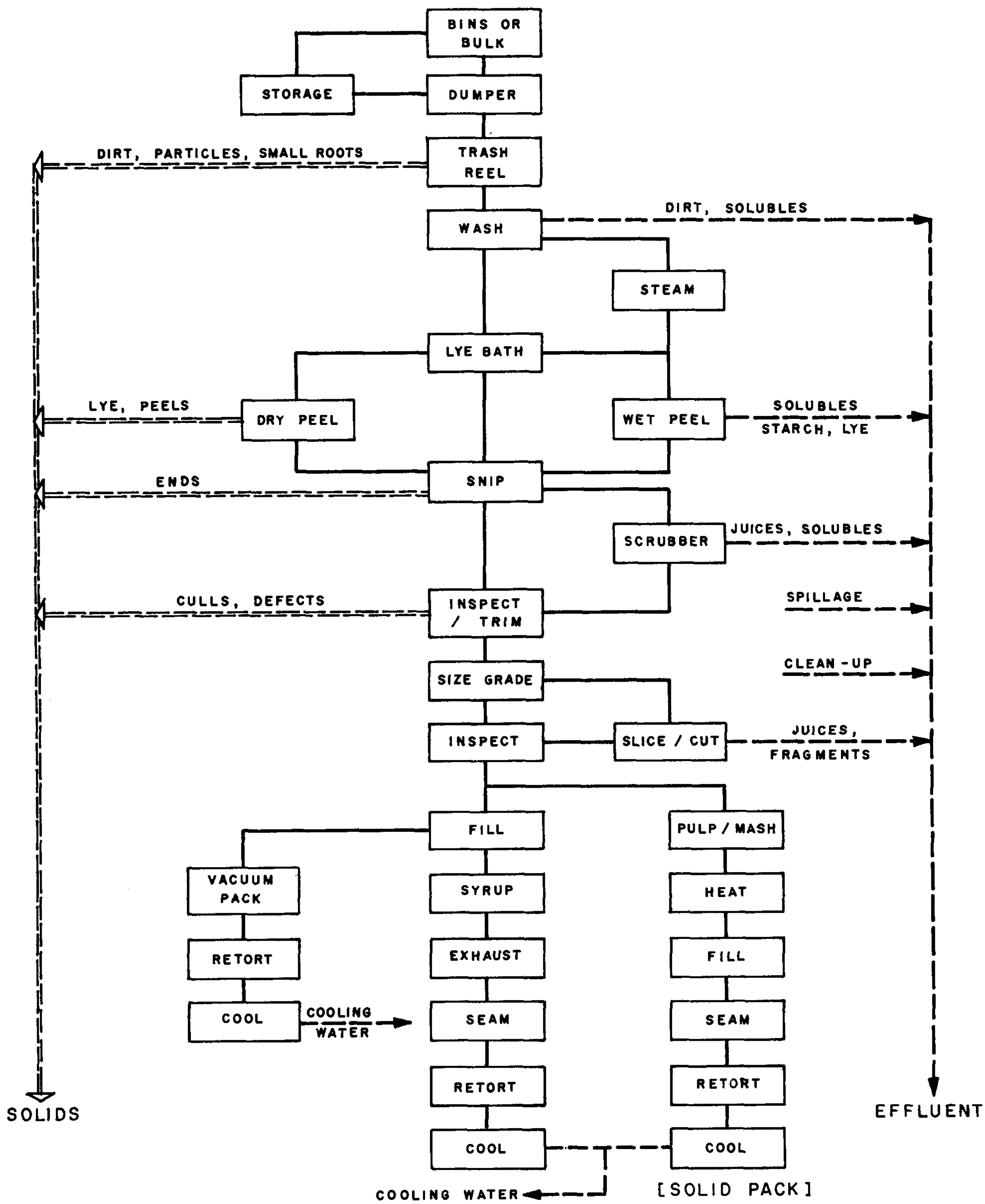
Pumpkin and squash are not harvested for processing until late fall when the fruit is fully mature. Harvesting is usually done after the leaves begin to turn yellow. This crop can be handled when ripe without undue damage because of the toughness of the outer rind. It is generally harvested by a machine which chops the fruit off at the stem, leaving vine and leaf materials behind and depositing the fruit directly into bins for transport to the plant.

Figure 39 shows a flow diagram from a typical pumpkin and squash processing plant. Separate lines are shown for the canning and freezing processes. Pumpkin and squash are usually delivered as harvested to the processor. They can be stored for several weeks in a wellventilated area if precautions are taken against freezing. When ready for processing, they are brought to the product lines by drag conveyor or front-end loader where they undergo a preliminary rough wash to remove adhering dirt, vines, and other extraneous material. They typically then go to a second washer which removes remaining dirt. The washers consist of rotary drums or soak tanks or a combination of both. The com- removed by strong water sprays. From the washers the pumpkins pass to an inspection belt where stems, blossom ends, and blemishes are removed. The pumpkin is then mechanically sliced or hand trimmed, and cut into smaller pieces which are further reduced in size by running them through a chopper or "rough finisher." An inspection for rot and other defects follows.

The pumpkins are wilted (partially cooked) in live steam (atmoshperic or pressurized steamers) until they are soft enough for further processing. The wilted pumpkins are soggy with liquid which is a mixture of condensed steam and pumpkin juice. The product is treated by passing it through an adjusted press, most commonly two belts, the upper one of which applies pressure on the lower. In some plants the pressing and wilting are done simultaneously by the use of augers fitted inside cone-shaped, perforated screens. Pumpkin from the press is conveyed to a pulper which both reduces particle size and eliminates hard pieces of pulp, shell, seeds, and some of the inner fibers. Further size reduction through a "finisher" results in pumpkin puree of finished product consistency and in the final elimination of seed, fiber, and hard particles. The temperature of the prepared pumpkin at the time of processing is a very important factor in the efficiency of the process. Heat penetration of the product is very slow because of its physical character, and the temperature at the beginning of the process is

FIGURE 40

TYPICAL SWEET POTATO PROCESS FLOW DIAGRAM



correspondingly important. Use of a heat exchanger to raise the temperature to 180-190°F results in a uniform fill. The product is then filled hot into cans and seamed, and the cans are washed, retorted (still or continuous type), and cooled. That product to be frozen is treated in almost the same manner as that to be canned except that after heating, the pulp is cooled and filled into individual packages which are check weighed, wrapped, and frozen.

The principal sources of wastewater loadings typically come from the washing, chopping, finishing, wilting, and pressing operations. The main pollutant from washing is normally soil and adhering dirt (settleable solids), whereas the wilting, pressing, and finishing operations generate considerable amounts of juices, seeds, and fine suspended organic particles. Condensate from wilting, a low volume, highly concentrated stream, can also be a significant contributor to the waste stream. Cleanup operations may also affect a pumpkin/ squash processor's effluent depending on the amount of spillage and accumulated juices and solubles. Wasteload reductions may be accomplished by separating chopper and finisher waste from the effluent stream. These can be removed manually or by dry conveyor belt and discarded as solid waste. The major water volume generations throughout the process are washing and can cooling. Can cooling water may be recirculated through a cooling tower (with proper chlorination controls) and be reused either for additional cycles of cooling or as makeup for initial washing operations.

Sweet Potatoes

The principal areas in which sweet potatoes are commercially canned are Maryland, Virginia, Louisiana, Mississippi, Texas, and Alabama, although small quantities are packed in Kansas, Georgia, North Carolina, Illinois, and California. Sweet potatoes are sold principally candied whole and/or cut and are packed in three main styles: solid pack, syrup pack, and vacuum pack. The amount of sweet potatoes processed represents about 40 percent of the total crop grown, the remaining 60 percent being sold on the fresh market. Canning sweet potatoes is a seasonal operation restricted mainly to the fall months--from September through December. After December, canning may be somewhat extended by using stored lots. For the purposes of this study, one plant in California, one in North Carolina, and two in Maryland were field visited for the collection of historical data. In addition, a total of three composite samples were collected and analyzed to verify this data.

Sweet potatoes are generally harvested in the fall of the year, though in some areas potatoes may be harvested as early as July or as late as December. The potatoes are harvested by both hand and machine and are usually delivered to the cannery for processing in field boxes or bulk trucks. The difference between fresh and aged sweet potatoes becomes significant in processing. Fresh sweet potatoes are preferred for canning for the following reasons: the skin of the fresh potato is thinner and more easily removed than that of the aged sweet potato and thus, the sweet potato is canned only as a late season fill-in operation or as a way of meeting a high sales demand for the product; the fresh potato has a higher starch content than the aged potato as aging results in part of the starch being converted into sugar; and after canning, aged sweet potatoes tend to break down in the can and become softer than do canned fresh potatoes.

Figure 40 shows a flow diagram for a typical sweet potato processing plant. Sweet potatoes are either washed prior to delivery to the cannery or are washed at the plant. Some plants dry clean the potatoes after receipt, and stones, some dirt, and some of the small potatoes are removed. After dry cleaning, the potatoes are washed in a reel washer consisting of a rotating drum and cold water sprays. Approximately five percent of the gross weight of the potato trucked in from the field is dirt that is removed during the receiving and cleaning operations. The most frequently used types of sweet potato peelers are hot lye and steam peelers. Either method may be used to soften the peel, after which the peel is generally removed by some type of abrasion. Steam peeling offers some potential advantages over lye peeling in terms of increased yields but may affect the resulting quality of the product. There are also associated additional maintenance and equipment costs. Lye peeling may basically be divided into two systems: wet peel removal and dry peel removal.

Wet Lye Peeling--The wet caustic peeling process involves several steps. After the potatoes have been cleaned, they are preheated in a hot water bath at 120° to 150°F for two to five minutes. The preheating enhances peel removal. After preheating, the potatoes are immersed in a lye bath of five to twelve percent caustic at 200° to 210°F for two to eight minutes. The strength of the lye bath, skin thickness, and the condition of the potatoes determine the length of exposure to the bath. The caustic softens the skin and outer layers of the potato and facilitates easy peel removal. Following the lye bath, the potatoes are conveyed to a rotating drum peeler, the inner sides of which are coated with a sand-like abrasive. As the drum revolves, the peel is rubbed off along with some potato solids. A continuous water spray removes the abraded peel from the sides of the drum. As much as 40 percent of the potato may be removed during this process and is lost as liquid waste.

Dry Caustic Peeling--The dry caustic peeling process is quite similar to the wet caustic process, the only difference being the peel removal. The dry peeler equipment employs rubber studs on planetary rollers in a rotating drum. In concept, the rubber studs are flexible and facilitate a more efficient removal of the potato eyes and the skin surrounding irregularities. Abrasion, by contrast, is not flexible and must remove more of the potato to achieve acceptable peel removal. Rubber studs may be provided in different lengths, sizes, and stiffness, allowing for interchange and combinations that provide the most efficient peeling operation. The rapid rotation of the planetary rollers discharges the peel waste to the interior wall of a containing drum where it can be scraped off. Only a small quantity of water is needed to lubricate the planetary rollers. The waste can be disposed of as a semi-solid. In terms of waste loading, the dry caustic peeling process offers an excellent opportunity for processors to significantly reduce both their BOD and suspended solids levels when compared with either wet peel removal and steam/abrasion peeling.

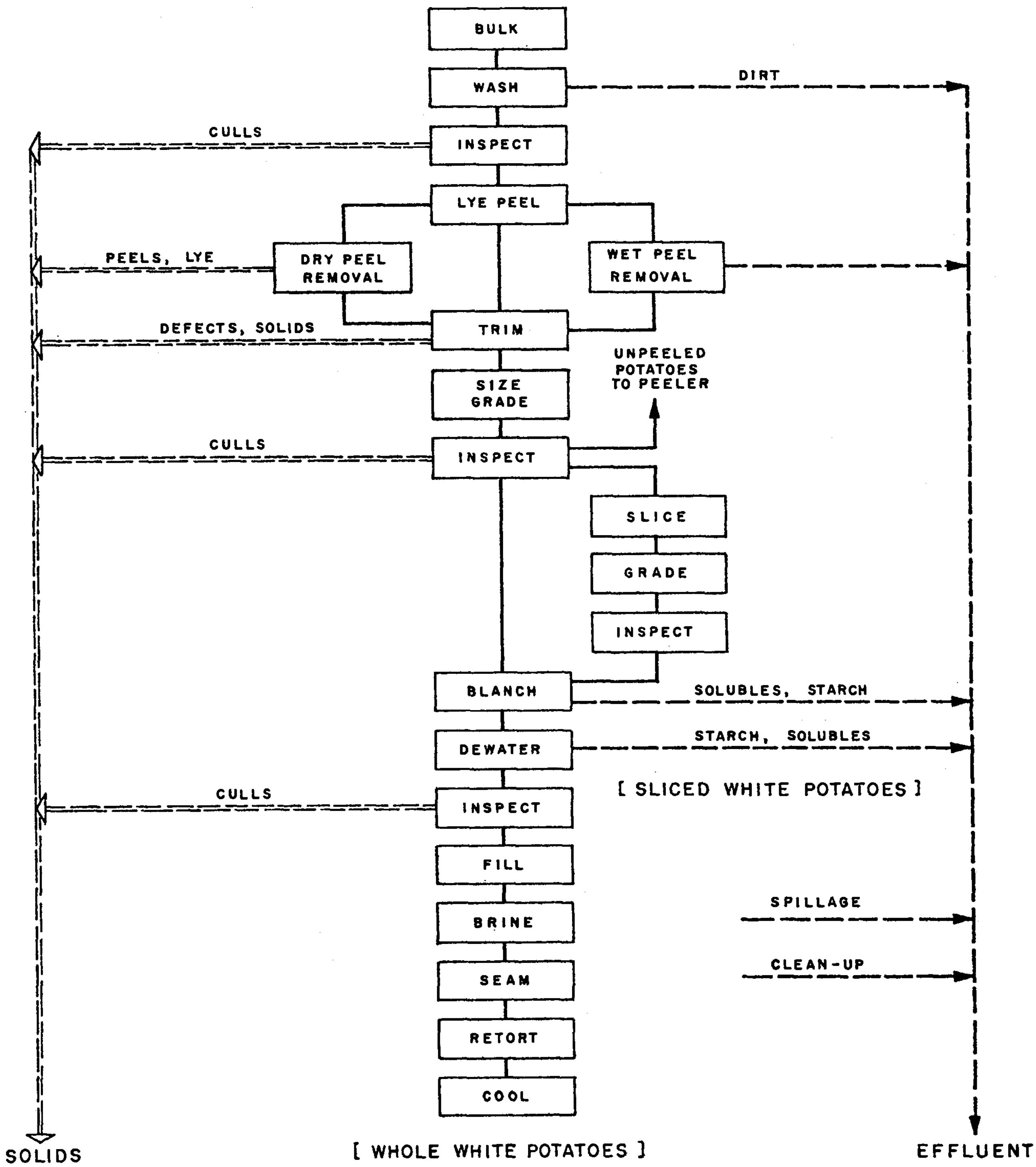
Steam peeling requires exposure of potatoes to high pressure steam for a short duration of time. The steam loosens or "blisters" the peel from the potato. Abrasive peelers or high pressure cold water sprays typically follow to remove the loosened peel. Alternately, the sweet potatoes may first be passed through a steam peeler (acting as a pre-heater) and then sent to a lye bath for further peel penetration. The operation of snipping the ends of the sweet potato may be placed either before or after the peeling operation. The snipper is a device that mechanically cuts off the ends of the potatoes. These ends then go into the clean-up stream or can be removed directly as solid waste. The mechanical snipping operation requires further manual labor to finish trimming the sweet potato. From the snipper, the potatoes travel along a sorting belt where manual labor is used to inspect, trim, and discard the parts not suitable for canning. A rotating drum with different size slots size grades the potatoes for canning. The larger potatoes move through a series of slicers to reduce size before canning. Quick handling of sweet potatoes after peeling, sorting, and trimming is important to avoid discoloration. Any contact with iron surfaces will cause considerable black discoloration if there is delay. The potato, after grading, moves onto a circular hand pack filler with a series of can-size openings around the perimeter. The potatoes are raked into cans passing below the openings. They may also be mechanically filled by a tumble type filler. Waste associated with this process is confined to spillage which can be discarded as a solid waste.

Sweet potatoes can be packed in three different styles: vacuum pack, syrup pack, and whole pack. The vacuum pack consists of filling the potato pieces into the can tightly and seaming the can under approximately 29 inches of vacuum. No top-off liquid is added. The syrup pack differs from the above in that the sweet potato pieces are topped with hot syrup, exhausted, and seamed. The third style, solid pack, usually consists of mashed or, pulped product which is heated and filled hot (about 190°F) into the cans. Seaming is done immediately after filling. In all three processes, the seamed cans are washed, retorted, and cooled.

The most significant wastewater stream generated in the sweet potato process results from the peeling operations. With wet peel removal equipment, peeling contributes the highest wasteload

FIGURE 41

TYPICAL CANNED WHITE POTATO PROCESS FLOW DIAGRAM



for both BOD and suspended solids; scrubbing and snipping contribute approximately one-third of the wasteload. Cooling uses the largest amount of water, but the wasteloadings are nil. Clean-up operations can also contribute significantly because of the heavy loadings of natural sugars and starches inherent in the sweet potato.

The use of dry peel removal can, of course, be used to full advantage for reduction of wasteloads. Properly managed, the peel removal operation can be kept almost completely separate from the main plant effluent stream with subsequent marked decrease in BOD and suspended solids loadings. Initial washing operations and volumes of water used can be extended by use of recirculating pumps. Can cooling water can also be used as initial make-up for first washings or can be recirculated through cooling towers to be reused again as can cooling water.

White Potatoes, Canned

White potatoes are processed in a variety of styles. This report, however, is limited to canned whole and sliced white potatoes. Two plants in Virginia, one in Pennsylvania, two in Delaware, one in New Jersey, one in Maine, and one in California were visited for the collection of historical data. In addition, a total of six composite samples were collected and analyzed to verify this data.

Figure 41 shows a typical canned white potatoes process flow diagram. Potatoes for processing are mechanically harvested and loaded into bulk containers to be shipped by truck or rail. Harvesting is a seasonal operation. However, since raw potatoes can be successfully stored for months, many processing plants operate ten to twelve months a year. An extended growing season is preferred to produce a tuber with higher specific gravity and low reducing sugar.

Potatoes are removed from bin storage to a large flume, sometimes in the floor of the bin, and conveyed by the water to a large-mesh metal conveyor situated over a sump. This initial wash removes some of the field soil and vine. This wastewater deposits in the sump where the overflow is discharged or reused. The potatoes are then mechanically conveyed to a drum washer equipped with high pressure sprays. As the potatoes tumble through the drum washer, the high pressure water removes practically all of the adhering field soil. This wash water may be reused in the initial fluming or washing operations or discharged directly. After washing, the potatoes are discharged to an inspection belt where culls and trash are manually removed as culls.

The most common type peeler is called a wet caustic peeler or lye peeler. Other types of peelers in use are steam and abrasion peelers. In a lye peeler operation, the potatoes are dumped in a caustic bath of fifteen to eighteen percent strength where they remain three to seven minutes, depending upon the condition of the raw material. A submerged screw pulls the potatoes through the bath. Lye is added periodically to maintain the caustic strength. The potatoes are conveyed out of the bath and into a wet or dry peeler. Wet peelers are more commonly used; they consist of brushes and water sprays in a revolving drum. The loosened potato skin is brushed off and washed as the potatoes tumble through. A thorough rinsing follows, to wash off excess peel and caustic and to prevent hardening and discoloration of the potato. The peels and potato waste are discharged to the wastewater stream.

Dry peelers are becoming more popular because of the decreased water usage, increased yield, and efficient waste disposal. The potatoes are conveyed from the caustic bath into a rotating scrubber consisting of rubber studs on planetary rollers in a rotating drum. The peels and potato waste is deposited on the outside of the drum where they are scraped off and disposed of as solid waste. A small amount of water is used for lubrication. An abrasive peeler follows the scrubber, where the potatoes are polished by abrasive rollers and brushers. The solids are again removed mostly as a solid waste. A water spray rinses the potato as it exits the peeler. Abrasive peelers contain discs or rolls which are coated with an abrasive material. These discs or rolls rotate and remove the peel and some potato tissue by physically tearing it from the whole potato. Strong water sprays continuously wash the abrasive material and the partially peeled potatoes. The potato is spun to ensure equal peeling on all sides. All waste is discharged to the wastewater stream. Steam peeling requires exposure of potatoes to high pressure for a short duration of time. The steaming vessel is followed by brushes and water sprays which remove the cooled peel and some of the potato tissue directly below the peel. Highpressure steaming of potatoes is an excellent procedure for producing a thoroughly peeled potato. Because of heat ring formation, this operation is not generally used for canned potatoes.

The peeled potatoes are discharged to a belt where unpeeled eyes and discolored areas are removed and discarded. Very small potatoes are removed in the size grader and are also discarded. The potatoes are sliced into one of several styles, and the sliced pieces are sent over a perforated shaker which removes the small pieces. Water is used to lubricate the blades and is sometimes used to remove excess starch. The slices are then passed through a size grader. Hot water blanching is used by some plants for both whole and sliced styles to improve the quality of the finished product. Nearly all the waste produced is in liquid form. Blanchers are dumped periodically, usually once per day during clean-up operations. The potatoes are immediately cooled by water sprays or flume, to halt the blanch. A dewatering screen follows, and the excess water is shaken off the potatoes by a rapid vibrating motion. Both whole and sliced styles are mechanically filled into cans, and heated brine is added to overflowing. Sometimes a salt tablet is dispensed along with fresh water in the place of brine. Minor spillage is unavoidable. The cans are then seamed, washed, retorted, and cooled.

As discussed, many steps along the process line use and discharge water. The washing and peeling operations generate significant volumes and high concentrations of wasteload. The caustic bath is seldom dumped, but the outside of the tank may be washed down during clean-up. Scrubbing, peeling, and rinsing the potato contribute high BOD and suspended solids from the lye, peels, pieces, and starch washed into the gutter. Fluming operations are located throughout the process line, and even though the water is recirculated, a continuous discharge results from spillage and overflow. Other major sources of liquid waste are blanching, cooling, and clean-up. Some cooling waters are recirculated through cooling towers to be used again for cooling or other operations such as washing or boilers. Cleanup operations usually occur after each shift; dumping of blanchers and washers may accompany the hosing down of equipment. As discussed above, some of the initial wash water may be recirculated as well as retort cooling water. Other wet operations, however, do not lend themselves to reuse because of the heavy starch contamination throughout.

Added Ingredients

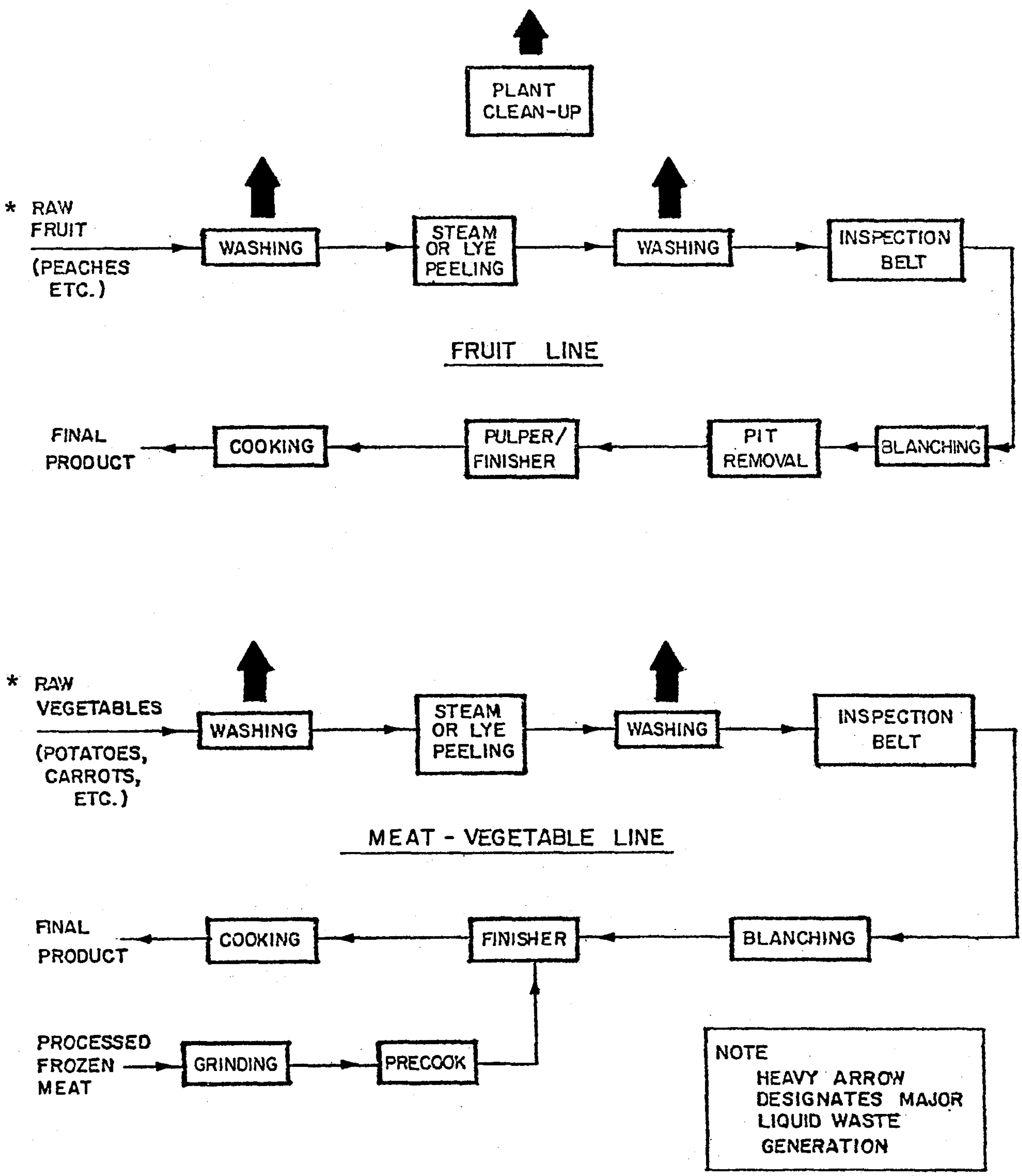
It is recognized that certain commodities described and subcategorized in this document utilize additional ingredients in the manufacture of finished products containing that commodity. For example, many frozen vegetables are now sold with butter, cheese, or cream sauce added. Other common ingredients are sugar, starch, and tomato sauce.

It was not possible to determine quantitatively the extent of usage of added ingredients as defined above. It was felt, however, that the handling of these added ingredients by the processing plant adds an incremental wasteload to the total plant waste production. The incremental wasteload primarily results from the clean-up of the equipment (vats, pipes, dispensers, etc.). Since these are expensive ingredients, it is assumed that a well-managed plant will keep spillage to a negligible minimum.

The added ingredients discussed are preprocessed and arrive at the plant in bulk form. Generally, the constituents of the sauce are combined in a predetermined formula, cooked in stainless steel tanks, and pumped to the filler. In the case of sauced frozen vegetables, the filling operation is performed in two stages: a weighted measure of the vegetable is filled into the bag, and prior to its closure the sauce is injected. The bags are then sealed, frozen, and stored. Prior to filling, the vegetables are processed identically to those non-sauced varieties, and a detailed description of each commodity can be found in the individual commodity process descriptions.

FIGURE 42

SIMPLIFIED BABY FOOD PLANT PROCESS FLOW DIAGRAM (2 LINES)



* REFER TO INDIVIDUAL COMMODITY PROCESS DESCRIPTIONS FOR DETAIL OF WASTE STREAMS FROM UNIT OPERATIONS

The processing of dry bean specialties is identical to that of a typical dry bean processor except that additional ingredients are added to produce the canned specialty; for instance, beef, tomato sauce, and spices are added to make chili con carne. Filling of the containers may be a one, two, or multi-step operation. In some instances, the containers are mechnanically filled, while in other circumstances much hand labor is required. After filling (the product is usually filled hot), the cans are closed, washed, retorted, and cooled.

The characteristics and generation of the wastewater are identical to the waste streams for the individual commodities with the addition of the cooking tank and pumping line cleanup. The clean-up waste stream, because of the "richness" of the various sauces, is a contributor to BOD levels. These premixing operations are usually done in a separate part of the plant, but the necessary constant sanitation (equipment flushing and floor clean-up) produces a waste volume that is combined with the raw commodity processing effluent before final plant discharge.

Baby Foods

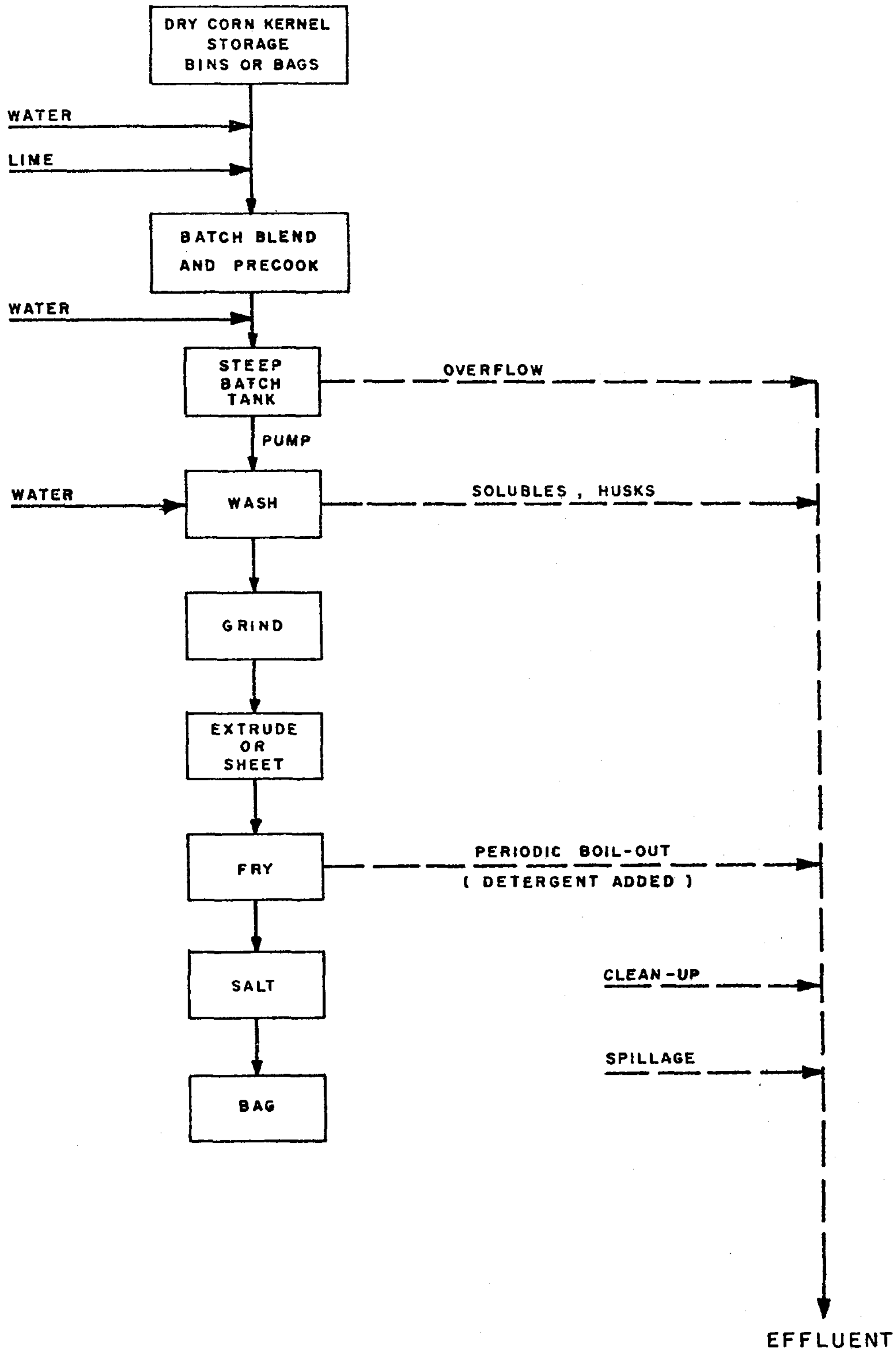
Baby foods are produced in California, Michigan, Arkansas, North Carolina, New York, and Pennsylvania. The plants are designed to take advantage of the natural harvest seasons in each area, while at the same time have the capability of year-round operation for non-seasonal items. The varieties and styles produced by the manufacturers virtually encompass each separate commodity covered individually in this study. Almost all production is marketed in glass jars with the exception of juices and cereals. For the purposes of this study, two plants in California were visitied for the collection of historical data. In addition, one wet sample was collected and analyzed to verify this data.

Figure 42 shows the various steps in a typical baby food plant. Baby food plants at one time in the year or another usually handle the following commodities fresh from the field: apples, apricots, green beans, beets, carrots, peaches, pears, peas, spinach, squash, sweet potatoes, and white potatoes. In addition, they may process fresh frozen plums and dried prunes. Other ingredients, such as corn, tomatoes, celery, and pineapple may be completely or partially preprocessed (canned or frozen) by another manufacturer.

The processes for washing, grading, inspecting, pitting, coring, blanching, and peeling are basically the same for any specific commodity and will not be dealt with in this section (see separate descriptions for detailed processing steps). There are several variations, however, which separate baby food processors from the typical raw product processor. A principal difference is blanching. Typically, because the resulting finished product is a puree or very small piece size, almost all raw materials are blanched (cooked). This may be a thermal screw or some similar device, the purpose of which is to pre-cook and soften the

FIGURE 43

TYPICAL CORN CHIP PROCESS FLOW DIAGRAM



product so that it may be more easily reduced by either disintegration or high-speed mills or a combination of both. These blanching and pre-cooking conditions are usually much longer than a normal canner or freezer because of the degree of pre-cooking desired.

Batching operations may be accomplished in several ways depending on the product and style desired. These usually include various starches, meats, condiments, and raw materials all brought together as per the various formulae. In some cases, this involves meat grinding, slurrying, and pre-cooking of starches, adjustment of brix concentrations, and various other mixing operations where products from the raw material processing area and other pre-processed ingredients are blended and pre-cooked prior to filling. For example, a product such as "Chicken Dinner" may contain freshly prepared carrots and potatoes, frozen deboned chicken, one or more starches which must be pre-cooked to obtain desired viscosity, processed tomato paste, and perhaps five or more minor ingredients for the desired flavor and product characteristic. These ingredients would then all be combined in a batch tank, pre-cooked, and pumped to the filler.

After batching and pre-cooking, the products may undergo several additional processes before filling. For example, fruit items may be pumped through heat exchangers where the product is exposed to high heat (230-250°F) and short-time (approximately 30-45 seconds) sterilization, pumped through a deaerator, and finally pumped to the filler at about 200°F. The product is then hot-filled into a glass jar; the jar is capped; and the unit is held for three to five minutes to achieve sterilization of container and closure. Cooling is achieved by cold water sprays. Formulated items containing meat and starch are usually pumped directly from the batch tanks to the filler. The jars are then exhausted and capped, retorted and cooled.

Wastewater generations throughout the raw material preparation are similar to those for any particular commodity being processed. Retort and cooling water, as is typical for a "canning" operation, is a major volume part of the final effluent, but it is normally low load water and does not affect the pollutant levels (except for dilution). The use of many raw materials, however, necessitates extensive clean-up operations. Volume of water used and subsequent BOD and suspended solids levels can be significant. Washed juices, suspended and partially solublized starches, meat particles containing fat, and the appropriate cleaning chemicals all contribute to the waste load. The principle reuse of water occurs in the retorting and cooling systems. In some cases, these waters are reused as make-up for initial produce washing operations. Part of this stream may also be used for gutter flushings. Cooling towers may also be used for recirculation.

Chips, Corn and Tortilla

Corn chips are usually manufactured in the same plant concurrently with potato chips; however, the manufacturing processes and wasteloads generated are much different from potato chips. Until about 1960, one major company held the patents on their manufacture, and this firm still dominates the industry. For the purposes of this study, two plants in Michigan were visited for the collection of historical data. The processing of corn chips is always a batch process, in that a group of ingredients are assembled in a container and then proceed through the following processing steps as a batch. A schematic flow diagram of the manufacturing process is shown in Figure 43. Major ingredients used are dry kernel corn, lime, and water. A typical ratio of corn to lime is 100:1 by weight.

Corn, water, and lime are measured and mixed into the simmering kettle, usually a stainless steel steam-jacketed kettle with a double motion agitator. Typically, one pound of lime and fifteen to twenty gallons of water are mixed with each 100 pounds of corn. The ingredients are brought to a boil and simmered for a period of time, ranging from 20 to 30 minutes, depending on the corn used. After the set period of time, cooling water is immediately metered into the mixture. The mixture is continually agitated so that it will cool uniformly. When the temperature has dropped to about 160°F, the mixture is transferred to a soaking tank. The mixture is allowed to soak for three to 24 hours in order to loosen the corn husks and build the moisture content of the corn to over 50 percent. An additional fifteen to twenty gallons of water per 100 pounds of dry kernel corn is added in this step. At the end of the soaking period, the steeping water, a very strong waste, is discharged to the sewer. After soaking, the corn is pumped into a continuous washer, usually a perforated drum with fresh water sprays that wash away the loosened husks. Water is generously used to wash away all contaminants.

The cooked and washed corn is transported by conveyor to the corn mill where it is screw-fed between two specially cut and matched stones which grind the corn into a substance called masa. No water is used in this unit process or any subsequent process except for routine plant clean-up. The masa is fed into an extruding machine which rolls the masa into a log and feeds it into a cylinder nine to ten inches in diameter at the other end of which is attached a die that forms the width and thickness of the chips. The product is cut to the desired length by adjusting a variable speed knife. A disc forces the masa through the extruder which shapes the chip and cuts it. The chips usually fall from the extruder directly into the fryer.

The chips are fried in oil at a temperature of between 390° to 410°F for between 75 to 105 seconds, depending on the type of finished product desired. The cooking vats usually have a continuous fines removal system for small bits of masa produced in the extrusion operation. The oil is usually cleaned at the end of each day by passing it through a filter press. Salting usually occurs immediately after removal from the fryer. A mechanical salter is normally used. The chips are usually tested for quality at this point by tasting. A quick cooler is sometimes used to cool the chips before packaging, although if the conveyor belt is of a sufficient distance, the chips may cool naturally while being transported to the packaging equipment. Various flavorings may be added at this time, the most popular being bar-b-que. Chips are usually mechanically packed into various types of containers. Tortilla chips are manufactured in almost the same manner as corn chips, up to the point of extruding. At this point, the masa is fed to a mechanical sheeter and cutter which presses the masa into sheets and cuts it into the desired shape, usually triangular. The chips are then fed into an oven where the moisture content is substantially reduced. The chips are removed from the oven, cooled, and fed into the fryer. The rest of the process is similar to that for corn chips.

Discharges to a plant's effluent stream are sporadic in nature but for the most part rather concentrated. The introduction of steeping water and clean-up water (floor and equipment) contributes to the organic loads, most of the effluent consisting of dissolved and/or suspended corn particles as well as small amounts of the added lime.

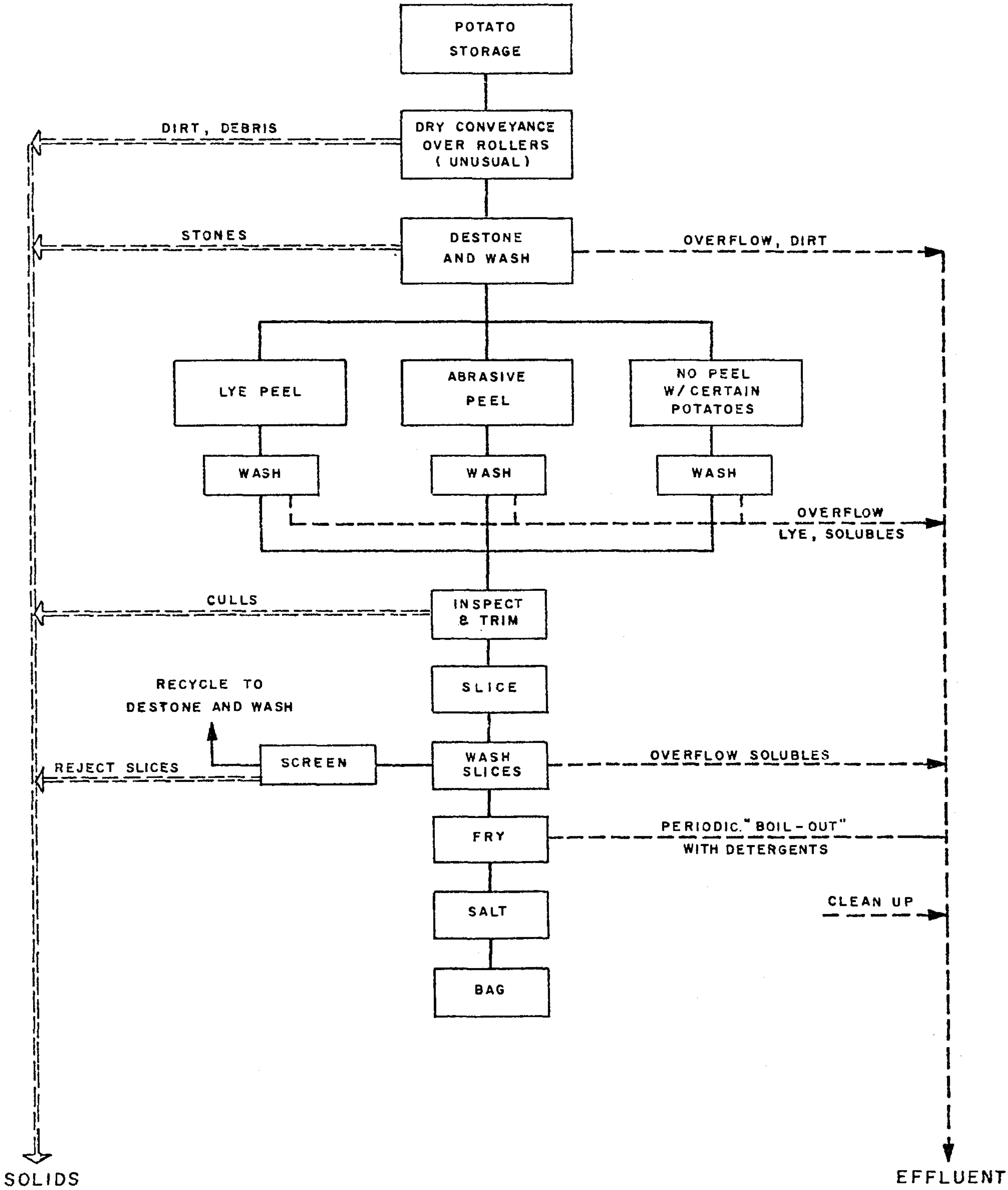
Chips, Potato

Potato chips are manufactured in plants spread throughout the nation. Because of the high cost of freighting the finished potato chips, plants are located in virtually all major population centers and vary greatly in size. For the purposes of this study, nine plants in Pennsylvania, two in Maine, and one in Texas were visited for the collection of historical data. The Potato Chip Institute, Cleveland, Ohio, provided background data and enlisted the cooperation of its membership.

In this report we are considering only potato chips manufactured from fresh potatoes. Reconstituted chips manufactured from dehydrated potatoes are not covered. The fresh potatoes used comprise a wide range of varieties and are grown in many states. The varieties best for chipping include Russet Rural, Russet Burbank, Smooth Rural, Irish Cobbler, Kennebec, Sebago, Katahdin, Delus, Merrimack, and Saco. Varietal differences of importance to wasteload generation include skin thickness, potato size, and percent solids. Potato solids content varies from about twelve and one-half to twenty percent depending upon variety, location grown, time of year, and length of storage prior to use. Generally, the potatoes are machine harvested and received at the chip plant unwashed. The amount of dirt on the potatoes, percentage of spoiled potatoes, and trash included depends primarily upon the type of soil and weather conditions where they were harvested. The potatoes usually arrive at the chip plant in

FIGURE 44

TYPICAL POTATO CHIP PROCESS FLOW DIAGRAM



half-ton wooden bins, but larger containers may be used at large plants, and 100 pound sacks may be used at small plants.

Potatoes may be stored under controlled conditions for long periods before use, and virtually all plants can store for at least several months. Therefore, effluent guidelines should be based upon final production and not upon receipt of raw product. Potatoes in storage may "weep" (go rotten) and create a liquid waste which must be cleaned up, but this is a minor amount generally, because the plant will process the potatoes before this happens. Potatoes in storage, however, do experience a thickening of the skin and an increase in percent solids.

The processing of potato chips is virtually a year round operation. Figure 44 shows a typical flow diagram for potato chip processing. There appears to be little deviation from the basic processing steps shown, only a difference in the design of the equipment used and the amount of water recycle practical. The binned potatoes are unloaded by forklift into a washer-destoner device which hydraulically lifts the potatoes at a velocity designed to separate dirt and debris from the potatoes. Water used may be fresh or recycled within the slice washer (see below), and is extensively recycled within the washer-destoner to reduce the volume of the wastewater discharged.

An estimated 95 percent of the potatoes used for potato chips are abrasive peeled. A few very large plants in the Northwest are reported to use lye peeling. No peeling at all may be required when the fresh potatoes are very thin skinned. The abrasive peeler removes the skins by means of high-speed abrasive rotating discs. Sprays to wash the peel from the potato are normally fresh water; however, in at least one plant, they are reported to be reclaimed water from the slicing washer described later. The peeled potatoes are transported usually by conveyor belt, to an inspecting and trimming station where unwanted portions of the potato, such as leftover peel, eyes, and blemishes, are trimmed usually by hand. The wastes generated in this operation are whole pieces, peels, and unwanted portions of the product. In the past, these wastes were generally disposed to the wastewater via continuous flumes; modern practice, however, recommends that they be placed in containers and disposed of as a solid waste.

The peeled and trimmed potatoes are fed into a centrifugal mechanical slicer which slices the potatoes into chips of between fifteen and twenty slices per inch. Blade sharpness and slice thickness have a bearing upon waste generation. Sharper blades and thicker slices cause less leaching of solubles from the slices during the following washing step. There appears to be no data available, however, to quantify the difference in waste generation. The major producer of soluble organic waste in potato chip manufacture is the slice washer. There are various designs of slice washers. The majority use a revolving drum with hard sprays. Others may wash the slices in a trough of water through which the slices are conveyed on a belt. The washer removes surface starch from the slices to prevent matting or sticking of the chips.

Wastes generated from the slicing and washing operations include suspended solids and white starch. The industry recognized the significant strength of this waste and has developed a means of reducing its strength. Recent developments have included systems for separating the white starch from the wastewater into a solid block of starch, which can be utilized as starch or animal feed. One method is through a hydraulic washing system. Slicers are mounted on the washer frame and discharge directly into a collector trough where slices are sluiced into a high-velocity water stream. The slices are washed by the combination of high agitation and a rapidly moving water stream. They travel with the water through a washing tube onto a separation flume, where both the slices and water are spread evenly over a draining conveyor. The draining conveyor consists of a stainless steel, open-mesh conveyor belt which allows water, small bits and pieces of potato, and peel to fall through and separate from the slices. The slices continue to drain as they are carried up the first draining conveyor; they are then dropped onto a second draining conveyor of similar construction, turning over in the process. The wastewater from this operation is run through centrifugal wastewater concentrators (hydrocones), which remove a substantial percentage of the starch in solution. The slurry is discharged into vats where it solidifies into blocks of solid starch, and the water can be recirculated for use in peeling or other operations. The economics of starch recovery depend upon transport cost and the market for recovered starch.

Following the slice washer, the slices are fried in a continuous fryer using a high grade of vegetable oil. The continuous fryer is normally boiled out weekly using detergent and water, producing a short-term, high-strength waste. This is considered part of the overall clean-up water. The industry has an odor problem from the frying operation. A recent development to reduce this odor is a system to reclaim steam from the fryer through a condenser and special heat exchanger. Chips are usually salted immediately upon removal from the fryer by a mechanical salter and then packaged.

The major volume of wastewater generated in a typical "chip" operation is attributable to the washing and peeling processes. Initial washings generally remove external dirt and debris resulting in low BOD and suspended solids levels but somewhat higher than normal levels in settleable solids. The method of peel removal and subsequent washings and slicings generate the highest concentration of BOD, suspended solids, and solid wastes. Peel losses and subsequent effluent loads are lower in this type of operation compared to other pota#o processing steps due to the "minimum" peeling desired by "chip" manufacturers. Routine daily clean-ups consist mainly of equipment and area washings with the occasional addition of various types of detergents. These

FIGURE 45

SIMPLIFIED FLOW DIAGRAM FOR CANNED AND FROZEN CHINESE SPECIALTIES

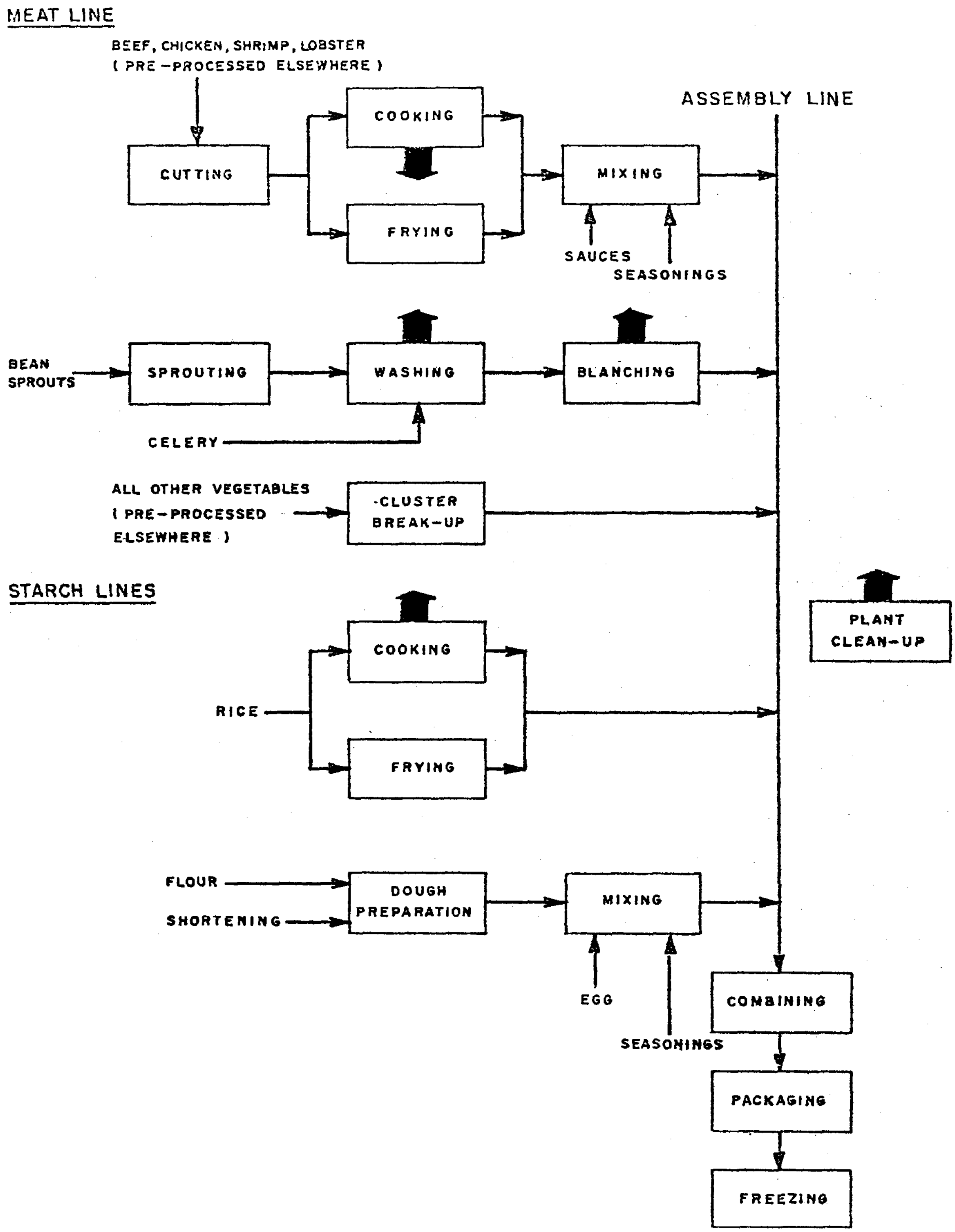
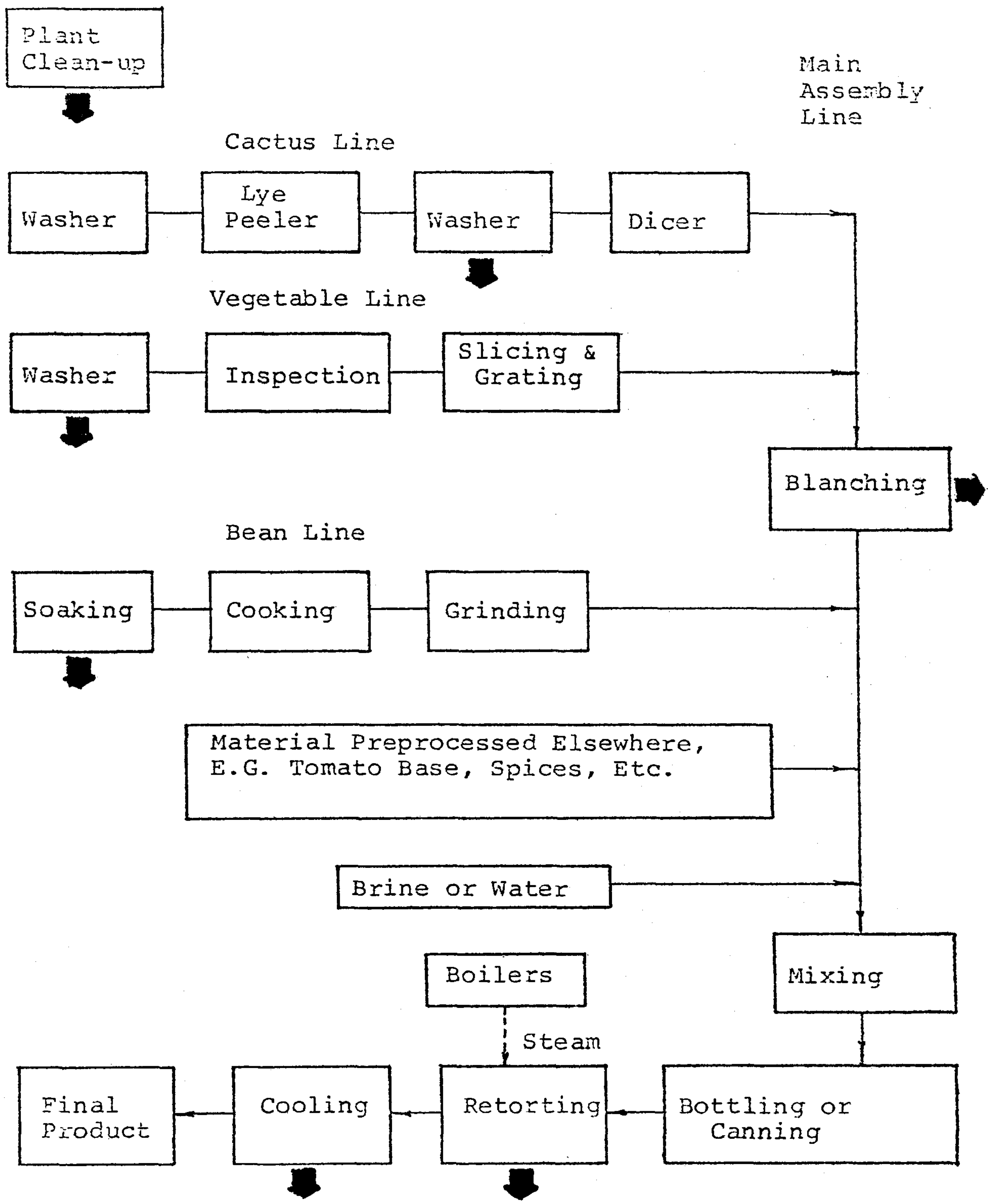


FIGURE 46

SIMPLIFIED MEXICAN SPECIALTY PROCESS FLOW DIAGRAM



chemicals directly affect the strength of the waste streams either by dilution or through added chemical ions.

The potential for water reuse in a typical potato chip manufacturing operation is greatly dependent upon ability to remove starch from slicing and post-slicing washing operations. The overflow from the washers can then be collected and pumped to the initial potato wash or the peeling (abrasive) operation. Fresh make-up water, therefore, only has to be added to the slicer and final wash operations.

Ethnic Foods

Ethnic foods, for the purposes of this study, include canned and frozen Chinese and Mexican foods. These products usually are assembled at the plant by combining a blend of pre-processed and plant-processed items. For example, Chinese food processing plants typically process their own sprouts (including sprouting), rice, noodles, meat, and celery. Other vegetable items, eggs, flour, and incoming raw meat and fish are usually pre-processed elsewhere. Mexican food processors typically process beans and cactus while utilizing such pre-processed items as tomatoes, beef, shrimp, chili, and various spices. For the purposes of this study, two Chinese and one Mexican processing plant were field visited for the collection of historical data.

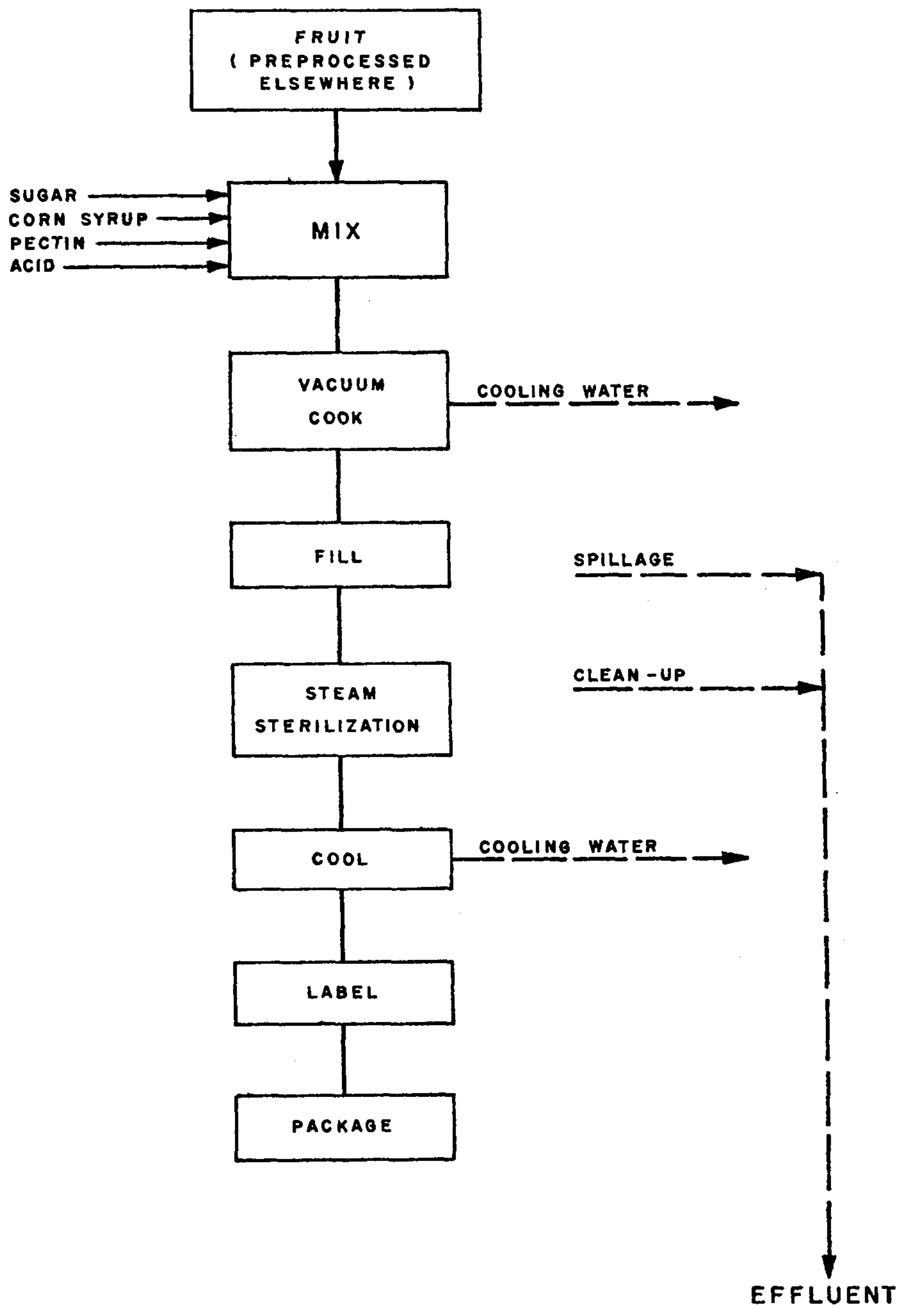
Figures 45 and 46 show typical Chinese and Mexican food process flow diagrams. As can be seen from the flow diagrams, there are a number of simultaneous operations occurring, the end result of which is a blending or mixing together of the various ingredients.

There are several basic operations in a Chinese specialty plant: meat or fish processing; sprout and vegetable handling; and starch and/or rice preparation. The various steps that each group follow are typically those necessary to prepare the ingredient groups for further processing. Meat is cut, cooked, and fried. Vegetables are washed, cut, and blanched. Rice is cooked and fried. Flour is mixed with various ingredients into dough for various egg roll combinations. All of these ingredient groups are combined in various combinations, the result of which is a finished frozen dinner, snack, or entree. Vegetables may also be processed by themselves, independently of the other ingredient groups. These are typically washed, inspected, sliced, diced, or cut and filled into cans. The cans are topped with hot water (with or without added ingredients), seamed, retorted, and cooled.

The assembly of Mexican foods is similar in many ways to Chinese foods. Typically, there are several operations happening at one time. Cactus and/or various vegetables are typically washed, lye peeled (for cactus), diced, sliced, or cut and blanched. Dried beans are processed as described in the canned dry bean process description. All or some of these ingredients are then combined

FIGURE 47

SIMPLIFIED JAMS AND JELLIES PROCESS FLOW DIAGRAM



in mixing or batch tanks. Automated filling into cans or glass bottles follows. The containers are then retorted and cooled.

Principal wasteloadings may come from both the processing of raw ingredients and clean-up. The processing operations generate dirt, solubles, and juices (from washing, slicing, cutting, and blanching), whereas clean-up operations normally involve the use of chemicals which contribute heavily to COD and BOD loadings. Can cooling and freezer defrost water are large volume generators, but these are essentially "no-contact" waters and serve to dilute the effluent stream. In any of the ethnic plants, the formulations being run on a particular day have a significant effect on the pollutants generated.

Jams and Jellies

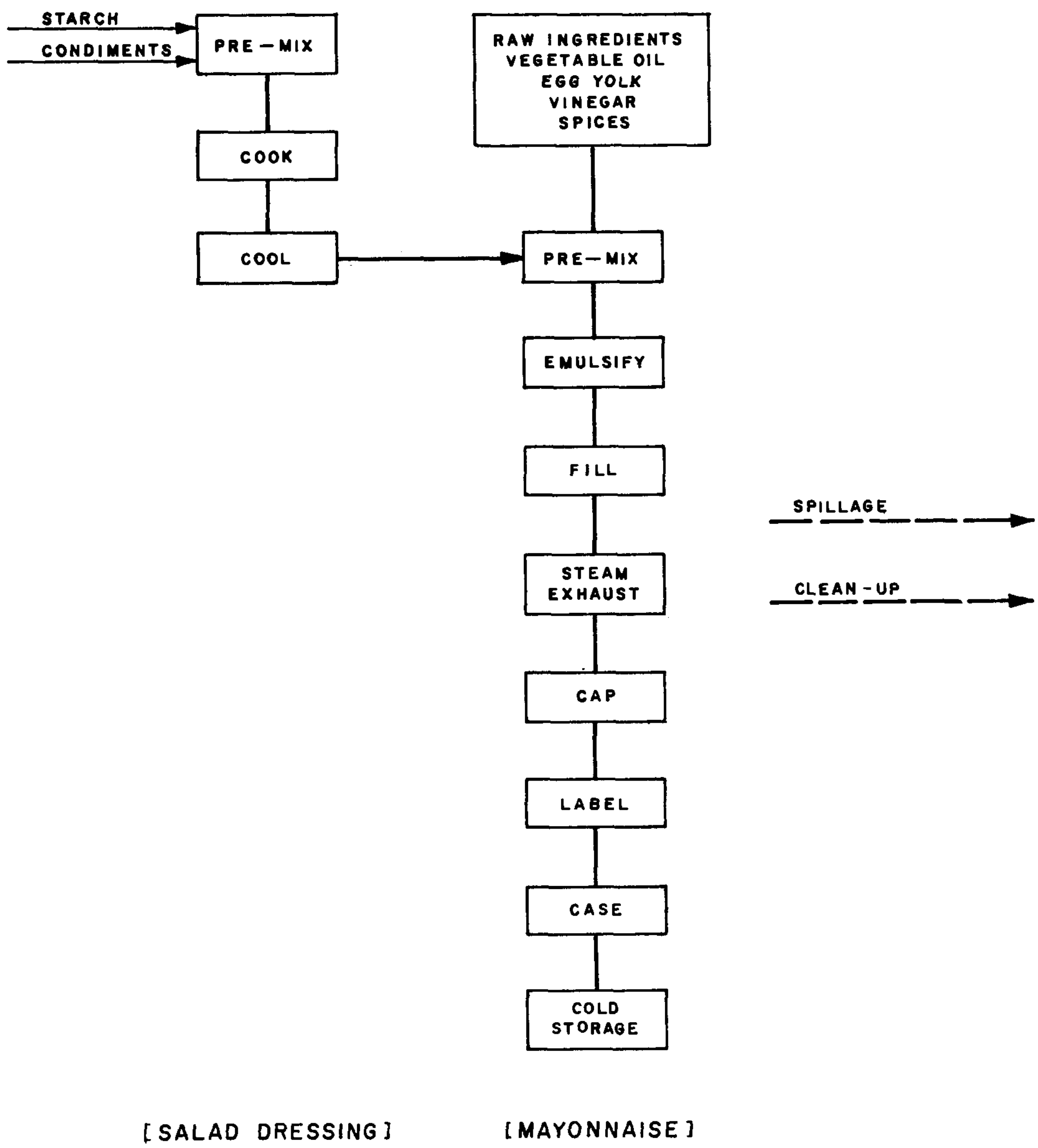
Processing, as it is applied to the manufacture of jams, jellies, and preserves, is essentially the combining of fruit or fruit concentrate, sugar, pectin, and certain other additives in a highly acidic medium, the result of which is a gelatinized and thickened commercial jam or jelly. For the purpose of this study, one plant in California was visited for the collection of historical data. Figure 47 shows a flow diagram for a typical jam and jelly processing plant.

Because of short harvesting season and physical characteristics of the finished product, most processors buy their fruits in pre-processed, bulk packs. These bulk packs consist of fruit juices used for jelly processing or fruit pieces used in the making of jams. Fruit concentrate is also utilized for jelly preparation. Cherries, currants, caneberries (blackberries, boysenberries, raspberries, loganberries, and gooseberries), and strawberries are usually pre-processed into frozen containers of various sizes, while apricots, peaches, grapes, plums, and pineapples may either be canned or frozen. Some plants may process the fruit fresh during the harvesting season, but even these plants usually pack the fruit into bulk packs and process the preserves to fit a pre-determined production schedule. A detailed description of the harvesting, transportation, and processing methods for each commodity can be located in the appropriate sections for the individual fruits.

The bulk containers are taken from refrigeration and transported by lift truck to the processing line. The containers are manually dislodged from the containers (usually 50 gallon drums or 30 lb tins), and dumped into a stainless steel mixing tank. The frozen fruits are allowed to thaw and are heated. The setting or gelling of jams and jellies requires the presence of four ingredients (pectin, sugar, acid, and water) in a definite relationship to each other. To the mechanically mixed fruit, sugar (as corn syrup or sucrose), water, and pectin are added and blended thoroughly. When sufficient pectin and sugar are present, no gel will form until the pH is reduced below a critical pH value (approximately 3.6).

FIGURE 48

TYPICAL MAYONNAISE AND SALAD DRESSING PROCESS FLOW DIAGRAM



The mixture is then transferred to the cookers. The product is vacuum cooked to prevent degradation (discoloration and off flavor) of the fruit, while concentrating the fruit to the desired degree brix (typically 65°-68° brix). To avoid gelling in the cooking process, the pH of the fruit is maintained above the critical pH value. From the cookers, the mixture is drained or vacuum pulled to holding tanks where acid is added to the hot solution. Citric, tartaric, and malic acids are used, as well as phosphoric and lactic acids. Citric is most often used. The sugar and acid act upon the pectin to cause it to gel. The mixture is heated (170°-190°F), homogenized (for some products), pH adjusted below the critical level, and pumped to the filler. The jam or jelly is hot filled and capped; the container is held hot for several minutes, cooled, and packaged.

The principal sources of wastewater generation are cooling water, spillage, and clean-up. Because of the high sugar content of the product, spills result in a low volume-high strength wastes. Cleanup wastes typically generate the highest strength waste loads on a consistent basis. This is due mainly to kettles and cookers which must be maintained in accordance with good sanitation practices. Can and jar cooling water is often recirculated by passing the water through a cooling tower. This provides the only practical reuse of water since the majority of water consumed is either used in the product itself, or for clean-up.

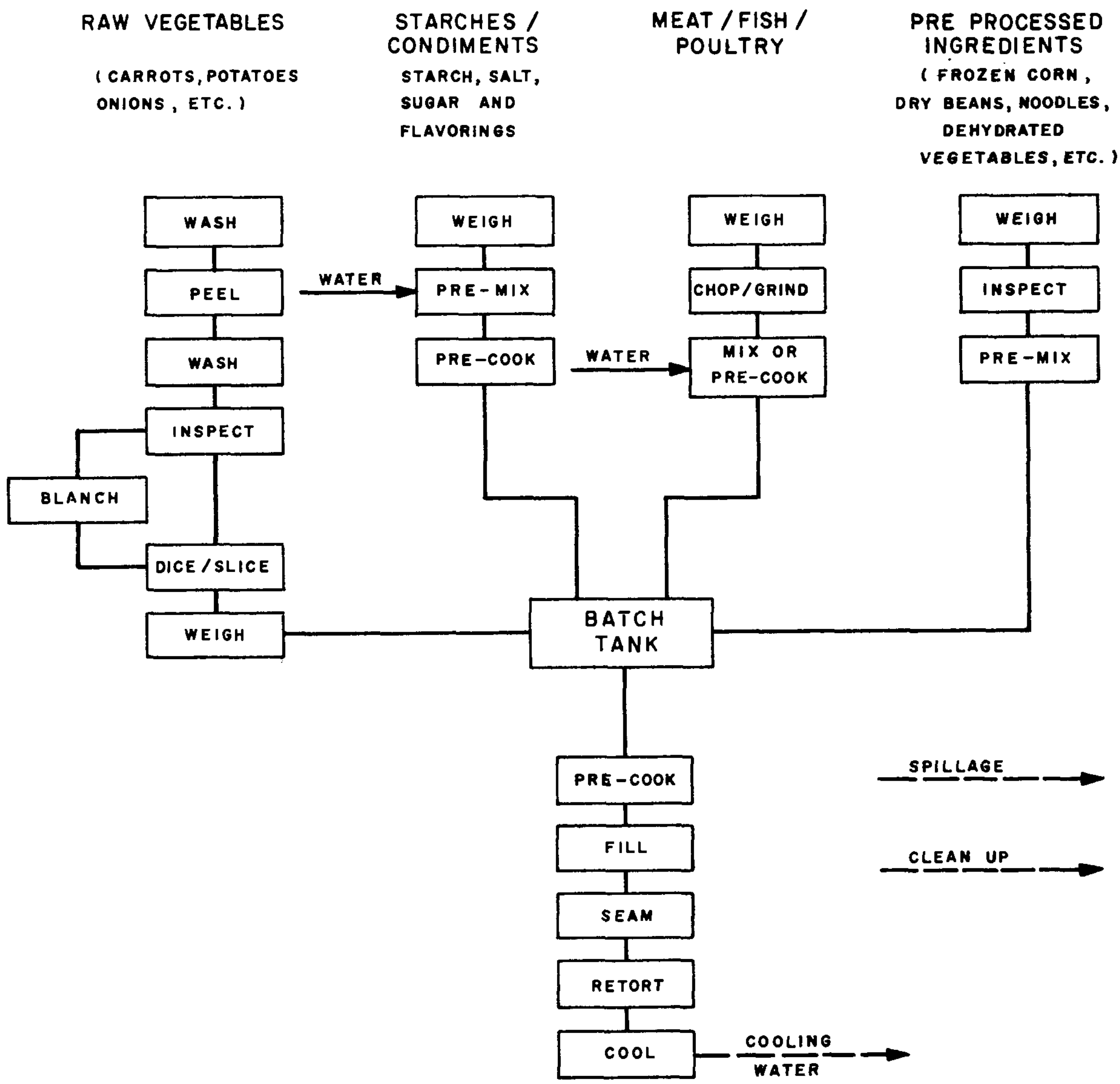
Mayonnaise and Dressings

Mayonnaise or salad dressing is the emulsified, semi-solid food prepared from edible vegetable oil and acidifying and egg yolk containing ingredients. For the purposes of this study, two plants in California were visited for the collection of historical data. In the manufacturing of mayonnaise and salad dressing, the vegetable oil is dispersed in an aqueous medium with egg yolk as the emulsifying agent. The purpose of this agent is to form a coating around the individual globules of oil and thus prevent them from coalescing into masses of oil visible to the eye.

The principal constituents of mayonnaise and salad dressing and their typical percents by weight are vegetable oil (usually soybean but sometimes cottonseed or corn oil)--80 percent; egg yolk containing substances (two-thirds white and one-third yolk which together exert a stabilizing influence)--8 percent; cider and distilled vinegar--37 percent; spices and seasonings (usually including mustard flour, pepper, paprika, onion, and garlic; and sometimes including ginger, mace, cloves, tarragon, and celery)--1/2 percent; water--six percent; sugar (extensively beet sugar but sometimes cane sugar, dextrose, or corn sugar)--two percent; and salt--1/2 percent. The principal difference in the processing between mayonnaise and salad dressings is the addition of a starch paste during salad dressing processing. The starch

FIGURE 49

TYPICAL SOUP PROCESS FLOW DIAGRAM



addition and subsequent differences in processing will be discussed in a separate section below.

Figure 48 shows a typical mayonnaise and salad dressing process flow diagram. If whole fresh eggs are used, the eggs are creamed by beating them in a vertical mixer until smooth or by creaming them in a premixing tank. If frozen egg yolk is used, it is thawed and put directly into the premix tank without previous creaming. The premixer is usually a jacketed stainless steel tank fitted with a double acting agitator. The eggs, vinegar, water, salt, sugar, and spices are put into the premixing tank and mixed until thoroughly blended. The oil is then fed into the tank in a steady stream with the premixer running. The rate this oil is added is very important to prevent viscosity differences later. The object is to incorporate the oil into the water phase as quickly as possible, leaving the actual emulsifying to the colloidal mill. As soon as the oil has been incorporated and the premix takes on a smooth, uniform appearance, the premixer is stopped. In some cases, it is necessary to operate the premixer intermittently while the batch is being pumped out to avoid separation.

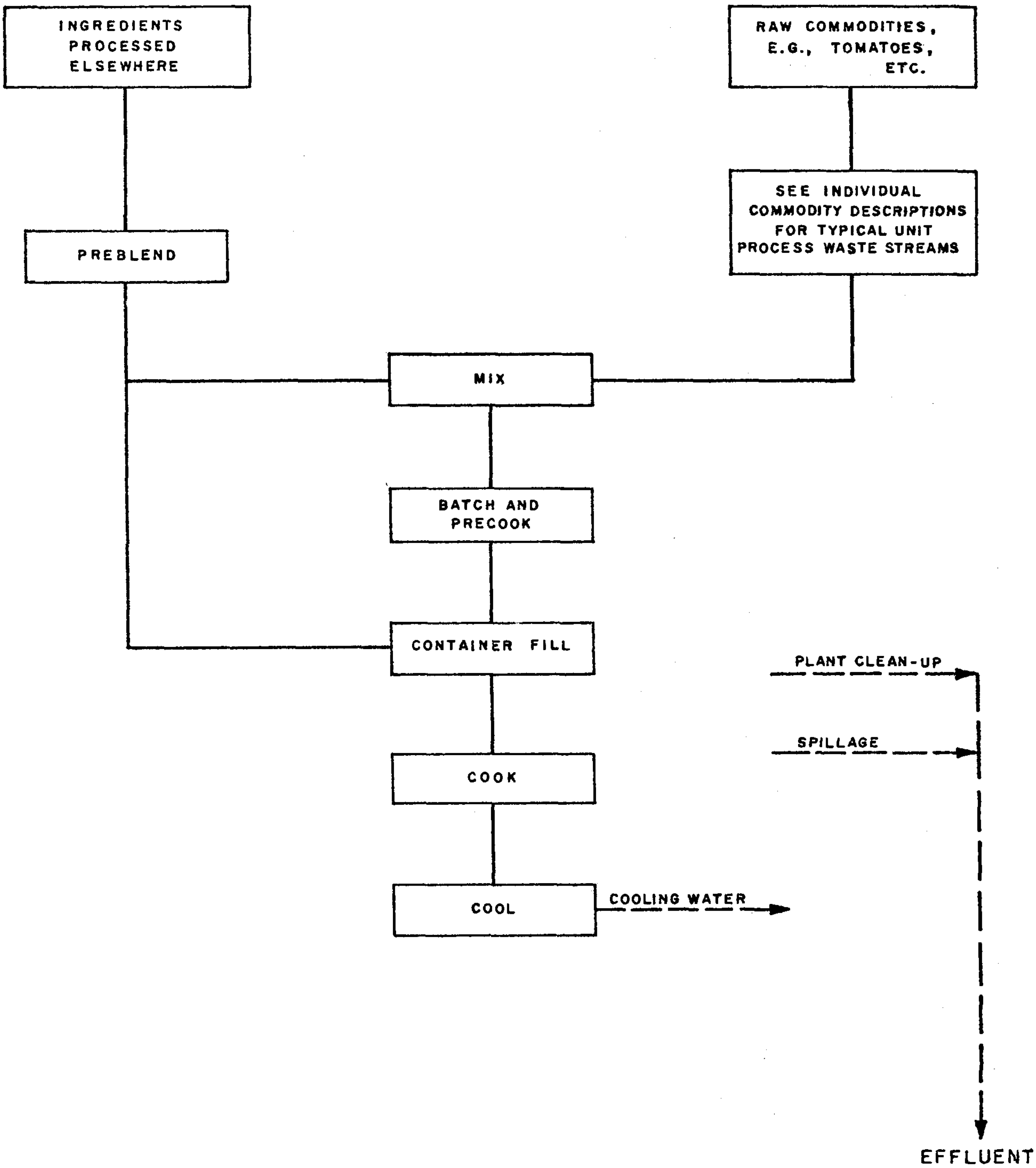
When premixing is completed, a valve at the bottom of the premix tank is opened, and the mixture is pumped through a homogenizing colloidal mill. The purpose of the milling operation is to disperse the oil in droplets throughout the medium and thus homogenize the oil and egg emulsion into the desired viscosity. The mayonnaise is pumped from the mill to an automatic filler. After filling, the jars travel by means of a conveyor to a capper and labeler. Capping is of the utmost importance since a large portion of the shelf-life of the finished product depends on the efficiency of this step. The cap must make a tight seal to minimize transfer of air at the top. This may be accomplished by sparging the headspace with steam. The jars are labeled, cased, and placed into cold storage (30-40°F).

Salad dressings are made from the same ingredients as mayonnaise with the addition of a starch paste. They are manufactured in an identical way with the addition of a starch base cooker and cooler system. Starch based cooking is done using two types of equipment: a batch type tank or a continuous starch cooker-cooler. In both systems, the starch base is stirred continuously while being cooked to prevent hardening or film formation. The principal ingredients of the starch base and their percent by weight include: water (52 percent), salad dressing starch or cornstarch (eight percent), salt (three percent), sugar (20 percent), and vinegar (17 percent). After cooking the mixture is cooled and pumped to premixing tanks and combined with the vegetable oil, egg, water, vinegar, and spices. The rest of the process is the same as mayonnaise.

The principal sources of wastewater generation are spillage and clean-up. The closed piping systems are broken down routinely, usually daily, and flushed with water and chemicals creating a

FIGURE 50

TYPICAL TOMATO-STARCH-CHEESE CANNED SPECIALTIES
PROCESS FLOW DIAGRAM



high-strength and in some cases high-volume waste. Principal pollutants such as suspended egg solids and varying levels of oil and grease are dissolved.

Soups

The preparation of canned soups involves the combining of various ingredients in preprocessed or fresh form. The principal categories of preprocessed items include: meat, fish, poultry; dairy products and eggs; flours, starches, rice, spaghetti, and noodles; spices, salt, sugar, fats, and oils; and tomato paste (a few manufacturers process fresh tomatoes into the desired consistency). Some vegetables are usually processed raw (onions, potatoes, mushrooms, carrots) while others such as corn, peas, beans, etc. arrive at the plant in bulk preprocessed form. The fresh processing involves cleaning, peeling, sizing, and stabilizing prior to final washing. These operations are conducted by the methods similar to those described for individual commodities. Generally, the plants operate the year around. However, the ratio of varieties canned may change as the seasonal availability of principal vegetable ingredients change. For example, a plant may can its entire year's output of tomato soup stock during the tomato harvest season. For the purpose of this study, one plant in Ohio was visited for the collection of historical data.

Figure 49 shows a typical soup process flow diagram. The essential ingredients are combined and cooked in several ways depending on the form of the raw materials. Vegetables to be processed fresh at the plant are typically treated as described in the separate commodity sections. These products are usually sliced, diced, or ground to suit particular formulations and are typically combined with preprocessed ingredients to form a "soup" blend. The various preprocessed items such as meat, starches, and condiments are typically weighed, chopped or slurried, and premixed in separate tanks as per individual formulation. Starch mixtures may additionally be precooked before final batch mixing. The batching operation normally combines the processed raw commodities and the several meat, starch, and condiment premixes into a final mixing tank. A final precooking is normally done and the product pumped to a filler bowl. The cans are filled, seamed, washed, retorted, and cooled.

The wastewater generations throughout the raw material prearation are similar to those for any particular commodity being processed. Retort and cooling waters are a major part of the final effluent, but it is normally low load water and does not affect the pollutant levels except for dilution and a very slight increase in water temperature. The use of many raw materials, however, necessitates extensive clean-up operations. Volume of water used and subsequent BOD and suspended solids levels can be significant. Washed juices, suspended and partially solubilized starches, meat particles containing fat, and the appropriate cleaning chemicals all contribute to the wasteload. The principal reuse of water occurs in the retorting and cooling systems. Part of these streams may be used for gutter flushings. Cooling towers may be used for recirculation of waters for further cycles of cooling. In the raw commodity processing sections of the plants, the various opportunities for water reuse are similar to those described in the individual commodity sections.

Tomato-Starch-Cheese Specialties

This segment of the industry includes canned spaghetti, canned raviolis, and other "Italian" type canned foods. The magnitude of this segment is not known in terms of total production or sales. In most cases, the making of tomato-starch-cheese canned specialities is basically a mixing and blending operation using almost exclusively pre-processed ingredients. The exceptions to this are the few large plants that process their own tomatoes, but even this processing is usually done in the form of paste or puree to be used at a later date in plant formulations. During their tomato processing season, these would, of course, fall under the tomato products subcategory.

Products that are mainly a tomato-cheese-starch combination (spaghetti, lasagne, and ravioli) generate wastes primarily from spills and clean-up of blending vats and cooking kettles. The wasteloads from these operations are dependent upon the volume of water used during clean-up. Their high-strength wastes will vary according to the volume of final effluent leaving the plant. Figure 50 shows a simplified flow diagram of the process.

In addition to commodity specific operations that lend themselves to wastewater recirculation and water reuse, the main operation contributing to the reuse of wastewater is cooling towers which recirculate retort and can cooling waters.

SECTION IV

INDUSTRY CATEGORIZATION

INTRODUCTION

The Fruits, Vegetables and Specialties segments of the Canned and Preserved Fruits and Vegetables industry includes all the sub-groups of the food and kindred products industries, identified as Major Group 20 in the Standard Industrial Classification (SIC) Manual, 1972, published by the Executive Office of the President (Office of Management and Budget). Within SIC 2099 this report also covers establishments processing potato and corn chips. Included in these segments are SIC Industry Numbers 2032, 2033, 2034, 2035, 2037, and 2099.

In developing wastewater effluent limitation guidelines and standards of performance for the canned and preserved fruits and vegetables industry, a judgement must be made as to whether such limitations and standards are appropriate for different subcategories within the industry. Before these subcategories can be determined, it is necessary that the industry be separated into three segments based on natural processing activities, principal sources of wastes and common usage. In developing this segmentation, canned and preserved fruits were differentiated from canned and preserved vegetables because of differences in their general properties, differences in their major processing activities and differences in their common usuage. The third segment, canned and miscellaneous specialties, was differentiated from fruits and vegetables on the basis of differences in processing activities and differences in major sources of wastes. Thus, three industry segments have been identified as follows:

Canned and Preserved Fruits
Canned and Preserved Vegetables
Canned and Miscellaneous Specialties

Table 7 shows a comparison of raw waste characteristics for the three industry segments. It is obvious there are significant differences among waste loads from processed fruits, vegetables and specialties. The water usuage and raw BOD_5 and TSS are lower for fruits than for vegetables or specialties. The water usuage for specialties is less than the water usage for vegetables but the raw waste BOD_5 and TSS for specialties is larger than the BOD_5 and TSS for vegetables. Thus, the differences in the raw waste characteristics substantiated the separation of this industry into three segments: Fruits, Vegetables and Specialties.

TABLE 7
Comparison of Raw Waste Loads
From Fruits, Vegetables and Specialties

INDUSTRY SEGMENTS

	FRUITS	VEGETABLES	SPECIALTIES
Average Water Usage cu m/kkg (gal/ton)	10.86 (2586)	22.91 (5454)	15.17 (3612)
Average BOD_5 kg/kkg (lb/ton)	11.8 (23.5)	13.0 (26.0)	14.8 (29.6)
Average TSS kg/kkg (lb/ton)	2.2 (4.4)	6.6 (13.1)	14.3 (28.5)

In order to identify any such subcategories within these segments, the following factors were considered to be potentially important:

Raw material
Products and by products
Production processes
Age of plant
Size of plant
Plant location
Waste treatability

In order to consider each of the above factors in the most complete manner, it was determined that the three fruit and vegetable segments should be separated by commodity. There are several advantages to studying the industry in this manner.

First, it separates the industry into relatively homogeneous groups within each segment in terms of four of the subcategorization factors: raw material, products and by-products, production processes, and waste treatability. The influence of the remaining three plant factors--age, size, and location--can be analyzed more effectively when the other four factors are held constant. Second, many of the information sources are commodity specific. Third, it provides a relatively high level of resolution as it divides the entire industry into three segments with a total of 58 commodity specific subcategories. Fourth, it provides basic modular information units which can be aggregated as desired for an economic analysis of the industry. Fifth, it is convenient for technical review as most commentors relate to individual commodites.

Once this commodity separation was made, the general approach for determining the final subcategorization was as follows: identify information sources; establish information handling and data analysis system; survey information sources; examine the information obtained from the initial commodity subcategorization with each segment and determine whether each commodity should be further divided, combined with another, or deleted from consideration.

The criteria for further dividing an initial commodity subcategorization was that the statistical characterization of the raw waste loads from two or more groups of plants had to be significantly different. Groups of plants were identified as being different based on the subcategorization factors. The criteria for combining two or more initial commodity subcategories were that the commodities are often processed at the same facility and the statistical characterizations of the raw waste loads were not significantly different. The criteria for deleting an initial commodity subcategory was that the commodity is of minor environmental or economic significance. That is, the waste loads and production levels are low and it is usually processed incidental to other commodities.

In the canned and preserved fruits industry segment, blackberries, blueberries, boysenberries, raspberries, loganberries, gooseberries and ollalieberries were combined in a subcategory labeled caneberries. However, cranberries and strawberries were separate subcategories. The subcategory dehydrated fruits include dried apricots, peaches, pears, apples, figs, prunes and prune juice. However, raisins are a separate subcategory. Five other fruit commodities were further divided into additional subcategories. Cherries were subcategorized into sweet, sour and brined subcategories. Grape juice was subcategorized into pressing and canning subcategories, and pickles were subdivided into processed, salt-stock pickles, fresh pack pickles, and pickle salting stations. Within each of these pickle subcategories, pickled cucumbers are included along with pickled beets, cauliflower, peppers, and miscellaneous vegetables. Peaches were subcategorized into canned and frozen styles and tomatoes were subcategorized into peeled and product styles.

In the canned and preserved vegetables industry segment, dehydrated beets, cabbage, carrots, parsley, horseradish, bell peppers, turnips, parsnips and celery were combined in a subcategory labeled dehydrated vegetables. However, dehydrated onions and garlic was a separate subcategory as were canned/frozen beets, carrots and onions. Collard, turnip, mustard, spinach, and kale greens were combined in a separate subcategory, either canned or frozen spinach. Another subcategory for dry beans includes several types of dry beans: butter, speckled, butter, chile, garganzo, great northern, red kidney, white kidney, navy, pinto, red, yelloweye, and lima. Five other vegetable commodities were further divided into additional subcategories. Sauerkraut was subcategorized into cutting and canning subcategories. Four vegetable commodities were subcategorized into canned and frozen styles: corn, peas, snap beans, and spinach.

In the canned and miscellaneous specialties industry segment, soup plants and baby food plants were considered separate subcategories. Jams, jellies and preserves were combined in a subcategory labelled Jams/Jellies. Mayonnaise and salad dressings were combined in a subcateogry called Mayonnaise and Dressings. A snack food, chips, was subcategorized into potato chips, corn chips and tortilla chips. Table 8 lists the final subcategories defined by industry segment. The influence of the subcategorization factors and the rationale used to establish final subcategories is detailed throughout the remainder of this section.

TABLE 8

FINAL SUBCATEGORY LIST

Fruits

- Apricots
- Caneberries
- Cherries
  - Sweet
  - Sour
  - Brined
- Cranberries
- Dried Fruit
- Grape Juice
  - Canning
  - Pressing
- Olives
- Peaches
  - Canned
  - Frozen
- Pears
- Pickles
  - Fresh Pack
  - Process Pack
  - Salting Stations
- Pineapples
- Plums
- Raisins
- Strawberries
- Tomatoes
  - Peeled
  - Products

Vegetables

- Asparagus
- Beets
- Broccoli
- Brussels Sprouts
- Carrots
- Cauliflower
- Corn
  - Canned
  - Frozen
- Dehydrated Onion/ Garlic
- Dehydrated Vegetables
- Dry Beans
- Lima Beans
- Mushrooms
- Onions (Canned)
- Peas
  - Canned
  - Frozen
- Pimentos
- Sauerkraut
  - Canning
  - Cutting
- Snap Beans
  - Canned
  - Frozen
- Spinach
  - Canned
  - Frozen
- Squash
- Sweet Potatoes
- White Potatoes

Specialties

- Added Ingredients
- Baby Food
- Chips
  - Corn
  - Potato
  - Tortilla
- Ethnic Foods
- Jams & Jellies
- Mayonnaise & Dressings
- Soups
- Tomato-Starch-Cheese Specialties

RATIONALE FOR SUBCATEGORIZATION

The influence of each of the seven subcategorization factors is discussed in the following subsections. The factors are discussed qualitatively with respect to the fruit and vegetable processing industry as a whole. However, any data obtained regarding the influence of these factors on the subcategorization is referenced.

Raw Material

The strongest argument for subcategorization within segments essentially by major groups of commodities is the difference in raw material or product delivered to the processing plant. Each raw product has a somewhat different chemical composition and/or physical character, which in turn results in the use of different unit production processes and the generation of different raw waste loads. In general, each type of raw product was placed in a separate subcategory. In a few cases, where two or more similar types of raw products were often processed at the same plant and the waste loads were not considered significantly different, a single subcategory including all of the raw products was included. Examples of this were the combination of blueberries, blackberries, boysenberries, raspberries, loganberries, gooseberries, and ollalieberries as caneberries, and the combination of collard, turnip, mustard, spinach, and kale greens as spinach. Table 9 shows the similarities between spinach and several leafy greens. The composite effluent samples for each type of green were analyzed for pollutant differences and statistically shown to be significant.

For several types of raw products, there are differences in quality when delivered to the plant. Unlike most other industries, where raw material quality is essentially constant, the fruit and vegetable industry experiences differing weather conditions, diseases, and other factors beyond the control of the processor which may cause significant changes in raw material conditions. It should be pointed out that these uncontrollable factors often result in differences of raw material appearance, texture or flavor which dictate to the processor certain end products. Thus, the quality of the raw material is considered when product styles are compared for differences. The quality of the raw material is further considered when a full year or several years' data is used in the determination of subcategory raw waste loads. In one case a processor reported annual average data for three seasons where the third year's BOD_5 was almost twice the preceding years. Since the processor made no physical changes in the plant which might account for the variation, it was concluded that the change shown in the third year was caused by a variation in the raw product which was beyond the control of the processor. While this variability is included when all three years data is utilized in the development of the regulations, the assumption regarding raw material variability beyond the control of the processor should be further investigated. For example, in

TABLE 9

THE PRODUCTION OF WASTE COMPONENTS FROM THE CANNING OF COLLARD, TURNIP, MUSTARD, SPINACH, AND KALE GREENS

Effluent	Processing operation	Type of greens[2]	Waste load, lb/ton[1] Total solids	Volatile solids	Suspended solids	Total acidity	COD	BOD
A	Dunker washer	C	4.30bc	3.13b	1.08b	0.08b	2.90NS	1.05NS
		T	6.83a	4.60ab	1.78b	0.16ab	5.12NS	1.60NS
		M	6.49ab	4.85ab	2.83ab	0.19a	5.91NS	1.47NS
		S	8.37a	6.34a	4.54a	0.17a	6.03NS	1.18NS
		K	4.04c	3.10b	1.41b	0.08b	3.64NS	1.32NS
B	Reel washer	C	7.14b	3.95NS	0.71d	0.15b	3.55b	1.46NS
		T	8.75ab	6.07NS	1.46b	0.24ab	6.47a	2.19NS
		M	6.83b	5.50NS	1.29bc	0.22b	5.11ab	1.73NS
		S	10.05a	7.00NS	1.09a	0.32a	6.34a	2.23NS
		K	6.94b	5.27NS	1.10cd	0.20b	5.20ab	1.90NS
C	Blancher	C	6.73b	4.55NS	.29b	0.22ab	4.59NS	1.87bc
		T	5.51b	3.43NS	.25b	0.15b	3.37NS	1.48c
		M	7.07b	5.12NS	.24b	0.18b	5.35NS	2.41abc
		S	13.26a	8.38NS	.72a	0.26ab	6.90NS	3.31a
		K	10.30ab	6.48NS	.26b	0.37a	7.04NS	2.77ab
D	Chopper	C	.60NS	.40NS	.03NS	0.02a	0.41NS	0.20NS
		T	.67NS	.44NS	.03NS	0.03a	0.36NS	0.21NS
		M	.79NS	.55NS	.04NS	0.03a	0.60NS	0.30NS
		S	.89NS	.49NS	.05NS	0.01b	0.48NS	0.22NS
		K	.79NS	.46NS	.04NS	0.03a	0.59NS	0.25NS
E	Tumbler fillers	C	5.11NS	3.35NS	.30NS	0.20a	3.75NS	1.73NS
		T	4.20NS	2.72NS	.28NS	0.18a	2.32NS	1.44NS
		M	4.83NS	3.60NS	.28NS	0.20a	3.83NS	2.25NS
		S	4.06NS	2.53NS	.25NS	0.08b	2.51NS	1.24NS
		K	4.37NS	2.87NS	.29NS	0.15ab	3.48NS	1.56NS
F	Receiving shed	C	.10ND	.08ND	.02ND	0.002ND	.04ND	0.02ND
		T	1.45ND	.97ND	.14ND	0.06ND	1.00ND	0.28ND
		M	2.28ND	1.58ND	.37ND	0.07ND	1.63ND	0.43ND
		S	-	-	-	-	-	-
		K	.03ND	.02ND	.003ND	.001ND	.01ND	.004ND
G	Composite	C	25.65NS	17.00NS	1.76NS	0.62NS	16.45NS	6.70NS
		T	30.34NS	19.67NS	3.14NS	0.94NS	18.79NS	8.07NS
		M	32.81NS	21.85NS	2.86NS	1.10NS	20.83NS	8.58NS
		S	39.91NS	24.20NS	4.02NS	1.08NS	22.29NS	9.27NS
		K	31.35NS	21.17NS	2.35NS	0.79NS	21.61NS	9.62NS

[1]Values followed by the same letter in each column and effluent are not significantly different at the 5% level.
NS mean square values not significantly different at 5% level.
ND significance not determined.

[2]C Collard greens; T, turnip greens; M, mustard greens; S, spinach greens, K, kale greens.

Source - Bough, Wayne A., " Composition and Waste Load of Unit Effluent From a Commercial Leafy Greens Canning Operation," J. Milk and Food Technology 36, 547-553 (Nov., 73).

this case when the pounds of BOD_5 per ton of raw material doubled the third year, the production had decreased by 34 percent and water usage decreased only 10 percent. At the same time the BOD_5 concentration increased 42 percent. These statistics indicate that water usage and plant management may be responsible for the rise in BOD_5. In any case, the conclusion cannot be substantiated that the change was caused by variation in the raw product beyond the control of the processor.

Some of the contributing variables influencing raw material quality as it arrives at the processing plant are weather and disease. It is not considered necessary, however, to subcategorize on the basis of such unpredictable events as drought or insect damage which would usually be localized in occurrence. It is concluded that some variations in raw product quality are normal and should be expected from week to week and season to season. Therefore, a plant's waste management program should be designed with sufficient flexibility to handle the problems inherent in the industry due to expected raw product quality variations. It is suggested that management of a processing plant should work in advance with its regulating agency to formulate an emergency plan to handle a situation where uncontrollable significant deterioration in its raw product quality causes its treatment facilities to be "overwhelmed."

Other variables which influence raw product quality and which are under the control of the processor to some extent are harvest method, type of container and length of haul, and degree of preprocess sorting and washing in the field. These variables should be considered when control options are being formulated to help meet the BATEA limitations for 1983. At this time, however, there is no conclusive data to quantify the influence of these variables.

Certain of the subcategories herein include processes which utilize several ingredients in addition to the basic raw product. For example, many frozen vegetables are now sold with butter, cheese, or cream sauce added. Other common added ingredients are sugar, starch, and tomato sauce. The handling, mixing, and clean-up of these additional ingredients by the processing plant adds an incremental organic waste load to the total plant waste production. This incremental waste load primarily results from the clean-up of the equipment (vats, pipes, dispensers, etc.) which comes in contact with the added ingredients. Since these ingredients have an inherently high waste load in terms of BOD_5, it was concluded that a separate subcategory would be established for additional ingredients. In practice, the added ingredients effluent standards will be incrementally added to the specific commodity subcategory guideline for plants which utilize these added ingredients in their final fruit, vegetable, or specialty products. The incremental addition of this subcategory guideline is not, however, intended to be added to subcategories where these ingredients have already been considered, such as for various styles of dry beans, baby foods or ethnic foods.

Products and By-Products

Variations in waste load generated within a commodity subcategory can also be due to the preservation technique and style of the end product produced. The differences of most potential significance are as follows:

Preservation method (freezing, canning, brining, etc.)

Peeling method and extent of cutting which occurs.

Product form (solid, juice, gel, emulsion, etc.)

The raw waste data was organized by preservation method and style for each initial subcategory to determine whether there was a significant difference due to any of these factors. The technique employed utilized a statistical "T" test of the significance between the mean BOD_5 and flow ratios of each group of data. If the difference was significant, then the groups were considered to belong to separate subcategories. If the difference was not significant, the groups were considered to belong to the same subcategory.

It is suspected that some differences due to style variations could not be determined because many of the plants investigated produced different styles, and it was impossible to separate the waste load generated by each style since other sources of variation (e.g., raw product condition, plant management attitude, etc.) obscured differences. Moreover, wastewater collection systems at many plants were not amendable to obtaining samples from waste streams of different product lines running simultaneously. Several commodities (corn, peaches, peas, snap beans, and spinach) were subcategorized into canned and frozen products. Brined cherries were separated from sweet or sour cherries. Tomatoes were divided into peeled and other products subcategories, and chips were separated into potato chips, corn chips, and tortilla chips. Many of the process operations are similar for these commodities, but the style of products or preservation method results in different waste loads. Thus, product differences have resulted in two corn, peach, pea, snap bean, spinach, and tomato subcategories, three chip subcategories, and separate subcategories for soups and baby foods.

By-products from this industry may include: (1) animal food generated by removal of solids during product processing and screening of wastewaters, (2) salable oil and grease generated by primary treatment of those raw wastes with a significant oil and grease constituent, and (3) starch removed from potato chip processing wastes. The extent of by-product recovery is generally determined by the market value rather than concern for pollution control and is practiced to some degree throughout the industry. The development of marginal by-products in some cases may be an attractive alternative to expanded end-of-pipe treatment. By-product recovery was therefore viewed from the standpoint of being a pollution control option rather than as basis for further subcategorization.

Production Processes

The unit processes employed by the industry for specific commodities are generally quite standard. However, there is much on-going pollution control research and development effort in this industry which is concentrating on developing and demonstrating alternate unit process technologies to generate lower volumes and/or strengths of liquid wastes. Significant progress is being made as described in the "In-plant treatment technology" subsection of Section VII of this document. Naturally, effort is being concentrated upon those production processes which generate the greatest amounts of pollution, e.g., peeling, blanching, product conveying, waste material handling, and brine fermentation. In each of these unit processes, promising new techniques are being tried for various commodities. It is concluded, therefore, that the use of alternate production process equipment will reduce raw waste generation by the fruit and vegetable processing industry in the future. Since the new techniques are not standard today, they were viewed as being a pollution control option rather than as a basis for further subcategorization. Subcategorization on the basis of these new methods was considered to be inequitable because the new techniques are largely still experimental for most commodities and the magnitude of the new techniques' effect upon raw waste load reduction is still largely undetermined.

The effects of water and steam blanching and of conventional and dry caustic peeling on raw waste loads were analyzed on a plant basis. It was found that differences in waste volume and characteristics attributable to any single operation did not affect the total effluent load in a manner sufficient to justify additional subcategorization. In one case, a vegetable plant utilizing a dry peel process exhibited a low water use and a low organic load. Yet the plant indicated that other water and waste reduction programs had also been implemented along with the peeler and that these practices reduced water and organic loads more than the dry peeler. It is apparent, therefore, that plant water and waste management programs must be combined with new operations such as the dry peel process if significant improvements in the total effluent raw waste load are to be achieved.

The differences in production processes used during the processing of cherries, grapes, sauerkraut, and pickles were investigated and found to be significant. In addition, the presence of the peeling operation during the manufacture of peeled tomatoes clearly increased the raw waste load over those plants which only processed unpeeled tomato products. As a result, three subcategories have been developed for pickles and cherries. Pickles processing has been subcategorized into fresh pickle processing, processed salt-stock or stored pickles, and pickle storage or salting stations. Cherries have been divided into brined cherries, sour cherries, and sweet cherries. Grape juice, sauerkraut, and tomatoes have been separated into grape pressing and grape juice packing, sauerkraut cutting and canning, and peeled tomatoes and other tomato products. Thus, it was shown that these commodities do require additional subcategorization.

Age of Plant

Age of plant is difficult to define. A processor may install new equipment into an old building, or vice versa. In the average processing line, the age of individual unit process equipment will vary. The industry is competitive so older, inefficient equipment is eventually replaced. The age of different unit processing equipment would be strongly correlated with the type of production processes just discussed in the previous subsection. Most plants tend to use similar equipment for certain commodities except for some which are testing new equipment to reduce their waste loads and increase by-product recovery. The logic for not subcategorizing by age is therefore similar to that expressed during the previous discussion of subcategorizing by production process.

Size of Plant

The size of plant may be significant from both the technical and economic point of view. Several commodities with data points from many plants were investigated to determine whether plant size affected either raw waste characteristics or volume. No significant correlation could be found between the variables. Tables 10, 11, 12 and 13 show the variability or scatter of water usage and BOD_5 values with various plant sizes for pea, corn, tomato, and snap bean processing plants.

This result should not be surprising, since plants in this industry usually run "lines," i.e., a chain of unit process steps to convert the raw material into the finished product. (These processing chains for different commodities are described in Appendix A of this report.) Generally, the size of the plant is a function of the number of processing lines; i.e., a large plant has many lines and a small plant has only one or two. Assuming the raw wasteload generated per processing line is fairly consistent, there should be no significant difference in raw wasteload generated per unit of production on the basis of plant size alone.

TABLE 10

NUMBER OF PEA PLANTS BY SIZE WITH INDICATED RAW WASTE LOAD

PLANT SIZE kg/day (ton/day)	WATER USAGE l/kkg (1000 gal/ton)						BIOCHEMICAL OXYGEN DEMAND (BOD) 2 kg/kkg (lb/ton)				
	≤3	3-4	4-5	5-6	6-7	≥7	≤30	30-40	40-50	50-60	≥60
(40-60)		1		1	1	1	1		2		1
(61-80)	2	1		1	1	1		1		1	4
(81-100)						1		1			
(101-120)				1		1	1	1			
(121-140)		1	1	1			1	1		1	
(141-160)	1	1		1				1		1	1
(161+)			1	2						2	1

TABLE 11

NUMBER OF CORN PLANTS BY SIZE WITH INDICATED RAW WASTE LOAD

PLANT SIZE kg/day (ton/day)	WATER USAGE l/kkg (1000 gal/ton)						BIOCHEMICAL OXYGEN DEMAND (BOD) 2kg/kkg (lb/ton				
	≤0.5	0.5-1	1-1.5	1.5-2	2-2.5	≥2.5	≤20	20-30	30-40	40-50	≥50
(50-150)	1					1	1				1
(151-200)		1		1		1	1	1	1		
(201-250)											
(251-300)			1				1				
(301-350)		1	1							1	
(351+)	1	2			1	1	2	1	1		1

TABLE 12

NUMBER OF TOMATO PLANTS BY SIZE WITH INDICATED RAW WASTE LOAD

PLANT SIZE kg/day (ton/day)	WATER USAGE l/kkg (1000 gal/ton)					BIOCHEMICAL OXYGEN DEMAND (BOD) 2 kg/kkg (lb/ton)					
	≤1	1-2	2-3	3-4	≥4	≥5	5-6	6-7	7-8	8-9	≥9
(<1000)	1	1					1			2	1
(1001-1500)	1		1	1	1	1			1		1
(1501-2000)		2	4			1	1	1	1		1
(2000-2500)		2	1	1					1		
(2501-3000)		2				1		1	1		
(>30001)		1								1	

TABLE 13

NUMBER OF SNAP BEAN PLANTS BY SIZE WITH INDICATED RAW WASTE LOAD

PLANT SIZE kg/day (ton/day)	WATER USAGE l/kkg (1000 gal/ton)					BIOCHEMICAL OXYGEN DEMAND (BOD) 2 kg/kkg (lb/ton)					
	≤2	2-3	3-4	4-5	≥5	≤4	4-6	6-8	8-10	10-12	≥12
(450)	1	1	1				1			1	1
(51-100)		1	2		1	1	2				2
(101-150)					1				1		
(151-200)			1	3		1		1			1
(>201)	1	1		1		1	1			1	

Plant size is also important from an economic viewpoint. Virtually all in-plant and end-of-pipe waste reduction technology is subject to economy of scale. A review of Section VIII of this report emphasizes the fact that waste treatment cost per unit of commodity production (as measured by waste volume) is less for large plants than for small plants. In addition, the large plant might be expected to have greater economic resources and finanical leverage in financing new waste treatment technology than does the small plant. However, the smaller plant may have more options for both waste treatment and in-plant measures to reduce waste generation.

The concurrent economic impact study conducted by EPA for this industry has addressed itself in great depth to the economic impact of the proposed guidelines. In this study, treatment cost alternatives have been developed in Section VIII in a very comprehensive manner in order to provide the EPA with the tools to make an accurate impact analysis. The results of this technical study indicate that size of plant does not significantly affect waste loads, and thus, size of plant is not a satisfactory basis for further industry subcategorization.

Interestingly, the cost of waste treatment and disposal per unit volume of wastewater is often affected more by the method of disposal than by the size of plant. Let us consider three cases. In the case of those plants discharging to municipal systems, the surcharge is usually calculated on the basis of waste volume and strength with equal unit charges applied to all, regardless of size. Thus large plants get no economy of scale advantage. However, a large plant discharging into a small community system may find itself paying much higher unit costs than would a small plant discharging into a large community system. In such a case, the economy of scale is a function of the community size--not plant size.

In a second case, the plant discharges to a land disposal system. Here, the cost of disposal is more dependent upon the availability, suitability, and cost of nearby land than to processing plant size. The small plant, because it requires less land, would even have an advantage in finding a suitable disposal area over a large plant.

In the third hypothetical case, the plant discharging to surface waters has little land available, and must install biological treatment facilities to meet discharge standards. In this case, the large plant will almost always derive substantial benefit from economy of scale. Even very small secondary treatment facilities are relatively expensive and the cost per unit volume treated may be significantly greater for the very small plant than for the large plant.

Plant Location

The importance of plant location from an economic point of view was touched upon in the previous subsection discussing plant size. There may be other potential effects connected with plant location including the following:

1. Geographical climate (weather) affects raw product quality. This was discussed in the raw material subsection of this section as were harvesting techniques and variety differences.

2. Geographical climate (weather) affects end-of-pipe waste treatment processes. Variations in temperature, rainfall, evaporation rate, and sunshine can all affect the performance of different types of treatment systems. For example, temperature effects have resulted in different treatment design in Section VII and different treatment costs in Section VIII.

3. Local situation with regard to nearby land for construction of treatment and/or disposal facilities. Land availability factors include cost, area, distance from plant, soil type, permeability, hydro-geology, zoning, future land use plans, and distance to nearest public development (odor complaints).

4. Availability of nearby municipal wastewater collection system. Such access may create one more wastewater handling alternative for the processor to consider.

5. Availability of solids disposal facilities near the plant. The cost of solids disposal (screenings and sludge) varies over a tremendous range depending on local situations. One California tomato processor estimates solids and sludge hauling and disposal costs are almost twice the daily operating cost of the rest of his activated sludge treatment plant. Some plants report no cost for solids disposal since they are picked up free of charge by a local farmer and used for cattle feed.

6. Local availability and cost of water. Many plants with a history of a largely unlimited supply of inexpensive water were designed with no consideration for water conservation, and are still operated that way.

7. The quality of the receiving water and the state effluent limitations being imposed. Plants located in areas designated by a state as being water quality limited generally have to meet very stringent requirements. It is likely that this factor will greatly affect new plant construction as there will be

TABLE 14

NUMBER OF CORN PLANTS BY LOCATION WITH INDICATED RAW WASTE LOAD

GEOGRAPHIC LOCATION	WATER USAGE l/kkg/(1000 gal/ton						BIOCHEMICAL OXYGEN DEMAND (BOD) 2 kg/kkg (lb/ton)				
	≤0.5	0.5-1	1-1.5	1.5-2	2-25	≥2.5	≤20	20-30	30-40	40-50	≥50
EAST						1	1				
North Central	2	2	3	3		3	2	2	2	1	2
West		2			1	2	1	1	2		1

TABLE 15

NUMBER OF PEA PLANTS BY LOCATION WITH INDICATED RAW WASTE LOAD

GEOGRAPHIC LOCATION	WATER USAGE l/kkg/(1000 gal/ton)						BIOCHEMICAL OXYGEN DEMAND (BOD) 2 kg/kkg (lb/ton)				
	≤3	3-4	4-5	5-6	6-7	≥7	<30	30-40	40-50	50-60	≥60
East			1	2				1	1	1	
North Central	1	4	1	1	1	3		1	2	5	4
West				2		2	1	1			1

TABLE 16

NUMBER OF SNAP BEAN PLANTS BY LOCATION WITH INDICATED RAW WASTE LOAD

GEOGRAPHIC LOCATION	WATER USAGE l/kkg/(1000 gal/ton)					BIOCHEMICAL OXYGEN DEMAND (BOD) 2 kg/kkg (lb/ton)					
	≤2	2-3	3-4	4-5	≥5	≤4	4-6	6-8	8-10	10-12	≥12
East		2	3				2		1	1	1
North Central			1	1	2	1		1			2
West	2	1		4		2	2			1	2

some tendency to locate outside of these areas, if raw product can still be reasonably obtained.

Most of the above potential effects are local, as opposed to regional, variations. Tables 14, 15 and 16 investigated the effect of location (East, North Central or West) on water usuage and organic loading. The variability shown throughout the tables substantiates the conclusion mentioned earlier under raw material that plant location does not significantly affect waste loadings, and thus is not a basis for further subcategorization. Climatic effect on raw material quality was discussed earlier in this section IV. Climatic effect on end-of-pipe treatment is discussed in Section VII and below.

There is no question that biological waste treatment processes (except land treatment) are affected by temperature, because the rate of bacterial metabolism is slowed by reductions in temperature. A gross "rule of thumb" sometimes used is a reduction of 50 percent in rate of bacterial metabolism for each 10°C reduction in temperture below 20°C. (A better indication of temperature effect is obtained by using the formulas developed by Eckenfeller and determining temperature effect constants for the specific waste under consideration.) However, the question of temperature effect is relevant only from the point of view of treatment plant design and cost. If a treatment plant must operate in cold climates, then the biological treatment facility must be conservatively designed to operate effectively under the expected temperature condition. Stated differently, it is recognized that for biological treatment systems to achieve consistent effluent quality, compensation in design and care of operation must be made if they operate for long periods of time significantly below 20°C. Consistent effluent quality has been demonstrated in this industry during protracted periods of very cold weather in northern climates. Therefore, neither climate nor temperature is a basis for further subcategorization.

An investigation was made as to the extent of each commodity being processed in a water quality limited (WQL) area. One problem is that some states are still in the process of defining these areas and another is that commodities are generally not confined to these areas. In general, however, plants located in WQL areas tended to have better effluent control. These plants were included among the exemplary or better plants, the peformance of which serve as the goal for other plants in the industry to achieve rather than being a basis for subcategorization.

Waste Treatability

Waste treatability is a function of the pollutant characteristics of the waste and the ability of treatment technology to remove those pollutants.

Liquid wastes generated by each segment of this industry contain principally biogradable organic matter in soluble and suspended form. The generation of such pollutants per unit of production varies between commodities because of the differences in the chemical composition of different commodities and the differences in the methods used to process raw commodities into finished products. Section V of this document details the raw waste load for each subcategory, and Section VII discusses the technology for treatment of these raw wastes. The successful application of similar treatment systems to the raw waste, from many subcategories supports the proposed subcategorization.

Cost and Economic Analysis

While the technical analysis determined that separate limitations were needed for twenty-two different types of fruit, twenty-six different types of vegetables and ten different specialty products within the fruits, vegetables and specialties industry segments, an economic analysis determined that separate limitations were needed for three plant sizes within each fruit, vegetable or specialty product. The economic study was based on financial and price effects, sales and investment, international trade and other factors. As a result of the analysis on representative model plant groups, potential plant impacts were found to differ among small, medium and large size plants Accordingly, no limitations have been established for small plants which process less than 1,816 kkg (2,000 tons) per year and separate limitations have been established for medium and large size plants for each of the twenty-two different types of fruits, the twenty-six different types of vegetables and the ten different specialty products.

A medium size plant has been defined as a plant that processes a total annual raw material production of fruits, vegetables, specialties and other products that is between 1,816 kkg (2,000 tons) per year and 9,080 kkg (10,000 tons) per year. A large plant has a production that exceeds 9,080 kkg (10,000 tons) per year.

SECTION V

WATER USAGE AND WASTE CHARACTERIZATION

INTRODUCTION

Raw waste characteristics were established for each subcategory; first, by making a comprehensive survey of the industry at the individual processing line level; second, by establishing subcategories using certain equity criteria; third, by selecting representative plants in each subcategory; and fourth, by obtaining a statistical representation of these plants for each subcategory. The design and implementation of the survey program was discussed in Section III, and the subcategorization rationale and selection of representative plants in Section IV. This section will present the statistical representation or characterization for each subcategory and discuss the methodology used, including the following points:

Data handling and reduction

Data distributions

Effluent-production correlations

Information was also obtained on treatment system performance and effluent characteristics from many plants and is presented in detail in Section VII and Section IX.

DATA HANDLING AND REDUCTION

Over 500 separate sources of information relating to raw waste load characteristics of the fruit and vegetable processing industry were obtained during this study. These represented over 50,000 individual data points. To handle and analyze this large volume of data, an initial computer assisted information system was developed. One of the principal parts of this system was the computerized data processing subsystem. The key to identifying, storing, sorting, and retrieving data in this system was the eight character "process code". This code uniquely defined the name of the plant from which the data was obtained, the commodity being processed, the origin of the data, the source of the data (historical or wet sample), and whether the data were for raw or treated effluent.

The process code, the key to data identification, was defined as follows. The first two alphabetical characters defined the commodity as listed in Table 17. Information obtained from multi-commodity processes was assigned a special character, an asterisk, in the first place. While multi-commodity information had limited use for characterizing the waste water from a segment of the industry, it was often useful for determining treatment

TABLE 17
ALPHABETICAL CHARACTERS DEFINING COMMODITIES

Apricots - AP
Asparagus - AS
Baby Foods - BF
Beets - BT
Blueberries - BU
Broccoli - BR
Brussels sprouts - BQ
Caneberries - BC
Carrots - CT
Cauliflower - CU
Cherries, brined - CB
Cherries, sweet and sour - CH
Corn - CO
Corn chips - KK
Cranberries - CR
Dehydrated vegetables - DV
Dried fruits - DF
Dry beans, canned - BD
Figs - FG
Garlic - GL
Grapes - GR
Greens - GN
Jams, jellies - JJ
Lima beans - BI
Mayonnaise and salad dressings - SD
Mushrooms - MU
Olives - OL
Onions - ON
Peaches - PC
Pears - PR
Peas - PE
Pickles - PK
Pimentos - PI
Pineapples - PS
Plums - PL
Potato chips - PP
Prunes - PN
Pumpkin and squash - SQ
Raisins - RA
Sauerkraut - SA
Snap beans - BN
Soups - SL
Spinach - SP
Strawberries - SW
Sweet potatoes - ST
Tomatoes - TO
Tomato - starch - cheese - CS
White potatoes - PO
Tortilla Chips - TC

effectiveness for food processing waste. The third and fourth numeric characters defined the name and location of a particular plant and the contract participant who obtained the data. This assignment ensured that different data would not be accidentally assigned the same code. The next four characters further defined the source of the data. A letter "H" in the fifth position represented historical data from a plant, government agency, or literature source. A "W" represented wet sample data collected and analyzed during the study. When data was obtained after treatment, the letter "T" was added, and when data was obtained from more than one point in the treatment system, a numeral was added after the "T". The information associated with each process code was considered to be separate although not necessarily independent. Independent process codes were established for different processing plants. When historical and wet sample data were obtained for the same plant, the data was combined as a single process code. Multiple years of data have been evaluated and only one process code has been established. The number of raw waste samples obtained from each process code can be determined by referring to individual plant tables.

Computer programs proved to be very efficient tools for analyzing and presenting characterization data. The first program was used to list the raw data, sort the data by code, plant name, or state, and calculate estimates of time averages, standard deviations, and observed minimums and maximums of wastewater parameters from individual plants. Listings of all the raw data inputs and tables showing the statistical representation of each plant from each source or point examined in this study are presented in Supplement B. The input data is arranged by the dates and the points where the samples were collected. All the wastewater parameters expected to be obtained during the study were entered and priorities assigned. Since the table format was limited to a standard page size, those parameters with the highest priorities are presented at the top of the table; and if more than ten parameters were available, only those ten with the highest priorities were presented. To achieve relatively consistent table formats, the top five parameters were always presented whether data were available or not.

Data from a plant with several outfalls could be mathematically composited into a single end-of-pipe sample in two ways. Data from sample points which were considered to be correlated were mathematically composited by adding the wasteloads from each point for each day to obtain daily estimates of the total load from these points. These daily composites were then averaged to obtain an estimate of the mean total daily load. This "mean of total daily loads" is a more accurate estimator when the loads at two or more sample points are considered to be correlated; however, the data must be present from each sample point on the same days to perform this correlated calculation. The wasteload for sample points where data was collected infrequently (such as washdown) was considered to be independent of the wasteload from other points. The average load from each of the independent points was computed over all days and then added to the daily average from the other points to determine the overall average.

The summary program provides a statistical characterization of a group of plants used to represent each subcategory. These tables describe the raw waste flow, BOD_5 and TSS for each subcategory. Both the arithmetic and logarithmic mean value are given for 1977. In determining these means, each individual sample was weighed equally. The logarithmic mean values were the raw waste characteristics used in establishing the 1977 limitations. The values listed for 1983 are the logarithmic mean minus one standard deviation. In calculating these values, each plant mean value was weighed equally. These values were the raw waste characteristics used in establishing the 1983 limitations. Each table is identified as a Raw Waste Load Summary, and these values were used as the basis for establishing effluent limitations and costs of pollution control options. This information is given for fruits, vegetables and specialty products in Tables 19-75. The process codes representing the data utilized for each subcategory table are listed at the bottom. An overall summary of the 58 individual subcategory summary tables is listed later in this section under "Raw Waste Load Summary - All Subcategories," Table 18.

DATA DISTRIBUTION ANALYSIS

To determine the natural distribution of the major wastewater parameters, cumulative probability plots were made for certain major commodities using computerized statistical routines. The purpose of these plots was to determine which theoretical probability distribution function (model) best fit the actual data. Once the best probability model is determined, then the best statistical representation can be determined. The first model tried was the standard normal distribution, since the arithmetic average, which is easy to compute, is a good estimator of the mean of this distribution. It was determined that while the normal distribution model was adequate for a few cases, in most cases the range of data was large and tended to be skewed with a few relatively large values. Also, the normal distribution allowed for negative values which do not occur in actuality for the pollution parameters being examined. The log normal distribution has only positive values and is skewed right to allow for a few large values. The set of logarithms of values (log normal distribution) conforms to the normal distribution and thereafter standard, readily available statistical techniques can be employed.

The rationale for selecting the log normal distribution to determine raw waste loads is based on data presented for flow, BOD_5 and TSS for each subcategory in Tables 19-75. The final two columns in each table present values (coefficient of symmetry) which describe the degree of difference between hypothetically perfect normal and log normal distributions and the actual plant data sets, for each pollutant parameter and commodity subcategory. Pollutant parameter mean values with coefficients of symmetry closer to zero more accurately describe the data set distribution. The sign (plus or minus) of the coefficient of symmetry indicates whether the "tails" of the distribution are curved up or down from the hypothetically perfect straight line probability plot.

From the final commodity summaries it was determined that more than 75 percent of the flow ratios and 85 percent of the BOD_5 and TSS ratios were found to be better described by a log normal distribution than by a normal distribution.

EFFLUENT PRODUCTION CORRELATION

A preliminary assumption made for each subcategory was that the wasteloads per unit of production (ratio) did not change with production level. To check this assumption, "scatter diagrams" were developed for some of the major subcategories where there was a significant range of production levels.

Figures 51-54 show scatter diagrams of flow versus production and BOD_5 versus production for corn and green beans, respectively. Figure 52 shows that the individual flow ratios for each canned corn plant are somewhat variable. It also shows that there is a trend among some plants for the flow ratio to decrease as production increases. This is offset, however, by four plants with relatively high water use. The log mean of the ratios for all the plants from the summary table is 1071 gal/ton. The line representing this ratio is drawn on the plot for comparison with the individual plants. It appears that even when using the log mean, the flow rate estimate is conservative and will tend to over-estimate the flow for most plants.

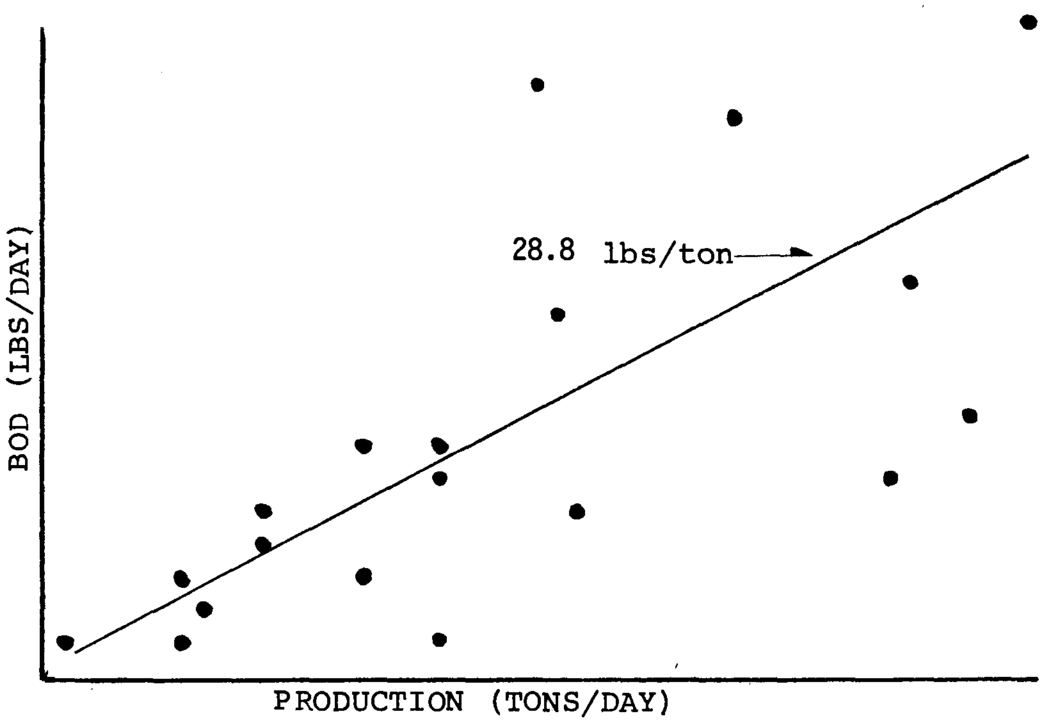
Figure 53 shows three canned green bean plants with relatively low water use, with the rest having much higher water use related to production. The mean flow ratio from the summary table of 3691 gal/ton will underestimate the flow at several plants. However, the figure also shows that there is much room for improvement in water use in this subcategory of the industry.

Figure 51 shows that BOD_5 load from corn processing is reasonably well correlated with production. The mean BOD_5 ratio from the summary table of 28.8 lbs/ton appears to be a good fit to the data with BOD_5 loads being under and over-estimated for about an equal number of plants. The BOD_5 loads are less correlated to production for the canned green bean plants (Figure 54). However, the mean BOD_5 ratio from the summary table of 6.25 lbs/ton appears to be a reasonable fit with an equal number of plants above and below the value.

None of the commodities studied showed a consistent trend for the flow or BOD_5 ratios to be a function of production level.

FIGURE 51

BOD VS. CORN PRODUCTION SCATTER DIAGRAM



FIGURE

FLOW VS. CORN PRODUCTION SCATTER DIAGRAM

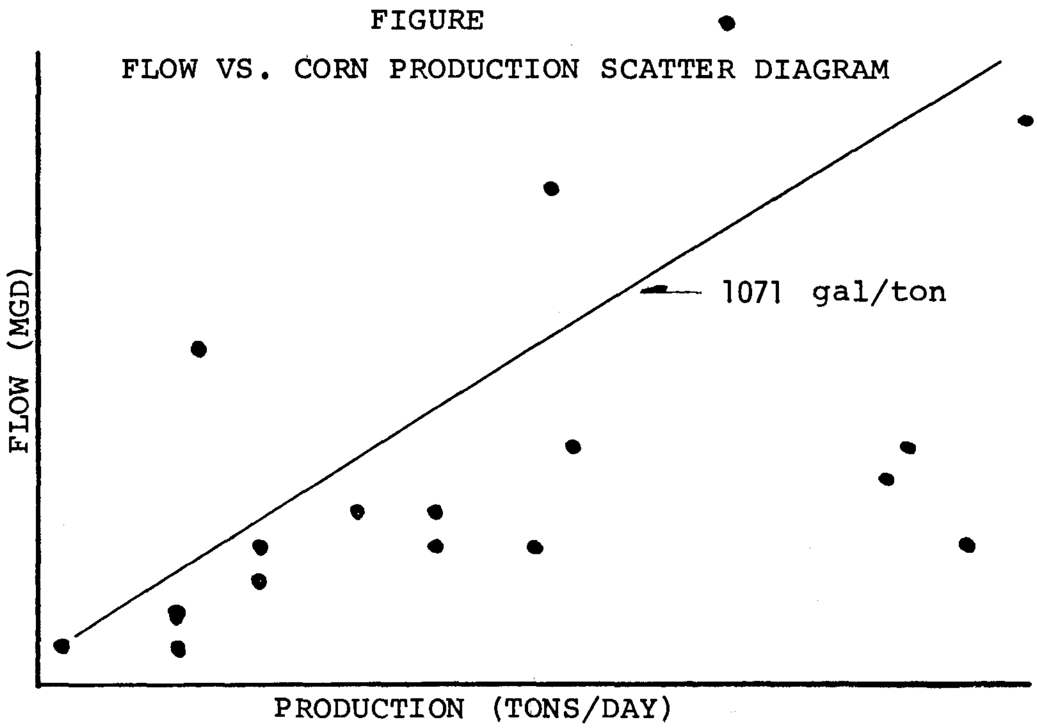
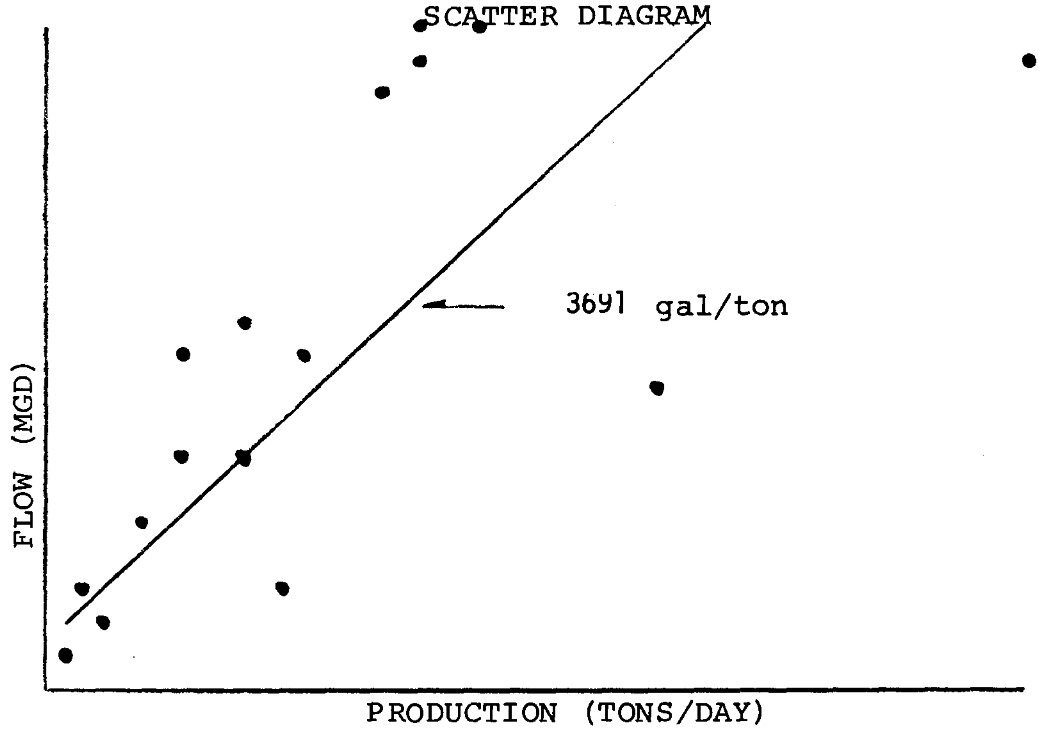


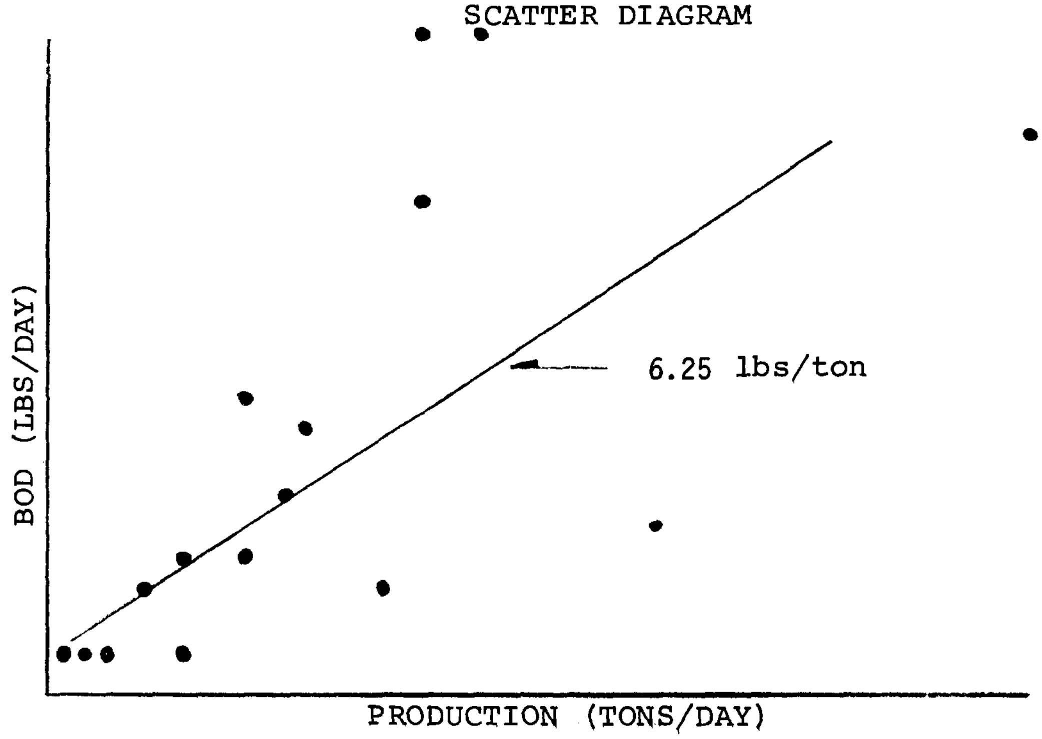
FIGURE 53

FLOW VS. GREEN BEAN PRODUCTION
SCATTER DIAGRAM



FIGURE

BOD VS. GREEN BEAN PRODUCTION
SCATTER DIAGRAM



Therefore, no subcategories were further subdivided based on production.

SUBCATEGORY SUMMARY TABLE

The following subsection presents a summary table (Table 18) which provides the major raw effluent pollution parameters for all of the subcategories. The individual subcategory summary tables follow in Tables 19-75. The form of the tables from which these summary tables were derived was discussed previously in the Data Handling and Reduction subsection.

TABLE 18
RAW WASTE LOAD SUMMARY - ALL SUBCATEGORIES

CATEGORY	FLOW - GAL/TON 1977	FLOW - GAL/TON 1983	BOD - LBS/TON 1977	BOD - LBS/TON 1983	TSS - LBS/TON 1977	TSS - LBS/TON 1983
APRICOTS	5263.	2946.	30.9	26.2	8.49	5.75
CANEBERRIES	1401.	679.7	5.66	3.98	1.17	0.574
SWEET CHERRIES	1863.	1067.	19.3	13.6	1.15	0.653
SOUR CHERRIES	2883.	2591.	34.3	22.4	2.09	1.96
BRINED CHERRIES	4783.	1356.	43.5	42.4	2.88	1.28
CRANBERRIES	2955.	1519.	19.9	17.0	2.85	1.58
DRIED FRUIT	3185.	1701.	24.8	23.7	3.71	2.18
GRAPE JUICE - CANNING	1732.	1479.	21.4	9.73	2.49	2.45
GRAPE JUICE - PRESSING	373.9	270.4	3.81	2.29	0.808	0.632
OLIVES	9156.	5578.	87.4	43.7	15.0	7.39
PEACHES - CANNED	3134.	2456.	28.1	19.7	4.61	5.18
PEACHES - FROZEN	1297.	1069.	23.4	20.2	3.70	2.76
PEARS	2839.	1638.	42.3	24.0	6.51	4.77
PICKLES - FRESH PACKED	2051.	1878.	19.0	5.89	3.82	1.91
PICKLES - PROCESS PACKED	2298.	1481.	36.7	17.2	6.54	1.57
PICKLES - SALTING STATIONS	253.1	76.86	15.9	3.17	0.834	0.432
PINEAPPLES	3133.	2739.	20.6	17.3	5.46	4.89
PLUMS	1193.	744.0	8.23	3.26	0.701	0.254
RAISINS	671.3	393.2	12.1	12.2	3.26	2.27
STRAWBERRIES	3148.	1662.	10.6	8.47	2.72	2.64
TOMATOES - PEELED	2146.	1183.	8.18	6.25	12.3	4.07
TOMATOES - PRODUCTS	1132.	920.7	2.58	2.08	5.33	4.34
ASPARAGUS	16520.	5594.	4.24	0.950	6.85	4.11
BEETS	1212.	802.2	39.4	34.3	7.89	7.53
BROCCOLI	10945.	5433.	19.6	7.65	11.2	4.61
BRUSSELS SPROUTS	8722.	7867.	6.85	5.60	21.6	4.27
CARROTS	2910.	2323.	39.0	30.7	23.9	13.4
CAULIFLOWER	21473.	20469.	10.5	7.60	5.13	3.91
CORN - CANNED	1071.	424.1	28.8	13.2	13.4	5.69
CORN - FROZEN	3194.	2772.	40.4	18.1	11.2	3.07
DEHYDRATED ONION AND GARLIC	4772.	3060.	13.0	10.3	11.8	6.55
DEHYDRATED VEGETABLES	5303.	4756.	15.8	14.2	11.3	10.0
DRY BEANS	4313.	3826.	30.7	15.0	8.80	4.70
LIMA BEANS	6510.	4746.	27.8	12.9	20.7	8.64
MUSHROOMS	5385.	3202.	17.4	13.1	9.60	7.24
ONIONS - CANNED	5516.	4073.	45.1	47.8	18.7	7.94
PEAS - CANNED	4721.	2908.	44.2	40.2	10.8	9.08
PEAS - FROZEN	3483.	2622.	36.6	20.2	9.78	6.21
PIMENTOS	6914.	6114.	54.5	43.0	5.77	4.50
SAUERKRAUT - CANNING	843.3	665.1	7.02	6.95	1.21	1.20
SAUERKRAUT - CUTTING	103.4	74.89	2.49	1.24	0.375	0.198
SNAP BEANS - CANNED	3691.	2631.	6.25	2.96	4.03	1.92
SNAP BEANS - FROZEN	3816.	3437.	12.1	12.0	6.01	6.83
SPINACH - CANNED	9039.	2776.	16.4	7.46	13.0	8.55
SPINACH - FROZEN	7024.	3588.	9.62	4.83	4.06	4.23
SQUASH	1341.	739.8	33.6	7.99	4.56	4.25
SWEET POTATOES	995.2	692.5	60.2	44.8	22.9	23.5
WHITE POTATOES	1992.	758.6	54.6	40.1	74.8	64.0
ADDED INGREDIENTS	-	-	8.00	8.00	-	-
BABY FOOD	1769.	1310.	9.12	8.93	3.20	1.13
CHIPS - CORN	2883.	2883.	70.4	70.4	59.8	59.8
CHIPS - POTATO	5628.	4214.	74.0	39.4	84.4	22.4
CHIPS - TORTILLA	4878.	4878.	59.4	59.4	72.1	72.1
ETHNIC FOODS	3108.	2193.	13.6	12.0	4.81	3.70
JAMS AND JELLIES	631.7	492.0	11.7	10.0	1.94	1.23
MAYONNAISE AND DRESSINGS	551.3	541.5	10.9	10.1	5.13	4.35
SOUPS	7342.	7342.	29.7	29.7	19.5	19.5
TOMATO - STARCH - CHEESE SPECIALTIES	5716.	2370.	9.58	6.49	5.24	5.23

TABLE 19

RAW WASTE LOAD SUMMARY
APRICOTS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	7.	6372.	5263.	2583.	2946.	1.6427	0.0096
	CU.METERS/KKG	7.	26.57	21.94	10.77	12.29		
BOD5	LB/TON	7.	32.9	30.9	26.3	26.2	1.1575	-0.1143
	KG/KKG	7.	16.5	15.5	13.1	13.1		
TSS	LB/TON	7.	9.72	8.49	5.81	5.75	0.9990	0.1206
	KG/KKG	7.	4.86	4.25	2.91	2.88		

<u>Process Codes:</u> AP01W, AP02H, AP03*, AP04H, AP05H, AP09H, AP11H*

TABLE 20

RAW WASTE LOAD SUMMARY
CANEBERRIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	5.	1698.	1401.	662.8	679.7	-0.1375	-1.2455
	CU.METERS/KKG	5.	7.079	5.843	2.764	2.834		
BOD5	LB/TON	5.	7.43	5.66	3.84	3.98	1.4553	-0.1293
	KG/KKG	5.	3.72	2.83	1.92	1.99		
TSS	LB/TON	5.	1.84	1.17	0.255	0.574	3.1130	-0.1633
	KG/KKG	5.	0.922	0.584	0.128	0.287		

<u>Process Codes:</u> BU28H, BU50H, BC50W, BC51*, BC56*

TABLE 21
RAW WASTE LOAD SUMMARY
BRINED CHERRIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	6682.	4783.	699.8	1356.	1.1763	-0.2060
	CU.METERS/KKG	4.	27.86	19.95	2.920	5.655		
BOD5	LB/TON	4.	62.5	43.5	38.8	42.4	1.4664	-0.2545
	KG/KKG	4.	31.3	21.8	19.4	21.2		
TSS	LB/TON	4.	4.86	2.88	0.823	1.28	2.4885	-0.6812
	KG/KKG	4.	2.43	1.44	0.412	0.642		

<u>Process Codes:</u> CB27H*, CB50H, CB51H*, CB52H

TABLE 22
RAW WASTE LOAD SUMMARY
SOUR CHERRIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	3165.	2883.	2676.	2591.	0.8597	0.4646
	CU.METERS/KKG	3.	13.20	12.02	11.16	10.81		
BOD5	LB/TON	3.	39.2	34.3	22.1	22.4	1.1448	0.5520
	KG/KKG	3.	19.6	17.2	11.0	11.2		
TSS	LB/TON	3.	2.48	2.09	1.89	1.96	1.2050	0.5916
	KG/KKG	3.	1.24	1.05	0.947	0.981		

<u>Process Codes:</u> CH50H*, CH57H*, CH60H

TABLE 23
RAW WASTE LOAD SUMMARY
SWEET CHERRIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	2484.	1863.	271.8	1067.	1.2116	0.3367
	CU.METERS/KKG	3.	10.36	7.767	1.134	4.448		
BOD5	LB/TON	3.	21.5	19.3	13.0	13.6	-0.1119	-1.0589
	KG/KKG	3.	10.8	9.66	6.49	6.81		
TSS	LB/TON	3.	1.68	1.15	0.737	0.653	-0.1090	-1.2545
	KG/KKG	3.	0.839	0.575	0.369	0.327		

<u>Process Codes:</u> CH51H, CH54H, CH59W

TABLE 24
RAW WASTE LOAD SUMMARY
CRANBERRIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	6.	3561.	2955.	1275.	1519.	1.7051	0.9270
	CU.METERS/KKG	6.	14.85	12.32	5.316	6.333		
BOD5	LB/TON	6.	23.5	19.9	15.7	17.0	2.4807	1.4260
	KG/KKG	6.	11.8	9.94	7.87	8.51		
TSS	LB/TON	6.	4.16	2.85	1.37	1.58	1.4198	0.0666
	KG/KKG	6.	2.08	1.43	0.687	0.790		

Process Codes: CR01H, CR02H, CR03H, CR04H, CR05H, CR51W

TABLE 25
RAW WASTE LOAD SUMMARY
DRIED FRUIT

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	5.	5455.	3185.	-702.4	1701.	2.9985	0.7655
	CU.METERS/KKG	5.	22.75	13.28	-2.931	7.093		
BOD5	LB/TON	5.	30.0	24.8	24.9	23.7	2.3847	-0.7186
	KG/KKG	5.	15.0	12.4	12.5	11.9		
TSS	LB/TON	5.	7.08	3.71	-0.055	2.18	2.8544	0.5400
	KG/KKG	5.	3.54	1.86	-0.028	1.09		

PROCESS CODES: DF01H*, DF03H*, PN03H, PN04*, PN25H*

TABLE 26

RAW WASTE LOAD SUMMARY

GRAPE JUICE - CANNING

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	2059.	1732.	1454	1479.	1.4573	0.7953
	CU.METERS/KKG	2.	8.587	7.223	6.066	6.168		
BOD5	LB/TON	2.	25.3	21.4	6.07	9.73	0.9058	-0.0108
	KG/KKG	2.	12.7	10.7	3.04	4.87		
TSS	LB/TON	2.	3.02	2.49	2.79	2.45	1.1017	-0.6163
	KG/KKG	2.	1.51	1.25	1.39	1.22		

Process Codes: GR33H, GR50H

TABLE 27

RAW WASTE LOAD SUMMARY

GRAPE JUICE - PRESSING

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	440.8	373.9	264.8	270.4	1.8603	1.1016
	CU.METERS/KKG	4.	1.838	1.559	1.104	1.128		
BOD5	LB/TON	4.	5.19	3.81	1.54	2.29	1.7115	0.7545
	KG/KKG	4.	2.60	1.91	0.77	1.15		
TSS	LB/TON	4.	0.836	0.808	0.614	0.632	0.8097	0.1718
	KG/KKG	4.	0.418	0.404	0.307	0.317		

Process Codes: GR27H, GR34H, GR40H, GR51H

TABLE 28
RAW WASTE LOAD SUMMARY
PEACHES - CANNED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	8.	3497.	3134.	2002	2456.	2.1052	-0.6434
	CU.METERS/KKG	8.	14.58	13.07	8.353	10.24		
BOD5	LB/TON	8.	32.2	28.1	18.0	19.7	2.2360	-1.3675
	KG/KKG	8.	16.1	14.1	9.00	9.88		
TSS	LB/TON	5.	5.54	4.61	5.18	5.18	1.0473	-1.4927
	KG/KKG	5.	2.78	2.31	2.59	2.59		

Process Codes: PC02H, PC05*, PC06W, PC09*, PC10H, PC11H, PC13H, PC50H*

TABLE 29
RAW WASTE LOAD SUMMARY
PEACHES -FROZEN

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	1470.	1297.	825.3	1069.	2.0629	0.7816
	CU.METERS/KKG	2.	6.131	5.408	3.44	4.458		
BOD5	LB/TON	2.	24.9	23.4	20.1	20.2	0.4461	-0.7666
	KG/KKG	2.	12.5	11.7	10.0	10.1		
TSS	LB/TON	2.	6.94	3.70	-0.391	2.76	3.5168	1.2435
	KG/KKG	2.	3.47	1.85	-0.196	1.38		

Process Codes: PC25H, PC30H

TABLE 30
RAW WASTE LOAD SUMMARY
PEARS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	9.	3553.	2839.	648.9	1638.	3.1024	0.5315
	CU.METERS/KKG	9.	14.82	11.84	2.71	6.829		
BOD5	LB/TON	9.	54.3	42.3	23.1	24.0	0.7714	-0.6311
	KG/KKG	9.	27.2	21.2	11.5	12.0		
TSS	LB/TON	7.	11.7	6.51	2.19	4.77	2.5157	-0.2427
	KG/KKG	7.	5.86	3.26	1.10	2.39		

<u>Process Codes</u>: PR06H, PR07H, PR08H, PR50H, PR51H*, PR52H, PR53H*, PR54H, PR55H

TABLE 31
RAW WASTE LOAD SUMMARY
PICKLES - FRESH PACKED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	7.	2229.	2051.	1825.	1878.	0.4288	-0.8582
	CU.METERS/KKG	7.	9.296	8.551	7.612	7.831		
BOD5	LB/TON	7.	26.2	19.0	4.34	5.89	1.2158	-0.5315
	KG/KKG	7.	13.1	9.52	2.17	2.95		
TSS	LB/TON	7.	5.60	3.82	1.91	1.91	2.2874	-0.1356
	KG/KKG	7.	2.80	1.91	0.957	0.954		

Process Codes: CC50H, CC57H, PK26H, PK39H, PK41H, PK50W, PK76H

TABLE 32
RAW WASTE LOAD SUMMARY
PICKLES - PROCESS PACKED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	10.	2780.	2298.	1575.	1481.	2.0542	-0.5502
	CU.METERS/KKG	10.	11.59	9.582	6.568	6.178		
BOD5	LB/TON	10.	48.8	36.7	18.4	17.2	2.8083	-0.0441
	KG/KKG	10.	24.4	18.4	9.22	8.62		
TSS	LB/TON	10.	12.0	6.54	0.050	1.57	3.2362	-0.4452
	KG/KKG	10.	5.99	3.27	0.025	0.785		

Process Codes: PK27H, PK38H, PK40H, PK51H, PK53H, PK54H, PK58, PK77H, PK80*, PK90

TABLE 33

RAW WASTE LOAD SUMMARY

PICKLES - SALTING STATIONS

		1977		1983			
	NUMBER OF PLANTS	ARITHMETIC MEAN	LOG MEAN	ARITHMETIC M-SD	LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW GAL/TON	6.	338.5	253.1	68.41	76.86	0.1683	-0.8199
CU.METERS/KKG	6.	1.412	1.055	0.2853	0.3205		
BOD5 LB/TON	6.	24.1	15.9	1.21	3.17	0.6506	-0.4421
KG/KKG	6.	12.1	7.95	0.60	1.59		
TSS LB/TON	4.	1.09	0.834	0.197	0.432	1.1694	0.4465
KG/KKG	4.	0.546	0.417	0.099	0.216		

Process Codes: CC10H, CC11H, CC12H, CC13H, PK37H, PK42H

TABLE 34

RAW WASTE LOAD SUMMARY

PINEAPPLES

		1977		1983			
	NUMBER OF PLANTS	ARITHMETIC MEAN	LOG MEAN	ARITHMETIC M-SD	LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW GAL/TON	2.	3235.	3133.	2573.	2739.	0.5928	0.4187
CU.METERS/KKG	2.	13.49	13.06	10.73	11.43		
BOD5 LB/TON	3.	22.6	20.6	12.0	17.3	1.6233	0.7038
KG/KKG	3.	11.3	10.3	6.00	8.65		
TSS LB/TON	3.	6.90	5.46	5.07	4.89	0.8915	-1.3042
KG/KKG	3.	3.45	2.73	2.54	2.45		

Process Codes: PS01W, PS02H, PS03H

TABLE 35a
RAW WASTE LOAD SUMMARY
OLIVES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	9911.	9156.	5794.	5578.	-0.5196	-0.6639
	CU.METERS/KKG	3.	41.33	38.18	24.16	23.26		
BOD5	LB/TON	3.	111.	87.4	39.6	43.7	0.5869	-0.3914
	KG/KKG	3.	55.5	43.7	19.8	21.8		
TSS	LB/TON	3.	23.8	15.0	8.11	7.39	1.8524	0.3686
	KG/KKG	3.	11.9	7.49	4.06	3.70		

Process Codes: OL11W, OL12W, OL13W

TABLE 35b
RAW WASTE LOAD SUMMARY
PLUMS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	1460.	1193.	517.5	744.0	2.3645	1.0417
	CU.METERS/KKG	4.	6.087	4.977	2.159	3.103		
BOD5	LB/TON	4.	14.4	8.23	-2.61	3.26	1.2071	0.4276
	KG/KKG	4.	7.20	4.12	-1.31	1.63		
TSS	LB/TON	4.	2.68	0.701	-2.31	0.254	2.6316	1.4789
	KG/KKG	4.	1.34	0.351	-1.15	0.127		

Process Codes: PL50H*, PL52H, PL54H*, PL66M4

TABLE 36
RAW WASTE LOAD SUMMARY
RAISINS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	893.7	671.3	29.35	393.2	2.3125	-0.2279
	CU.METERS/KKG	3.	3.727	2.799	0.1225	1.640		
BOD5	LB/TON	3.	16.5	12.1	11.3	12.2	0.9322	-0.9027
	KG/KKG	3.	8.25	6.04	5.65	6.10		
TSS	LB/TON	3.	4.56	3.26	0.690	2.27	2.2183	-0.4628
	KG/KKG	3.	2.28	1.63	0.345	1.14		

Process Codes: RA02H, RA03H*, RA04H

TABLE 37
RAW WASTE LOAD SUMMARY
STRAWBERRIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	5.	4092.	3146.	1423	1662.	1.7061	0.1971
	CU.METERS/KKG	5.	17.06	13.13	5.937	6.930		
BOD5	LB/TON	5.	13.6	10.6	8.53	8.47	0.9172	-1.0490
	KG/KKG	5.	6.82	5.32	4.27	4.24		
TSS	LB/TON	5.	3.70	2.72	2.46	2.64	1.2420	-0.5220
	KG/KKG	5.	1.85	1.36	1.23	1.32		

Process Codes: SW02H, SW50W, SW51W, SW53H, SW55H

TABLE 38

RAW WASTE LOAD SUMMARY

TOMATOES-PEELED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	15.	2433.	2146.	1115.	1184.	2.1136	0.3642
	CU.METERS/KKG	15.	10.15	8.950	4.651	4.936		
BOD5	LB/TON	14.	9.40	8.18	6.18	6.25	3.7383	-0.0546
	KG/KKG	14.	4.70	4.09	3.09	3.13		
TSS	LB/TON	12.	16.7	12.3	2.88	4.07	4.1342	0.0074
	KG/KKG	12.	8.37	6.17	1.44	2.04		

Process Codes: T002H, T004H, T005H*, T007H, T009H, T012H2, T013H, T015H, T020H*, T023H*, T024H*, T025H, T051H*, T052H*, T095H

TABLE 39

RAW WASTE LOAD SUMMARY

TOMATOES-PRODUCTS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	5.	1290.	1132.	939.2	920.7	2.9093	1.4854
	CU.METERS/KKG	5.	5.381	4.720	3.92	3.84		
BOD5	LB/TON	5.	3.28	2.58	2.67	2.08	2.6042	0.8974
	KG/KKG	5.	1.64	1.29	1.34	1.04		
TSS	LB/TON	5.	6.45	5.33	4.95	4.34	3.8290	0.0842
	KG/KKG	5.	3.23	2.67	2.48	2.17		

Process Codes: T001*, T008H, T012H1, T020W, T080H*

TABLE 40

RAW WASTE LOAD SUMMARY
ASPARAGUS

			1977		1983			
		NUMBER OF PLANTS	ARITHMETIC MEAN	LOG MEAN	ARITHMETIC M-SD	LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	22785.	16520.	486.7	5594.	0.1338	-0.3614
	CU.METERS/KKG	2.	95.01	68.89	2.03	23.33		
BOD5	LB/TON	2.	6.87	4.24	0.656	0.950	0.6937	-0.5354
	KG/KKG	2.	3.44	2.12	0.328	0.475		
TSS	LB/TON	2.	8.79	6.85	3.61	4.11	1.0670	-0.2896
	KG/KKG	2.	4.40	3.43	1.81	2.06		

Process Codes: AS03*. AS05H

TABLE 41

RAW WASTE LOAD SUMMARY
BEETS

			1977		1983			
		NUMBER OF PLANTS	ARITHMETIC MEAN	LOG MEAN	ARITHMETIC M-SD	LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	7.	1605.	1212.	766.8	802.2	1.4440	0.2962
	CU.METERS/KKG	7.	6.693	5.054	3.197	3.345		
BOD5	LB/TON	7.	47.1	39.4	32.8	34.3	1.2757	0.2839
	KG/KKG	7.	23.6	19.7	16.4	17.2		
TSS	LB/TON	6.	11.7	7.89	- 1.39	7.53	3.0565	0.1332
	KG/KKG	6.	5.85	3.95	- 0.695	3.77		

Process Codes: BT28H, BT50*, BT52H, BT53H*, BT54*, BT55H*, BT57*

TABLE 42
RAW WASTE LOAD SUMMARY
BROCCOLI

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	11892.	10945.	5005	5433.	0.3863	-0.2700
	CU.METERS/KKG	3.	49.59	45.64	20.86	22.65		
BOD5	LB/TON	3.	33.0	19.6	2.41	7.65	1.5798	0.6006
	KG/KKG	3.	16.5	9.83	1.21	3.83		
TSS	LB/TON	3.	31.1	11.2	2.03	4.61	2.7817	0.4585
	KG/KKG	3.	15.6	5.59	1.02	2.31		

Process Codes: BR01H, BR02W, BR04H

TABLE 43
RAW WASTE LOAD SUMMARY
BRUSSELS SPROUTS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	8916.	8722.	7313.	7867.	1.9006	1.6516
	CU.METERS/KKG	2.	37.18	36.37	30.51	32.80		
BOD5	LB/TON	2.	8.15	6.85	5.15	5.60	1.5964	-0.0505
	KG/KKG	2.	4.09	3.43	2.57	2.80		
TSS	LB/TON	2.	39.8	21.6	-6.96	4.27	0.6613	-0.4903
	KG/KKG	2.	19.9	10.8	-3.98	2.14		

Process Codes: BQ01W, BQ02H

TABLE 44
RAW WASTE LOAD SUMMARY
CARROTS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	7.	3259.	2910.	2346.	2323.	1.1842	0.3060
	CU.METERS/KKG	7.	13.59	12.13	9.783	9.686		
BOD5	LB/TON	7.	46.6	39.0	31.9	30.7	1.4140	-0.6348
	KG/KKG	7.	23.3	19.5	15.9	15.4		
TSS	LB/TON	6.	40.9	23.9	9.64	13.4	1.5145	-0.4731
	KG/KKG	6.	20.5	12.0	4.82	6.69		

Process Codes: CT01*, CT20H, CT51H*, CT58H, , CT59H*, CT60H*, CT61H*

TABLE 45
RAW WASTE LOAD SUMMARY
CAULIFLOWER

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	21647.	21473.	20446	20469.	0.6706	0.3299
	CU.METERS/KKG	3.	90.27	89.54	85.30	85.36		
BOD5	LB/TON	3.	14.1	10.5	7.52	7.60	0.5968	-0.2127
	KG/KKG	3.	7.07	5.28	3.76	3.80		
TSS	LB/TON	3.	6.85	5.13	−0.231	3.91	3.5065	1.1985
	KG/KKG	3.	3.43	2.57	−0.116	1.96		

Process Codes: CU02W, CU03H, CU50H

TABLE 46
RAW WASTE LOAD SUMMARY
CORN - CANNED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	10.	1306.	1071.	511.8	424.1	1.5675	-0.4506
	CU.METERS/KKG	10.	5.446	4.466	2.134	1.769		
BOD5	LB/TON	10.	38.6	28.8	15.6	13.2	1.1277	-0.1387
	KG/KKG	10.	19.3	14.4	7.78	6.63		
TSS	LB/TON	8.	15.4	13.4	7.50	5.69	0.9721	-0.7965
	KG/KKG	8.	7.71	6.69	3.75	2.85		

<u>Process Codes</u>: C056H2, C061H, C064H, C069H*, C070H*, C075H, C077H, C078H*, C084H*, C085H

TABLE 47
RAW WASTE LOAD SUMMARY
CORN - FROZEN

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	3338.	3194.	2773.	2772.	1.3854	0.7781
	CU.METERS/KKG	3.	13.92	13.32	11.56	11.56		
BOD5	LB/TON	3.	49.0	40.4	10.4	18.1	1.5562	-0.6086
	KG/KKG	3.	24.5	20.2	5.20	9.06		
TSS	LB/TON	3.	15.7	11.2	-1.45	3.07	1.5343	-0.9758
	KG/KKG	3.	7.86	5.60	-0.723	1.54		

<u>Process Codes</u>: C025H, C050H1, C059H2

TABLE 48
RAW WASTE LOAD SUMMARY
DEHYDRATED ONION AND GARLIC

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	5215.	4772.	2064.	3060.	1.8759	1.2720
	CU.METERS/KKG	4.	21.75	19.93	8.61	12.76		
BOD5	LB/TON	4.	14.9	13.0	10.8	10.3	2.0751	0.8750
	KG/KKG	4.	7.47	5.50	5.39	5.16		
TSS	LB/TON	3.	15.5	11.8	1.55	6.55	1.2753	0.4962
	KG/KKG	3.	7.75	5.93	0.778	3.28		

Process Codes: ON01W, ON02H, ON03H, GL02W

TABLE 49
RAW WASTE LOAD SUMMARY
DEHYDRATED VEGETABLES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	5512.	5303.	4764.	4756.	2.4269	1.7501
	CU.METERS/KKG	3.	22.98	22.11	19.87	19.83		
BOD5	LB/TON	3.	17.9	15.8	14.2	14.2	0.5697	-0.9322
	KG/KKG	3.	8.98	7.89	7.12	7.10		
TSS	LB/TON	3.	11.8	11.3	9.88	10.00	0.2485	-0.0324
	KG/KKG	3.	5.89	5.64	4.94	5.00		

Process Codes: DV01H, DV10H, DV11H

TABLE 50
RAW WASTE LOAD SUMMARY
DRY BEANS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	7.	4892.	4313.	3800.	3826.	1.4247	-1.4998
	CU.METERS/KKG	7.	20.40	17.99	15.85	15.96		
BOD5	LB/TON	7.	35.7	30.7	14.9	15.0	1.0737	-0.0417
	KG/KKG	7.	17.8	15.4	7.47	7.50		
TSS	LB/TON	5.	13.6	8.80	-3.09	4.70	2.2047	0.5186
	KG/KKG	5.	6.82	4.40	-1.55	2.35		

Process Codes: BD25H*, BD34H, BD38H, BD48W, BD51H, BD52H, BD54H

TABLE 51
RAW WASTE LOAD SUMMARY
LIMA BEANS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	7164.	651[illegible].	1777	4746.	2.9761	1.9139
	CU.METERS/KKG	3.	29.87	27.15	7.414	19.79		
BOD5	LB/TON	3.	33.5	27.8	7.09	12.9	0.3829	-0.2003
	KG/KKG	3.	16.8	13.9	3.55	6.46		
TSS	LB/TON	3.	26.4	20.7	3.43	8.64	0.5022	-0.3193
	KG/KKG	3.	13.2	10.4	1.71	4.33		

Process Codes: BI03W, BI31W, BI40H

TABLE 52
RAW WASTE LOAD SUMMARY
MUSHROOMS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	7.	6310.	5385.	3405.	3202.	1.3671	-0.2356
	CU.METERS/KKG	7.	26.31	22.46	14.20	13.35		
BOD5	LB/TON	7.	19.9	17.4	14.0	13.1	0.5580	-1.0349
	KG/KKG	7.	9.98	8.73	7.02	6.53		
TSS	LB/TON	7.	10.8	9.60	6.88	7.24	0.8280	-0.2163
	KG/KKG	7.	5.38	4.80	3.45	3.62		

Process Codes: MU01H, MU02H, MU03H, MU04H, MU05H, MU06H, MU07H

TABLE 53
RAW WASTE LOAD SUMMARY
ONIONS - CANNED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	5758.	5516.	4090.	4073.	-0.7450	-0.9118
	CU.METERS/KKG	3.	24.01	23.00	17.06	16.98		
BOD5	LB/TON	3.	53.5	45.1	47.9	47.8	-0.5276	-1.4022
	KG/KKG	3.	26.8	22.6	24.0	23.9		
TSS	LB/TON	3.	25.8	18.7	6.32	7.94	0.0733	-0.6184
	KG/KKG	3.	12.9	9.36	3.16	3.97		

Process Codes: ON26H, ON35H, ON51H

TABLE 54

RAW WASTE LOAD SUMMARY
PEAS - CANNED

	NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW GAL/TON	18.	5896.	4721.	2716.	2908.	1.3842	-0.1823
CU.METERS/KKG	18.	24.59	19.69	11.33	12.13		
BOD5 LB/TON	18.	52.3	44.2	41.5	40.2	1.4226	-1.0446
KG/KKG	18.	26.2	22.1	20.8	20.1		
TSS LB/TON	17.	14.3	10.8	9.32	9.08	2.6562	-0.3283
KG/KKG	17.	7.16	5.38	4.66	4.54		

Process Codes: PE02H, PE26*, PE31H, PE42*, PE53H, PE60H, PE67H*, PE68H*, PE69H*, PE70H*, PE73H, PE75H, PE76H, PE78H*, PE79H*, PE80H*, PE81H, PE85H*

TABLE 55
RAW WASTE LOAD SUMMARY
PEAS - FROZEN

	NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW GAL/TON	5.	4087.	3483.	2473.	2622.	2.0586	0.4019
CU.METERS/KKG	5.	17.04	14.52	10.31	10.93		
BOD5 LB/TON	5.	44.5	36.6	16.4	20.2	1.5454	0.3630
KG/KKG	5.	22.3	18.3	8.22	10.1		
TSS LB/TON	5.	14.0	9.78	5.87	6.21	1.2873	-0.2324
KG/KKG	5.	7.01	4.90	2.94	3.11		

Process Codes: PE27W, PE50*, PE55H*, PE59H*, PE62H

TABLE 56

RAW WASTE LOAD SUMMARY
PIMENTOES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	6967.	6914.	5761.	6114.	—	—
	CU.METERS/KKG	2.	29.05	28.83	24.04	25.50		
BOD5	LB/TON	2.	56.0	54.5	37.6	43.0	—	—
	KG/KKG	2.	28.0	27.3	18.8	21.5		
TSS	LB/TON	2.	5.95	5.77	3.90	4.50	—	—
	KG/KKG	2.	2.98	2.89	1.95	2.25		

PROCESS CODES: PI80H1, PI80H2

TABLE 57
RAW WASTE LOAD SUMMARY
SAUERKRAUT - CANNING

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	959.4	843.3	602.9	665.1	0.9845	0.4848
	CU.METERS/KKG	4.	4.001	3.517	2.515	2.774		
BOD5	LB/TON	4.	8.16	7.02	6.87	6.95	1.7613	-0.0911
	KG/KKG	4.	4.08	3.51	3.44	3.48		
TSS	LB/TON	4.	1.78	1.21	1.25	1.20	3.3326	0.0693
	KG/KKG	4.	0.891	0.606	0.625	0.601		

PROCESS CODES SA02H, SA27A, SA28H, SA51H

TABLE 58
RAW WASTE LOAD SUMMARY
SAUERKRAUT - CUTTING

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	5.	129.0	103.4	66.64	74.89	0.3859	-0.6913
	CU.METERS/KKG	5.	0.5381	0.4311	0.278	0.3123		
BOD5	LB/TON	5.	3.23	2.49	1.33	1.24	0.4548	-0.2402
	KG/KKG	5.	1.62	1.25	0.667	0.622		
TSS	LB/TON	5.	0.599	0.375	0.168	0.198	0.5630	-1.4385
	KG/KKG	5.	0.300	0.188	0.084	0.099		

Process Codes: SA05H, SA06H, SA09H, SA97H, SA98H

TABLE 59
RAW WASTE LOAD SUMMARY
SNAP BEANS - CANNED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	11.	4266.	3691.	2693.	2631.	1.1520	-1.0866
	CU.METERS/KKG	11.	17.79	15.39	11.23	10.97		
BOD5	LB/TON	11.	10.7	6.25	-1.76	2.96	2.4865	-1.1574
	KG/KKG	11.	5.36	3.13	-0.88	1.48		
TSS	LB/TON	11.	6.69	4.03	1.47	1.92	1.8472	-0.9081
	KG/KKG	11.	3.35	2.02	0.736	0.961		

Process Codes: BN25H, BN35H*, BN43H*, BN45W, BN55H, BN58H, BN59H*, BN62H, BN63H*, BN65H*, BN66H*

TABLE 60
RAW WASTE LOAD SUMMARY
SNAP BEANS - FROZEN

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	4162.	3816.	3405.	3437.	0.6061	-0.1476
	CU.METERS/KKG	2.	17.35	15.91	14.20	14.33		
BOD5	LB/TON	2.	14.9	12.1	11.4	12.0	1.9059	-0.2602
	KG/KKG	2.	7.45	6.05	5.7	6.00		
TSS	LB/TON	2.	7.25	6.01	6.82	6.83	2.5625	-0.1367
	KG/KKG	2.	3.63	3.01	3.41	3.42		

Process Codes: BN26H*, BN50H

TABLE 61
RAW WASTE LOAD SUMMARY
SPINACH - CANNED

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	9662.	9039.	3160.	2776.	-1.2185	-2.7242
	CU.METERS/KKG	4.	40.29	37.69	13.18	11.58		
BOD5	LB/TON	4.	18.9	16.4	3.83	7.46	1.0100	-0.1528
	KG/KKG	4.	9.47	8.23	1.92	3.74		
TSS	LB/TON	4.	15.4	13.0	6.84	8.55	0.2775	-1.0941
	KG/KKG	4.	7.73	6.52	3.42	4.28		

<u>Process Codes:</u> SP08H, SP14*, SP53H, SP54H

TABLE 62
RAW WASTE LOAD SUMMARY
SPINACH - FROZEN

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	6.	9106.	7024.	3129.	3588.	0.5056	-0.5778
	CU.METERS/KKG	6.	37.97	29.29	13.05	14.96		
BOD5	LB/TON	6.	15.0	9.62	4.48	4.83	1.9739	-0.8803
	KG/KKG	6.	7.49	4.82	2.24	2.42		
TSS	LB/TON	5.	9.62	4.06	4.34	4.23	2.9356	0.1320
	KG/KKG	5.	4.82	2.03	2.17	2.12		

<u>Process Codes:</u> SP05W, SP06H, SP13H, SP25H, GN80W, GN90H

TABLE 63
RAW WASTE LOAD SUMMARY
SQUASH

			1977		1983			
		NUMBER OF PLANTS	ARITHMETIC MEAN	LOG MEAN	ARITHMETIC M-SD	LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	1620.	1341.	-128.6	739.8	3.3152	2.1982
	CU.METERS/KKG	4.	6.756	5.592	-0.5364	3.085		
BOD5	LB/TON	4.	38.6	33.6	5.92	7.99	0.4285	-1.6181
	KG/KKG	4.	19.3	16.8	2.96	4.00		
TSS	LB/TON	4.	5.88	4.56	3.27	4.25	2.7613	0.3345
	KG/KKG	4.	2.94	2.28	1.64	2.13		

Process Codes: SQ01H, SQ26H*, SQ50H, SQ51H

TABLE 64
RAW WASTE LOAD SUMMARY
SWEET POTATOES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	1278.	995.2	505.2	692.5	1.9820	0.5004
	CU.METERS/KKG	4.	5.329	4.150	2.11	2.888		
BOD5	LB/TON	4.	85.1	60.2	22.7	44.8	1.4663	0.1152
	KG/KKG	4.	42.6	30.2	11.4	22.4		
TSS	LB/TON	4.	46.6	22.9	11.3	23.5	1.5561	-0.9870
	KG/KKG	4.	23.3	11.4	5.65	11.8		

Process Codes: ST25H1, ST30H*, ST40*, ST70H

TABLE 65
RAW WASTE LOAD SUMMARY
WHITE POTATOES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	2550.	1992.	827.7	758.6	-0.4033	-0.6239
	CU.METERS/KKG	3.	10.63	8.305	3.452	3.163		
BOD5	LB/TON	3.	56.3	54.6	39.3	40.1	0.1429	-0.0432
	KG/KKG	3.	28.2	27.3	19.7	20.1		
TSS	LB/TON	3.	75.7	74.8	61.1	64.0	0.5280	0.4698
	KG/KKG	3.	37.9	37.4	30.6	32.0		

Process Codes: P045H, P050H, P051H

TABLE 66

COMPOSITION OF COMMON ADDED INGREDIENTS

Sauce (Prin. Ingr.)	Protein (Percent)	Fat (Percent)	Carbohydrate (Percent)	Raw BOD	
				kg/kkg	(lb/ton)
Butter	0.6	81.0	0.4	7.3	14.6
Cheese	16.0	21.4	8.2	4.1	8.2
Salad Oil	---	100.0	---	8.9	17.8
Starch	0.3	---	87.6	6.1	12.2
Sugar	---	---	99.5	6.9	13.8
Tomato	2.5	0.3	24.8	2.0	4.0
Wheat	13.3	2.0	71.0	6.3	12.6
			Typical Sauce BOD Composition	8.0	16.0

TABLE 67
RAW WASTE LOAD SUMMARY
BABY FOOD

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	2002.	1769.	1263	1310.	2.3467	-1.1927
	CU.METERS/KKG	2.	8.350	7.376	5.269	5.463		
BOD5	LB/TON	2.	12.0	9.12	8.78	8.93	1.3207	-0.8280
	KG/KKG	2.	5.99	4.56	4.39	4.47		
TSS	LB/TON	2.	6.35	3.20	0.056	1.13	2.6574	-0.3482
	KG/KKG	2.	3.18	1.60	0.028	0.567		

Process Codes: BF01H*, BF26W

TABLE 68
RAW WASTE LOAD SUMMARY
CHIPS - CORN

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	1	2883.	2883.	2883.	2883.	--	--
	CU.METERS/KKG		12.03	12.03	12.03	12.03		
BOD5	LB/TON	1	78.2	70.4	78.2	70.4	0.9902	0.3550
	KG/KKG		39.1	35.2	39.1	35.2		
TSS	LB/TON	1	66.6	59.8	66.6	59.8	1.6896	-0.1275
	KG/KKG		33.3	39.9	33.3	39.9		

Process Codes: KK01H

TABLE 69
RAW WASTE LOAD SUMMARY
CHIPS - POTATO

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	5.	1497.	1407.	958.8	1053.	1.2209	0.5109
	CU.METERS/KKG	5.	6.244	5.867	4.000	4.393		
BOD5	LB/TON	5.	22.3	18.5	7.40	9.85	1.3213	-0.7748
	KG/KKG	5.	11.2	9.28	3.70	4.93		
TSS	LB/TON	5.	30.2	21.1	7.09	5.60	1.5099	-1.4686
	KG/KKG	5.	15.1	10.6	3.55	2.80		

<u>Process Codes</u>: PP25H*, PP26H*, PP27H*, PP28H*, PP80H

TABLE 70
RAW WASTE LOAD SUMMARY
CHIPS - TORTILLA

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	1	4878	4878	4878	4878	—	—
	CU.METERS/KKG		20.35	20.35	20.35	20.35		
BOD5	LB/TON	1	65.0	59.4	65.0	59.4	1.0360	-0.0684
	KG/KKG		32.5	29.7	32.5	29.7		
TSS	LB/TON	1	84.5	72.1	84.5	72.1	-0.1713	-1.3186
	KG/KKG		42.2	36.1	42.2	36.1		

<u>Process Codes</u>: TC01H

TABLE 71

RAW WASTE LOAD SUMMARY
ETHNIC FOODS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	3232.	3108.	2166.	2193.	-0.0968	-0.2891
	CU.METERS/KKG	3.	13.48	12.96	9.032	9.144		
BOD5	LB/TON	3.	13.7	13.6	11.6	12.0	0.5280	0.4831
	KG/KKG	3.	6.84	6.79	5.80	6.01		
TSS	LB/TON	3.	5.13	4.81	2.74	3.70	0.7057	0.7041
	KG/KKG	3.	2.57	2.41	1.37	1.85		

Process Codes: ET01H, ET02H, ET03H

TABLE 72

RAW WASTE LOAD SUMMARY
JAMS AND JELLIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	2.	670.2	631.7	405.9	492.0	0.8465	0.7387
	CU.METERS/KKG	2.	2.795	2.634	1.693	2.052		
BOD5	LB/TON	2.	13.0	11.7	9.89	10.0	-0.2603	-1.1062
	KG/KKG	2.	6.51	5.85	4.94	5.02		
TSS	LB/TON	2.	2.86	1.94	0.725	1.23	1.8688	0.8161
	KG/KKG	2.	1.43	0.973	0.363	0.616		

Process Codes: JJ51H, JJ01H

TABLE 73
RAW WASTE LOAD SUMMARY
MAYONNAISE AND DRESSINGS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	3.	614.8	551.3	535.2	541.5	2.9804	0.8319
	CU.METERS/KKG	3.	2.564	2.299	2.233	2.258		
BOD5	LB/TON	3.	13.5	10.9	9.80	10.1	2.9835	0.8322
	KG/KKG	3.	6.75	5.46	4.90	5.08		
TSS	LB/TON	3.	5.75	5.13	3.92	4.35	1.5640	0.3707
	KG/KKG	3.	2.88	2.57	1.96	2.18		

Process Codes: SD01H, SD02H, SD03H*

TABLE 74
RAW WASTE LOAD SUMMARY
SOUPS

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	1	7342.	7342.	7342.	7342.	3.1623	3.1623
	CU.METERS/KKG		30.62	30.62	30.62	30.62		
BOD5	LB/TON	1	30.4	29.7	30.4	29.7	-1.3029	-1.7017
	KG/KKG		15.2	14.9	15.2	14.9		
TSS	LB/TON	1	21.4	19.5	21.4	19.5	1.9329	1.3200
	KG/KKG		10.7	9.78	10.7	9.78		

Process Codes: SL01H

TABLE 75

RAW WASTE LOAD SUMMARY
TOMATO - STARCH - CHEESE SPECIALTIES

		NUMBER OF PLANTS	1977 ARITHMETIC MEAN	1977 LOG MEAN	1983 ARITHMETIC M-SD	1983 LOG M-SD	ARITHMETIC COEFF. OF SYMMETRY	LOG COEFF. OF SYMMETRY
FLOW	GAL/TON	4.	6286.	5716.	2148.	2370.	1.6053	-0.0654
	CU.METERS/KKG	4.	26.21	23.84	8.96	9.883		
BOD5	LB/TON	4.	17.1	9.58	5.85	6.49	2.1078	-1.4767
	KG/KKG	4.	8.54	4.79	2.93	3.25		
TSS	LB/TON	3.	7.33	5.24	5.28	5.23	0.1654	-0.3395
	KG/KKG	3.	3.67	2.62	2.64	2.62		

Process Codes: CS01H, CS03H, CS04H1, CS50H1

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

WASTEWATER PARAMETERS OF POLLUTIONAL SIGNIFICANCE

The wastewater parameters of major pollutional significance to the fruit and vegetable processing industry are: five-day (20°C) biochemical oxygen demand (BOD5), total suspended solids (TSS), oil and grease (O&G), fecal coliforms, and pH. Of peripheral or occasional importance are chemical oxygen demand (COD), nitrogen, phosphorus, total dissolved solids, and temperature.

RATIONALE FOR SELECTION OF MAJOR PARAMETERS

Biochemical Oxygen Demand

Two general types of pollutants can exert demand on the dissolved oxygen regime of a body of receiving water. These are: (1) chemical species which exert an immediate dissolved oxygen demand (IDOD) on the water body due to chemical reactions; and (2) organic substances which indirectly cause a demand to be exerted on the system because indigenous microorganisms utilizing the organic wastes as substrate flourish and proliferate, their natural respiratory activity utilizing the surrounding dissolved oxygen. Fruit and vegetable wastes, because of natural sugars, contain constituents that exert an immediate demand on receiving water. These products contain levels of organics such that their strengths are most commonly measured by the BOD5 test.

The biochemical oxygen demand is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The term "decomposable" may be interpreted as meaning that the organic matter can serve as food for the bacteria, and energy is derived from this oxidation.

The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Fruit and vegetable processing and other organic effluents exert a BOD during their processes of decomposition which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

The BOD5 test may be considered as a wet oxidation procedure in which the living organisms serve as the medium for oxidation of the organic matter to carbon dioxide and water. A quantitative relationship exists between the amount of oxygen required to convert a definite amount of any given organic compound to carbon dioxide, water, and ammonia, and this can be represented by a generalized equation. On the basis of this relationship it is possible to interpret BOD5 data in terms of organic matter as well as in terms of the amount of oxygen used during its oxidation. This concept is fundamental to an understanding of the rate at which BOD5 is exerted.

The BOD5 test is widely used to determine the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require within the first five-day period if discharged into natural watercourses in which aerobic conditions exist. The test is one of the most important in stream pollution control activities. By its use, it is possible to determine the degree of pollution in streams at any time. This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacities of receiving bodies of water.

The BOD5 test (Standard Methods, 1971; Methods of the Chemical Analysis of Water and Wastes, 1971) is essentially a bioassary procedure involving the measurement of oxygen consumed by living organisms while utilizing the organic matter present in a waste under conditions as similar as possible to those that occur in nature. Since this is a bioassay procedure, it is extremely important that environmental conditions be suitable for the living organisms to function in an unhindered manner at all times. This requirement means that toxic substances must be absent and that accessory nutrients needed for microbial growth (such as nitrogen, phosphorus, and certain trace elements) must be present. Biological degradation of organic matter under natural conditions is brought about by a diverse group of organisms that carry the oxidation essentially to completion (i.e., almost entirely to carbon dioxide and water). Therefore, it is important that a mixed group of organisms commonly called "seed" be present in the test. For most industrial wastes, this "seed" should be allowed to adapt to the particular waste ("acclimate") prior to introduction of the culture into the "BOD bottle." In order to make the test quantitative, the samples must be protected from the air to prevent reaeration as the dissolved oxygen level diminishes. In addition, because of the limited solubility of oxygen in water (about nine mg/l at 20°C), strong wastes must be diluted to levels of demand consistent with this value to ensure that dissolved oxygen will be present throughout the period of the test.

The oxidative reactions involved in the BOD_5 test are results of biological activity, and the rate at which the reactions proceed is governed to a major extent by population numbers and temperature. Temperature effects are held constant by performing the test at 20°C, which is more or less a median value for natural bodies of water. The predominant organisms responsible for the stabilization of most organic matter in natural waters are native to the soil.

The rate of their metabolic processes at 20°C and under the conditions of the test (total darkness, quiescence, etc.) is such that time must be reckoned in days. Theoretically, an infinite time is required for complete biological oxidation of organic matter, but for all practical purposes the reaction may be considered to be complete in 20 days. A BOD test conducted over the 20 day period is normally considered a good estimate of the "ultimate BOD." However, a 20 day period is too long to wait for results in most instances. It has been found by experience with domestic sewage that a reasonably large percentage of the "ultimate" or total BOD is exerted in five days. Consequently, the test has been developed on the basis of a 5-day incubation period. It should be remembered, therefore, that BOD_5 values represent only a portion of the total BOD. The exact percentage depends on the character of the "seed" and the nature of the organic matter and can be determined only by experiment. In the case of domestic and some industrial wastewaters, it has been found that the BOD_5 value is about 70 to 80 percent of the ultimate BOD.

Total Suspended Solids

This parameter measures the suspended material that can be removed from the wastewaters by laboratory filtration but does not include coarse or floating matter that can be screened or settled out readily. Suspended solids are a vital and easily determined measure of pollution and also a measure of the material that may settle in tranquil or slow-moving streams. Suspended solids in the raw wastes from fruit and vegetable processing plants correlate well with BOD_5 and COD. Often, high levels of suspended solids are the primary parameters for measuring the effectiveness of solids removal systems such as screens, clarifiers, and flotation units.

Oil and Grease

The standard method for determining the oil and grease level in a sample involves multiple solvent extraction of the filterable portion of the sample with trichlorotriflouroethane (Freon) in a Soxhlet extraction apparatus. As cautioned in Standard Methods, (1971) this determination is not an absolute measurement producing solid, reproducible, quantitative results. The method measures, with various accuracies, fatty acids, soaps, fats, waxes, oil, and any other material which is extracted by the solvent from an acidified sample and which is not volatilized during evaporation of the solvent. Of course the initial assumption is that the oils and greases are separated from the aqueous phase of the sample in the initial filtration step. Acidification of the sample is said to greatly enhance recovery of the oils and grease therein (Standard Methods, 1971).

Fecal Coliforms

Fecal coliforms are used as an indicator since they have originated from the intestinal tract of warm blooded animals. Their presence in water indicates the potential presence of pathogenic bacteria and viruses.

The presence of coliforms, more specifically fecal coliforms, in water is indicative of fecal pollution. In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms, pathogenic to humans and animals, may be carried in surface water, particularly that derived from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentary, *Salmonella* gastroenteritis, typhoid, and paratyphoid fevers, leptospirosis, chlorea, vibriosis, and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of *Salmonella*, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops, and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of *Salmonella* was 53.5 percent.

pH, Acidity, and Alkalinity

The pH, depending upon the process involved, can be of significance, especially in terms of treatability. Acidic pH conditions (pH of five or lower) may be produced during the slicing, grinding, or macerating processes of the various commodities dealt with in this document. For example, the discharge of wastewater from steam peeled carrots and blanched prunes was observed to be acidic enough to require treatment with lime before final plant discharge.

In discussions in Section III, it was shown that most peeling processes involve the use of lye (sodium hydroxide), a very powerful alkaline substance. The exposure of various commodities to hot lye and the subsequent removal of the peel with water sprays can contribute significantly to producing an effluent stream with a pH of nine or more. In this case, neutralization with an inorganic acid is necessary prior to final plant discharge. The pH of the wastewater then should be returned to its normal range before discharge. The effect of chemical additions for pH adjustment should be taken into consideration, as new pollutants could result. Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis, and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of seven, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below six are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to seven. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH. The lacrimal fluid of the human eye has a pH of approximately seven and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Minor Parameters

Of the minor parameters mentioned in the introduction to this section, five were listed - chemical oxygen demand (COD), nitrogen, phosphorus, temperature, and total dissolved solids. At no time during the course of this study was phosphorus found to be of significance. Furthermore, phosphorus levels are sufficiently low to be of very little importance, except under only the most stringent conditions, i.e., those involving eutrophication which dictate some type of tertiary treatment system.

Agricultural chemicals and pesticides are known to exist in wastes waters from fruit and vegetable processing plants, primarily in the initial wash of the raw commodities needed to remove surface residuals. However, available information including analyses of various fruits and vegetables indicated low levels of pesticides in process wastewaters in comparison to recommended allowable levels (Water Quality Criteria - 1972). At the present time, therefore, pesticides are not considered significant pollutants in the fruit, vegetable and specialty industry.

Chemical Oxygen Demand

The chemcial oxygen demand (COD) represents an alternative to the biochemical oxygen demand, which in many respects is superior. The test is widely used and allows measurement of a waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water under severe chemical and physical conditions. It is based on the fact that all organic compounds, with a few exceptions, can be oxidized by the action of strong oxidizing agents under acid conditions.

During the COD test, organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substances; for instance, glucose and lignin are both oxidized completely. As a result, COD values are greater than BOD_5 values and may be much greater when significant amounts of biologically resistant organic matter are present. In the case of fruit and vegetable processing wastes, this does not present a problem.

One drawback of the COD test is its inability to demonstrate the rate at which the biologically active material would be stabilized under conditions that exist in nature. In the case of fruit and vegetable processing wastes, this same drawback is applicable to the BOD_5 test, because the soluble nature of fruit and vegetable processing wastes lends them to more rapid biological oxidation than domestic wastes. Therefore, a single measurement of the biochemical oxygen demand at a given point in time (five days) is no indication of the difference between these two rates.

Another drawback of the chemical oxygen demand is analogous to a problem encountered with the BOD: high levels of chloride interfere with the analysis. Normally, 0.4 grams of mercuric sulfate are added to each sample being analyzed for chemical oxygen demand. This eliminates the chloride interference in the sample up to a chloride level of 40 mg/l. At concentrations above this level, further mercuric sulfate must be added. However, studies indicated that above certain chloride concentrations the added mercuric sulfate itself causes interference.

The major advantage of the COD test is the short time required for evaluation. The determination can be made in about three hours rather than the five days required for the measurement of BOD. Furthermore, the COD requires less sophisticated equipment, less highly-trained personnel, a smaller working area, and less investment in laboratory facilities. Another major advantage of the COD test is that the seed used in the BOD_5 test to inoculate the culture should have been acclimated for a period of several days, using carefully prescribed procedures, to assure that the normal lag time (exhibited by all microorganisms when subjected to a new substrate) can be minimized.

For the above reasons the contractor recommends that COD be considered the primary pollutant parameter for measurement of organics in fruit and vegetable processing wastes. The effluent limitations recommended, however, will still be in terms of five-day BOD_5 (since insufficient information is available on the COD monitored after treatment systems are installed) such that sufficient information can be generated to allow conversion from BOD_5 to COD in the future.

Nitrogen

The amount of nitrogen present in fruit and vegetable processing wastes is important principally because of its low levels. Nitrogen is required by all forms of life as a major constituent of protein and several other biomolecules. Most treatment and/or disposal methods of fruit and vegetable wastes involve some form of biological stabilization of the organic matter present. This biological activity and the resulting waste stabilization are greatly inhibited if sufficient nitrogen for microorganism growth is not present. This is a problem with fruit and vegetable wastes which normally have high concentrations of carbohydrates but low levels of nitrogen. In order to get adequate waste stabilization, it may be necessary to add nitrogen to the waste. This added nitrogen must be carefully controlled so that excesses are not discharged to receiving streams. Excess nitrogen in receiving waters may cause an oxygen demand when the ammonia is oxidized, and it may enhance eutrophication in waters where nitrogen is the limiting element.

The forms of nitrogen important to living organisms are ammonia, organic nitrogen, nitrite, and nitrate. Nitrite and nitrate concentrations in fruit and vegetable processing wastes are insignificant. Thus, only ammonia nitrogen and organic nitrogen are important.

The total kjeldahl nitrogen test as outlined in Standard Methods (1971) was used to monitor nitrogen levels both to show any nitrogen deficiency that would affect treatment and any excess that could affect the receiving water. Total kjeldahl nitrogen (TKN) includes both ammonia nitrogen and organic nitrogen. Since nitrogen is not a major pollutant released by fruit and vegetable processors, it is sufficient to report total kjeldahl nitrogen rather than organic and ammonia nitrogen separately.

Temperature

Temperature is important in those unit operations involving transfer of significant quantities of heat. These include evaporation, cooking, cooling of condensers, and the like. The temperature of the waste from a unit operation may be relatively high; however, the temperature of the total effluent is generally not significant.

Total Dissolved Solids

Total dissolved solids are a measure of dissolved inorganic salts and solublized organics. Relative to inorganics, a high TDS level may indicate an excessive discharge of salt brine. High TDS levels may also be predictors of high BOD_5 levels in as much as the organic fractions dissolved are generally natural sugars from the various fruits and vegetables. These levels, however, must be compared with natural water supplies which in some cases inherently contain TDS levels in excess of 1,000 mg/l. For this reason, the TDS test would be used as an indicator and not a control tool.

The presence of chloride ion in the waters emanating from pickle, sauerkraut, olive, and other brine vegetable processing plants is frequently of significance when considering biological treatment of the effluent. These discharges must be considered in the light of intermittent and fluctuating processes.

Aerobic biological systems can develop a resistance to high chloride levels, but to do this they must be acclimated to the specific chloride level expected to be encountered. The subsequent chloride concentrations should remain within a fairly narrow range in the treatment plant influent, either through in-plant control of brine dumps, or through flow equalization of brine waste streams before discharge to the treatment plant. If chloride levels fluctuate widely, the resulting shock loadings on the biological system will reduce its efficiency at best, and possibly prove fatal to the majority of the microorganisms in the system at worst. For this reason, in situations where biological treatment is anticipated or is currently being practiced, measurement of chloride ion content must be included in the list of parameters to be routinely monitored. The argentometric method was used to determine chloride concentrations for this study.

Flow

In the fruit and vegetable processing industry, as a general rule, the amount of pollutant dissolved or suspended in a wastewater stream is a function of the contact time between the product and the water. Minimizing contact time minimizes pollution. Therefore, it is important to note water usage and to minimize it.

Furthermore, the effluent guidelines listed in this document are based on weight of waste produced per unit of raw material or finished production weight. This conversion requires knowledge of the wastewater flows at the time of sampling.

For these reasons and reasons of design, it is necessary to monitor wastewater flows in fruit and vegetable processing plants. On a non-routine basis, flows can be measured using the "bucket and stopwatch" technique or the "float and stopwatch" technique or (in certain cases) a portable flow meter may be employed. For permanent installations, flow measurement in a Parshall flume having unrestricted discharge is recommended.

Production

The production rate at the time the flows and waste concentrations are taken is required to determine the waste produced per unit of production. In almost all cases it has been found to be best to measure the rate at which the raw product enters the plant rather than the final product leaving. Canned specialties are an exception, however, because of the many ingredients in each formula and the fluctuating production schedules employed. The specialties' raw waste loads and effluent limitations were therefore defined in terms of finished product, except for soups. In the vegetables segment, limitations based upon final product have been found to be more meaningful only for the cauliflower subcategory.

ANALYTICAL METHODS

The analytical methods for the samples collected for this project were based on Standard Methods for the Examination of Water and Wastewater, 13th Edition (1971), and Methods for the Chemical Analysis of Water and Wastes, EPA (1971). There were a few minor modifications, since the organic content of the samples were extremely variable from one to another (e.g., less than one to BOD_5 of more than 20,000 mg/l). A brief description of the analytical method follows.

Total Suspended Solids

Total suspended solids is reported in terms of screened solids and suspended solids. Screened samples were obtained from 20 mesh Tyler screen oversize particles and suspended solids by filtering the undersize through a 4.2 cm Whatman GF/C glass fiber filter. The screened and filtered solids were dried in an oven for one hour at about 104°C before weighing.

Five-Day BOD

BOD_5 was determined according to *Standard Methods* (1971). For samples with BOD_5 of higher than 20 mg/l, at least three different dilutions were made for each sample. The results among the different dilutions were generally less than 6 percent. The data reported were the average values of the different dilutions. For samples with BOD_5 of less than 20 mg/l, one or two dilutions with two duplicate bottles were incubated. Most of replicates in this low range were within ± 5 percent, but some had as much as ± 30 percent difference. Seed for this dilution water was taken from the primary clarifier effluent from domestic sewage. It was rough filtered to remove any large particles prior to use.

Chloride

Chloride levels in the samples were determined for the purpose of making corrections for COD test. The argentometric method was used. Samples were adjusted to a pH of seven to eight and after addition of potassium chromate indicator, were titrated with 0.282 N silver nitrate solution.

Since chloride correction was not necessary when the chloride level was below 1,000 mg/l, a special screening technique was developed to sort out those samples with a chloride level of less than 1,000 mg/l. One ml of samples was pipetted into a small beaker and diluted to ten ml with distilled water. Three drops of phenolphthalein and 0.5 N sodium hydroxide were added dropwise until a pink color persisted. Then the sample was neutralized with 0.02 N sulfuric acid dropwise until the indicator showed a very faint pink color. This would make the sample pH about eight. To this, 1.0 ml of 0.0282 N silver nitrate was added. When the chloride level was less than 1,000 mg/l, a definite reddish silver chromate precipitate was formed. The chloride level in these samples was reported as less than 1,000 mg/l, and no further precise determination was pursued. When the chloride level was higher than 1,000 mg/l, the red precipitate would not form when 1.0 ml of silver nitrate was added. In this case, the sample was titrated with 0.0282 N silver nitrate solution with a semimicroburet until the end point.

Chemical Oxygen Demand

COD tests were based on *Standard Methods* (1971). When the chloride content was less than 2,000 mg/l, 0.4 g of mercuric sulfate was added to the refluxing flask. Chloride levels higher than 2,000 mg/l were always accompanied by very high COD levels, e.g., pickle processing wastes. It was necessary for analytical purposes to dilute these strong wastes which subsequently reduced the chloride levels to less than 2,000 mg/l.

Total Dissolved Solids

Total dissolved solids were determined by evaporating a portion of the filtered liquor resulting from the removal of the suspended solids. A known volume of liquid was placed into an evaporating dish which in turn was transferred to a steam bath until the liquid was completely evaporated. Standard Methods (1971), with EPA modification, called for subsequent final drying in an air convection oven at 180°C to constant weight. However, with this method employed, many of the samples "charcoaled" because of their high carbohydrate content. In order to prevent this pyrolytic breakdown, therefore, it was necessary to reduce the drying temperature and time to 105°C and four to six hours, respectively.

Oil and Grease

Oil and grease were determined by Soxhlet extraction using Freon 113 as the solvent, according to Standard Methods, (1971). All samples were acidified at the sampling site with sulfuric acid to a pH of less than two.

Total Kjeldahl Nitrogen

Total kjeldahl nitrogen (TKN) was determined according to Standard Methods (1971). Basically, the test consists of digesting the sample by boiling it with sulfuric acid, potassium sulfate, and mercuric sulfate catalyst to convert the organic nitrogen to ammonia. The digested solution is then made basic with a sodium hydroxide-sodium thiosulfate reagent. The ammonia is then distilled and measured by titrating with sulfuric acid or by Nesslerization. If ammonia is distilled off before digestion, it must be measured and added to the organic nitrogen from digestion to give total kjeldahl nitrogen. Concentrations are reported in mg/l of nitrogen.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

INTRODUCTION

In Section V, determination has been made of the wastewater volume and pollutant concentrations generated by the various subcategories of the industry. In this section of the study, the alternate treatment technologies applicable to these wastes are considered. To the maximum extent possible, it will be shown that a variety of different treatment systems are being successfully used to produce exemplary results-this in order to give individual plants a variety of alternatives from which the most cost-effective method can be selected which best fits its unique situation. In Section VIII, a method of costing various treatment unit process chains is presented.

The modular approach to treatment is used in this section in order to allow the evaluation of alternate treatment chains, both as to probable treatment efficiency and average cost. There are sixteen treatment modules presented, ranging from screens to advanced tertiary treatment. Some of the modules, e.g., lagoons, have several variations described.

Numerous factors bear upon the selection of an optimum treatment system. The significance of each factor will depend upon the circumstances of the individual plant. For example, one plant may have an abundance of inexpensive land available that is suitable for land treatment or lagoon treatment, while another plant has no such land available. In addition to land availability and cost, other factors to be considered include:

- Seasonality of plant operation
- Total volume, average daily volume, maximum daily volume
- Range of important effluent characteristics such as BOD_5, TSS, pH, etc.
- Range of treatment system operating temperature to be expected in processing plant's climate
- Reliability required, i.e., how often and how long could treatment systems failure be tolerated
- Skill of operating personnel
- Interest of plant management
- Other environmental factors such as energy required, noise, odor, solids residue disposal, etc.
- Distance to available municipal system and long term operating/surcharge cost trade-offs
- Distance to available land
- And the treatment efficiencies of various alternate treatment systems

IN-PLANT CONTROL TECHNOLOGY

The food industry, through its large corporate research facilities and allied organizations, has spent considerable effort dedicated to the reduction of in-plant waste. As a result of this effort, progress has been made in the development of important new alternate methods of accomplishing certain process steps and in increasing management awareness of the importance of personnel education.

This section of the report discusses methods for reducing waste generation by means of changes in unit processes. Each category and/or commodity is not discussed separately since the methods discussed are generally applicable to more than one commodity.

Harvesting-Transportation

Food processing, when viewed on an overall basis, begins with the planting of the various crops or the maintenance of existing crops. The harvesting operations have been designed to yield the maximum amount of fruits or vegetables while utilizing the least cost principles, and producing commodities with high quality standards. Research in harvesting is an on-going process in which design is experimentally modified and evaluated under laboratory and field conditions to produce higher yields per unit cost at no sacrifice in quality. Similarly, research efforts are continuously being directed to reduce those field parameters that are most responsible for the various in-plant liquid and solid waste streams generated. Those on-going studies include:

1. Improved field trimming operations to remove unwanted stems, tops, leaves, and dirt.
2. Implementation of additional field labor for removal of defective units.
3. Machinery research to further reduce rough handling and subsequent bruising and other related damage.
4. Investigation of preliminary field washing operations to reduce soil and other organic loading.
5. Joint efforts between seed research and machinery companies to develop new varieties or hybrids that are compatible with each other.

In conjunction with harvesting techniques, new methods of transportation are being developed. New varieties of vehicle suspension, experimental containers, and "harvest-time vehicle destinations" have been utilized to allow for delivery of fruits or vegetables with the highest raw product quality economically possible. Further improvements should continue to yield even less damage which ultimately lowers in-plant wastes.

Receiving, Washing, and Sorting

Harvested crops are generally brought to the processing plants in bulk loads, bins, or lug boxes, and often dumped into washwater tanks. The recirculated water in these tanks pre-washes the product to remove leaves, stems, and soil residues. If the crop was pre-washed in the field, this step would be unnecessary and the resultant water use and effluent generation eliminated. If this proves impractical, washing can almost always be done with water recirculated from another unit process in the plant, e.g., cooling water. In addition, it is normal to recirculate the initial washwater to the maximum extent feasible.

During the summer of 1973, the U.S. Department of Agriculture, in cooperation with EPA and industry successfully demonstrated for tomatoes the use of a washer which utilizes soft rubber discs and foam to mechanically scrub the incoming tomatoes with a minimum use of water. An earlier study showed the advantage of using high pressure, low volume sprays to reduce wastewater volume.

For some commodities air cleaning is a feasible alternative to a first washing step. In general, air separation equipment is useful in removing waste material differing from process material in shape, density, size and/or surface roughness. If air cleaning is used, the separate contaminants should, of course, be handled as a solid waste.

After pre-washing, the product is often sorted by size and/or quality. Discards and culls generated during this step should be kept out of the wastewater. These solids should be used whenever possible or disposed as a solid waste. Uses might include secondary products, e.g., nectar or concentrate, or innovative uses of the solid waste for animal feed or the making of charcoal.

A convenient method of eliminating waste generation during the sorting step is to provide convenient means for the laborers to discard the unwanted material into a dry solid handling system. Many of the plants visited had installed barrels adjacent to the sorting lines or built dry conveyors to receive the unwanted material. Unfortunately, however, it is still a prevalent custom in many other plants to flume discards from the sorting lines into the wastewater stream.

In-Plant Transport

Commodities are moved around in the plant from one process step to another by means of conveyor belts, water carriage, pneumatic transport, or lug bins carried by fork lifts.

Water carriage is very popular because it often serves to combine several process steps: washing, cooling, and transport. In addition, it is usually efficient and does not damage the produce. Whenever possible, however, an alternate method of transport should be used because large quantities of water are used, and the water in which fruits or vegetables are being transported tends to leach out soluble organics into the wastewater stream. While it is impractical to completely discard this method of transport, for most commodities a conveyor belt or pneumatic transport can be substituted between many unit process operations.

Where water carriage cannot be replaced by a dry transport method, a plant should seek to minimize the volume of water wasted by recirculating to the maximum extent feasible. Reuse of cooling water for water carriage purposes is very common. Conveyors usually utilize sprays at periodic intervals to wash the conveyor belt and prevent buildup of organic slimes. These sprays should be high-pressure, low-volume. In addition, the spray water used should be recycled or reclaimed to the maximum extent compatible with satisfactory sanitation.

Pneumatic transport is used in some instances to move solid waste such as seeds, pits, and a certain amount of pulp. In this way, these solids are prevented from entering the wastewater stream. A tomato products plant reports greatly reduced waste generation after installation of a pneumatic system to remove residue from its finishing operation.

Peeling

Peeling and subsequent peel removal washing operations, typical of many fruit and vegetable processes, usually generate large volumes of high strength wastewater. In most cases, the waste streams contain high BOD, COD, and total suspended solids levels. Peel can be removed from fruits or vegetables by one method or a combination of several methods including hydraulic pressure, immersion in hot water or lye solution, exposure to steam, mechanical knives, mechanical abrasion, hot air blast, exposure to flame, and infra-red radiation. The more extensively used procedures for peeling root crops include steam/abrasion, immersion in lye solution/hydraulic or abrasion, and abrasion. Frequently used procedures for peeling fruits include mechanical knives and immersion in lye solution. Commodities that undergo some form of peel removal are: apricots, onions, beets, carrots, garlic, pineapples, tomatoes, peaches, pears, pimentos, and potatoes (white and sweet).

Most peeling methods are designed to minimize peel loss with minimum sacrifice of product identity or quality. Recent technology, however, has placed emphasis upon reduction of pollution entering the plant wastewater streams, while not sacrificing product yield or quality.

The dry caustic peeling system has gained great acceptance during the past four years since its development at the Western Regional Research Laboratory, USDA, Berkeley, California. Originally designed for use on white potatoes, the system has shown commercial application also for sweet potatoes, beets, carrots, tomatoes, and peaches. Several designs of the system are commercially available. The principal pollutant load reduction feature of each is that the loosened peel is removed mechanically by rotating rubber discs instead of the conventional watersprays. The rubber discs wipe off the peel, using little or no water, and peel waste is separately discharged as a slurry which does not enter the regular plant effluent. The peel waste slurry is then handled separately and usually disposed to land by truck hauling.

These results indicate the importance of a single unit operation. However, waste management programs including steps outlined later in this section (See Water Conservation and Reuse) are also needed if significant improvements in the total effluent raw waste load are to be realized.

The major manufacturer of dry caustic peeling equipment reports that over 200 units are installed, the majority for white potato peeling. At least five commercial units are also in operation for peeling tomatoes, sweet potatoes, carrots, beets, and peaches. Successful demonstrations have also been shown for peeling pears and several Canadian potato chip plants use the system.

Other experimental work includes freezer-heat (cryogenic) peeling and hot vapor peeling studies of tomatoes. Both of these concepts have potential for reducing product losses and contaminants to the effluent streams but are not proven for commercial application.

The following paragraphs discuss the peeling operations found in the plants investigated for this project. Of these plants, 62 percent used lye as the peel softening or loosening agent, 12 percent used steam and/or hot water, 5 percent used a combination of lye and steam, 18 percent had no peel presoftening or loosening, and 3 percent gave no information as to the softening or loosening agent used. Table 76 shows an individual commodity summary of peeling methods currently being used.

About forty percent of the visited lines with peeling operations used water sprays for peel removal. This includes cascade and tumble lye peelers. Thin-skinned commodities such as tomatoes and apricots used water sprays while thick-skinned root crops such as beets and onions used mechanical abrasion following lye or steam softening or loosening. Thirty percent used mechanical abrasion for peel removal. Six percent of the processing lines with peeling operations, used a mechanical knife for peel removal. These were pear processing lines. Four pear processing lines used a lye/ water spray removal peeling operation. Two processing lines used hand peeling. These were both small volume tomato processing lines, one of which also used a lye/water spray peeling operation. Nine percent of those processing lines with peeling operations used dry caustic peeling systems. These included two tomato processors, two beet processors, one apricot

TABLE 76

SUMMARY OF PEELING METHODS AND PEEL DISPOSAL METHODS
UTILIZED AT PLANTS VISITED

Commodity	No. Plts. Incl.	No. Lines Incl.	No. Lines With Peel. Op.	Softening					Removal						Disposal			
				Steam/ Hot Water	Lye	Steam/Lye	None	No Info.	Water Spray	Abrasion	Mech. Knife	Hand	Dry Caustic	No Info.	Handled as Solid Waste	Disch. into Wastewater	No Info.	Neg. Air Removal
Apricots	9	16	6		5			1	4				1	1	1	4	1	
Peaches	15	17	15		13	1		1	12				1	1	1	14		
Pears	8	10	10		4		6		4		6				2	7	1	
Beets	13	13	12	5	4	3				10			2	1	1	10	1	
Carrots	12	12	12	4	5	1	2		2	9				1	1	11		
Onions	5	5	5		1		4		1	5						5		
Peppers	5	5	1		1				1							1		
Pimientos	4	4	2		2				2							2		
Potatoes	8	8	7	1	6				2	4			2		1	6		
Tomatoes	32	51	23	1	21			1	12	4		2	2	3	4	18	1	1
Canned Spec.	8	1	1	1						1						1		
Potato Chips	6	6	6				6			6					2	3	1	
Total	125	148	100	12	63	5	18	3	40	39	6	2	8	7	13	78	5	1

processor, one peach processor, one sweet potato processor, and two canned potato processors. Ten percent of those processing lines with peeling operations gave no information as to the peel removal method.

Of those processing lines with a peeling operation, 15 percent handled the peels as solid waste, either through dry caustic peeling or through a screening operation at the peeling operation with dry removal from the plant; 77 percent dumped the peels into the plant wastewater system; and 5 percent gave no information as to peel disposal. One tomato processor utilized a negative air conveyance system to remove peels from the processing line. One tomato processor utilized dry caustic peeling and then dumped the peels into the plant wastewater system. One canned potato processor followed a dry caustic peeling operation with a mechanical abrasion peeling operation. Only four processing lines used reclaimed water in the peeling operation. In three of the four lines the reclaimed water was from the can cooling operation, and in the remaining line the reclaimed water was from the wash operation.

Size Reduction

Sizing includes such operations as pitting and coring, slicing, dicing, pureeing, juicing, and concentrating. In all of these operations the cells of the raw product are broken with resulting loss of soluble organics. In pureeing, juicing, and concentrating, however, the solubles largely become part of the finished product, and, in general, the waste loads are not excessive. For example, the waste generation per unit weight processed from a tomato paste operation is less than that from a peeled whole tomato operation. By contrast, those sizing operations where the product emerges in a sliced or diced form are heavy generators of organic pollution.

Blanching

Blanching of vegetables for canning, freezing, or dehydration is done for one or more reasons: removal of air from tissues; removal of solubles which may affect clarity of brine or liquor; fixation of pigments; inactivation of enzymes; protection of flavor; leaching of undesirable flavors or components such as sugars; shrinking of tissues; raising of temperature; and destruction of microorganisms.

Water blanching may be accomplished in several different ways. The most common type of water blancher consists of a continuous stainless steel mesh conveyor situated in an elongated tank (typically four to five feet wide and twenty to thirty feet long) which is usually half-filled with heated (150°-210°F) water. The product to be blanched is continuously fed onto the mesh conveyor at a constant rate (to maintain desired bed depth) so that the product is totally submerged. Residence times vary with the type of end product desired and the vegetable being processed.

TABLE 77

SUMMARY OF BLANCHING METHODS AND POST-BLANCH COOLING PRACTICES FOR THOSE PLANTS VISITED

Commodity	No. plts. incl.	No. lines incl.	No. lines w/blanch	Method			Cooling method				Water input			Water disposition			
															Reuse		
				Steam	Hot water	No info.	Air	Water	No cooling	No info.	Fresh	Reclaimed	No info.	Disch. into wastewater	Wash/ convey	Other	No info.
Apricots	9																
Berries, cane	3																
Blueberries	4																
Cherries	12																
Figs	1																
Grapes	6																
Peaches	15																
Pears	8																
Plums	8	8	1	1			1										
Prunes	7	9	4	2	2		1	3			3			3			
Raisins	2																
Strawberries	6																
Dried fruit	1																
Artichokes	1	2	2			2		1	1		1			1			
Asparagus	8	8	8	3	2	3		7	1		7			7			
Beans, dry	10	10	10	3	5	2	1	2	7		2			2			
Beans, lima	6	6	6	2	2	2	2	1	3		1			1			
Beans, snap	26	31	30	4	11	15	4	12	12	2	12			12			
Beets	13																
Blackeyed peas	1	1	1		1			1			1			1			

TABLE 77 (Continued)

Commodity	No. plts. incl.	No. lines incl.	No. lines w/blanch	Method			Cooling method				Water input			Water disposition			
															Reuse		
				Steam	Hot water	No info.	Air	Water	No.cooling	No info.	Fresh	Reclaimed	No info.	Disch. into wastewater	Wash/ convey	Other	No info.
Broccoli	2	2	2	2				2			2			2			
Carrots	12	13	5	2	1	2	1	3		1	3		1	3			1
Cauliflower	2	2	2	1	1			2			2			2			
Celery	4	5	2	1	1			2			2			2			
Corn	19	23	16	5	4	7	5	7	3	1	6	1	1	5	2		1
Garlic	2																
Greens	9	9	9	1	2	6	1	5	3		5			4		1	
Mushrooms	2	2	1			1			1								
Okra	3	3	3		1	2		3			3			3			
Onions	5																
Peas	33	33	33	4	10	19	1	25	6	1	19	6	1	18	7		1
Peppers	5	5	1	1					1								
Pimentos	4	4	2	2				1	1		1			1			
Potatoes	8	8	1			1		1			1			1			
Spinach	13	13	13	5	4	4		7	5	1	7		1	5	2		1
Squash	5																
Sweet potato	1																
Tomatoes	32																
Zucchini	2	2	2		1	1		1	1		1					1	
Canned spec.	8	2	2		2		1		1								
Cherries, brined	6																

TABLE 77 (Continued)

Commodity	No. plts. incl.	No. lines incl.	No. lines w/blanch	Method			Cooling method				Water input			Water disposition			
															Reuse		
				Steam	Hot water	No info.	Air	Water	No cooling	No info.	Fresh	Reclaimed	No info.	Disch. into wastewater	Wash/ convey	Other	No info.
Corn chips	1																
Olives	6																
Pickles	11	11	2		2				2								
Potato chips	6																
Sauerkraut	5																
Total	353	210	158	39	52	67	18	86	48	6	79	7	6	74	11	2	6

A second type of hot water blancher is a tube or pipe type arrangement through which the vegetable is conveyed by pumping heated water and product together (e.g., peas and sliced or diced carrots). The length of the pipe, the velocity of the hot water-product combination, and the temperature of the water are all variables that can be changed to produce the desired end product. A third type of water blancher typically used on dry beans consists of an auger which screw-conveys the product through heated water.

Steam blanching is typically done in an elongated (three to five feet wide and twenty to thirty feet long) stainless steel tank through which a continuous stainless steel mesh chain is passed. The chamber is typically fed by several inputs of steam so that when vegetables are run through the blancher, they are surrounded and permeated by the steam. Length of blancher, product bed depth, and speed of conveyor are the controlling variables.

Vegetables are typically water blanched to inactivate enzymes, to remove air, and to leach solubles for clarity of brine. These are factors in the USDA grades of canned vegetables. Blanching in water removes more solubles including minerals sugars, and vitamins, than does steam blanching. The leaching and solubilizing directly affects the wasteloads, however, with resultant blanching water entering the waste stream as carryover. Significant percentages of both BOD_5 and TSS can be generated by the use of hot water blanching.

Steam blanching, while basically performing the same tasks as hot water blanching, has been shown to significantly reduce leaching of solubles. Only the condensate water enters the waste stream. This effluent, while being extremely high in BOD_5 and suspended solids concentrations, is of very small volume.

It is usually quality and grading factors that dictate which type of blanching is to be used, however, for any particular type of vegetable. As can be readily seen from Table 77, many styles of blanching are used on each commodity. This table refers to the plants investigated during this study.

The pollution loads from blanching are a significant portion of the total pollution load in the effluent stream during the processing of certain vegetables. During recent years considerable research has been done on alternate methods of blanching, methods which would minimize the waste generated. The most promising of these methods, known as IQB, is described below.

A blanching process known as individual quick blanch (IQB) has been extensively evaluated since 1970, primarily under the sponsorship of the U.S. Department of Agriculture (USDA). The IQB process is a two-stage unit operation. In the first stage, the food piece is exposed to a heat source (condensing steam) for such duration that the mass-average temperature is in the range required for blanching (generally greater than 85°C (185°F)). The piece is then transferred to a second stage where the piece is held adiabatically until the thermal gradients have equilibrated to the mass average temperature and the objectives of blanching have been accomplished. The process results in less waste generation because:

1. Steam condensation is limited to that required for heating the product into the blanching temperature range;

2. There is a minimial opportunity for tissue damage and subsequent loss of cellular juices; and

3. There is no overheating of some of the tissues as in deep bed steam blanching which can result in tissue damage.

Lund reported on the application of IQB to vegetables prior to canning. In that study, peas, corn, lima beans, and green beans were blanched, canned, stored, and objectively and subjectively evaluated. Evaluation of IQB, IQB with predrying, and conventional pipe blanching showed that up to a 99% reduction in wastewater generation could be achieved with vegetables, e.g., peas, corn, lima beans, but is still tentative for large unit size vegetables; e.g., whole broccoli, whole asparagus, cauliflower, etc.

The American Frozen Food Institute (AFFI) in cooperation with USDA and a northern California processing plant is initiating a study on a further modification of IQB beginning in late 1974. The modification involves the reuse of the steam condensate for cooling purposes following the blanch.

A second new blanching process known as "hot-gas blanching" has been studied on a pilot plant basis by the National Canners Association (NCA) with partial sponsorship by EPA. A report by NCA concluded that the new method of blanching, now called "hot-gas blanching" shows exceptional promise in reducing wastewater volume to very low levels while providing commerically acceptable blanching.

A third experimental method is microwave blanching. This method has been known for many years but has never become popular because of high cost and technical difficulties. One new blancher which requires less water per pound of product is now being used in a cauliflower, broccoli, brussels sprouts and asparagus processing operation. It is a sealed system which uses venturi tubes to recycle the steam heat through the blancher. Unlike conventional continuous steamflow blanchers, it utilizes steam only on demand from its preset control instruments. It eliminates the steam stack, yet provides a vapor-free plant environment.

Of those processing lines with blanching operations, 25 percent used steam blanchers, 33 percent used hot water blanchers, and 42 percent gave no information as to the type of blancher used. All but one of the blanchers were described as continuous blanchers with continuous overflow recirculation, with the blanchers being dumped at various intervals, usually at the end of the day or shift. One dry bean processing line exhibited a batch blancher, dumping after each blanching operation.

Thirty percent of the processing lines with a blanch operation exhibited no post-blanch cooling operation. These were all canning operations. All freezing lines with a blanch operation exhibited some type of post-blanch cooling operation. Of those processing lines with a post-blanch cooling operation, 16 percent used an air cooling operation, 78 percent used a water cooling operation, and 6 percent gave no information as to the cooling method.

Ninety-four percent of those processing lines with a water cooling operation used fresh water for this operation. One plant used reclaimed water. The remaining five percent were pea processors who used a brine quality grader after the blanching operation to cool the peas while grading for quality.

Eighty six percent of those lines with a water cooling operation discharged the water used in this operation into the plant wastewater system; 13 percent reused this water for washing and/or conveyance; and one processor reused this water in its freezer condensor system.

Preservation

The wide range of commodities covered within the scope of this document lend themselves to five basic preservation processes: freezing, retorting, pasteurization, dehydration, and chemical preservation. The first three usually are responsible for using considerable volumes of water for either cooking or cooling or both, while the latter two use virtually no related processing water.

Freezer defrost water, usually coming in large volumes for short time periods, contributes significantly to a plant's total effluent. Typically, those waters are discharged directly to the main waste stream, but they are, in some instances, discharged under permit to navigable streams. The water quality in terms of BOD_5 and TSS of this effluent is usually identical to a plant's incoming water supply. Reuse of this water has generally been observed to be infrequent. It is principally used for in-plant fluming prior to any final product washings.

Retorting of tin or glass requires the use of large volumes of water, in the case of tin for cooling, and for glass both in cooking and cooling. Conventional retorting is done usually by either "still" or "continuous" means. The continuous cookers offer labor, energy, and water saving advantages in as much as the container being processed is usually rotated on flights through pressurized cooking vessels, and either low pressure or atmospheric cooling vessels, or both.

The use of cooling towers greatly reduces the volume of water used for cooling cycles. This water, when properly maintained, can be reused for several weeks or longer. These waters can alternately be recycled for various fluming and first washing operations. Direct discharge of cooling waters to navigable streams has also been frequently observed.

The process of pasteurization followed by cold water sprays can contribute significantly to a plant's effluent. Water reuse, as in the above section, can be greatly increased through the use of cooling towers.

Tomato evaporation and concentration operations can contribute large volumes of water to a plant operation. The use of cooling towers to condense evaporated water and the reuse of this water for condenser cooling is very typical in this industry. This water has also been utilized as make-up water for initial washings of tomatoes.

<u>Water Conservation and Reuse</u>

Substantial reduction in both processing raw waste load (flow and pollutant content) and wastewater treatment cost can be realized by careful in-plant water management and reuse. The following examples were obtained from plant investigations and literature reviewed during this study:

1. Installation of automatic shut-off valves on water hoses may save up to 60 gallons per minute per hose. Without automatic shut-off valves, employees do not turn off hoses. Cost for a long life valve is approximately $40.

2. Installation of central clean-up systems (valved or triggered hoses). These commercial systems generate a controlled high pressure supply of hot or warm water containing a detergent. They are reported to clean better with less volume of water used.

3. Installation of low-volume, high-pressure systems on all water sprays which cannot be eliminated.

4. Elimination of all unnecessary water overflows. Many plants operate water valves wide open regardless of actual need. Examples are make-up water supplies to recirculating flumes, spray lines, and washers. One way to help solve this problem is installation of quick opening ball valves in water lines after globe valves. The globe valve is used by the operator for on-off operation.

5. Elimination of water carriage for the product by flumes or pumps, except where absolutely necessary to cool the product. Water carriage should not be used for the sole purpose of conveying the product. Keeping the product away from water will decrease pollutant generation.

6. That portion of very dilute wastewater (cooling water, defrost water, etc.) which is not reused or recirculated, should be discharged separately from the process wastewater. Care should be exercised, however, to prevent the direct discharge of high temperature cooling water without adequate cooling.

7. Maximization of in plant water recirculation by multiple use of water in the same unit process or reuse in other unit processes. Can cooling water provides an excellent source of water to be reused. Table 78 shows can cooling water disposition by commodity as determined during plant visits conducted during this study. Of those processing lines with can cooling operations, 40 percent discharged the can cooling water separately from the processing water; 56 percent discharged this water with the process water; and 4 percent gave no information as to the disposition of the can cooling water. Ten percent of those processing lines with can cooling operations, recirculated the can cooling water through a cooling tower; 14 percent recirculated this water through a canal, tank, pond, or other means; 74 percent exhibited no significant recirculation; and 3 percent gave no information as to recirculation of can cooling water.

8. Counter-current systems are used extensively in which the fresh water is introduced to the product last in the process and then reused in earlier stages of the process. In this way, the product is exposed to successively cleaner water as it progresses through the process unit.

9. Good housekeeping is an important factor in normal pollution control. Spills, spoilage, trash, etc. resulting from sloppy operation may be a heavy contribution to liquid wasteloads. Improvements will result from educating operating personnel in proper attitudes toward pollution control and providing strategically located waste containers, the basic aim being to avoid loss of product and normal solid waste into the liquid waste stream.

10. In addition to implementation of water conservation and reuse, the processor should look at his handling of solid waste. A well-operated plant will, insofar as possible, avoid solid waste contact with the liquid waste stream. Where this is not feasible, the solid

TABLE 78

SUMMARY OF CAN COOLING WATER RECIRCULATION AND DISPOSITION FROM PLANT VISITS

Commodity	No. plts. incl.	No. lines incl.	No. lines with can cooling	Discharge			Recycle within Cooling System				Reuse for Other Processes				
				With process water	Separately	No info.	Cooling tower	Other	None	No info.	Wash/convey	Boiler feed	Other	None	No info.
Apricots	9	13	8	6	2		2		6		2		1	5	
Berries, cane	3	5	1		1				1					1	
Blueberries	4	6	4	2	1	1			4			1		3	
Cherries	12	16	11	9	2			3	8		1			10	
Figs	1	1	1	1						1				1	
Grapes	6	7	6	5	1		1		5				1	5	
Peaches	15	15	11	9	2		2		8	1	8			3	
Pears	8	8	8	6	2		2		6		1		2	5	
Plums	8	11	7	5	2			1	6		1	1	1	5	
Prunes	7	7	5	4		1			5					5	
Raisins	2	2													
Strawberries	6	9	2	1	1				2					2	
Dried fruit	1	1													
Artichokes	1	2	1		1				1					1	
Asparagus	8	8	6	4	1	1		1	5		2			4	
Beans, dry	10	10	10	3	5	2	1	4	4	1				10	
Beans, lima	6	6	4	3	1			1	3					4	
Beans, snap	26	29	20	10	10		1	1	17	1	2	1	2	15	
Beets	13	13	12	4	8		1		11		4	1	1	7	

TABLE 78 Continued)

Commodity	No. plts. incl.	No. lines incl.	No. lines with can cooling	Discharge			Recycle within Cooling System				Reuse for Other Processes				
				With process water	Separately	No info.	Cooling tower	Other	None	No info.	Wash/convey	Boiler feed	Other	None	No info.
Blackeyed peas	1	1	1		1										
Broccoli	2	2													
Carrots	12	13	8	4	4		1	1	6		1				
Cauliflower	2	2													
Celery	4	4	2	2				1	1				1	1	
Corn	19	22	13	5	8				12	1		3	1	9	
Garlic	2	2													
Greens	9	10	5	4	1			3	2					5	
Mushrooms	2	2	2	2				1	1					2	
Okra	3	3	1	1					1					1	
Onions	5	6	3	1	2			2	1					3	
Peas	33	34	22	9	12	1		2	20		2	4		16	
Peppers	5	5	2	2				1	1		1			1	
Pimentos	4	4	4	3	1			1	3		2			2	
Potatoes	8	9	8	6	2			3	5					8	
Spinach	13	13	6	4	2		2		4		1		1	4	
Squash	5	6	4	2	2			1	3					4	
Sweet potatoes	1	1	1		1			1						1	
Tomatoes	32	49	36	18	16	2	8	5	21	2	23	1	3	12	
Zucchini	2	2	1	1					1					1	
Canned spec.	8	8	8	2	6		2		6			1		7	

TABLE 78 (Continued)

Commodity	No. plts. incl.	No. lines incl.	No. lines with can cooling	Discharge			Recycle within Cooling System				Reuse for Other Processes				
				With process water	Separately	No info.	Cooling tower	Other	None	No info.	Wash/convey	Boiler feed	Other	None	No info.
Cherries, brined	6	7	1	1					1					1	
Corn chips	1	1													
Olives	6	6	5	1	4	1			4			1		4	
Pickles	11	11	10	7	3			3	7					10	
Potato chips	6	6													
Sauerkraut	5	5	4	3	1		1	1	2					4	
Total	353	402	264	149	106	9	26	37	194	7	51	14	14	190	

waste is removed prior to reaching the waste treatment system. Screens of 20 mesh or smaller are usually adequate to remove a large portion of settleable solids. Continuous removal of the screenings is desirable to avoid excessive leaching of solubles by the liquid waste stream from separated solids.

11. It is, of course, impossible to predict with exactness the effect of in-plant pollution control such as water use reduction and water reuse. Volume reductions of 50 percent and upwards are not unusual, however, and in most cases, it is reported that volume reduction is accompanied by reduction in total organic pollution generated.

SCREENS

Discrete waste solids in fruits and vegetables waste streams, such as trimmings, rejects, and pits, are effectively and economically separated from liquid wastes at almost all canning plants by screening.

Screening has several objectives, including: recovery of useful solid by-products; a first stage end-of-pipe primary treatment operation; or pretreatment for discharge to a municipal wastewater treatment system.

Screening efficiency is affected by the following:

1. Mechanical features

   a. wastewater flow rate;
   b. area of screen;
   c. screen inlet and outlet locations;
   d. screen motion;
   e. screen opening size;
   f. screen fabric (wedgewire, flat, or round).

2. Wastewater properties

   a. discrete particle dimensions;
   b. concentration of discrete materials;
   c. shape of discrete material (irregular, round, fibrous);
   d. consistency of discrete material (hard, soft, sticky).

Screens are often characterized by the size of the openings. There are several methods of designating the open area in a screen. Wire screen openings are usually measured in meshes per inch, and are available in increments of the Tyler Standard Sieve sizes. For example, the popular 20 mesh screen has a standard wire diameter which is woven in a rectangular grid with 20 wires per linear inch. A second method of screen size measurement describes the clear opening between screening elements (usually flat or wedgewire in shape) either in mm or mils. For example, a 0.76 mm opening is equal to 30 mils (0.030 in) and approximately equivalent to a 40-mesh screen as described above. Bar screens, because of their very large openings, are measured by their clear opening, usually in cm.

There are many different types of screens in common use within the fruits and vegetables industry, including: bar conveyer (endless belt); rotary vibrating or oscillating; tangential; and centrifugal.

pH CONTROL SYSTEMS

It is sometimes necessary to install pH control systems to treat wastes from the fruit and vegetable processing industry. Typically, municipal ordinances require wastes discharged to its sewers to be between pH 6 and 9, and many biological treatment systems cannot tolerate wide ranges in raw waste pH. Wastes with low pH result from processing of acidic fruits; e.g., plums and wastes with high pH result from the use of lye during peeling such as a typical peach peeling.

If it is necessary for the individual plant to install a pH control system, it will generally be found that the automatic control of pH for the neutralization of waste streams can present problems including:

1. The relationships between the amount of reagent needed and the controlled variable; pH being non-linear.

2. The pH of the wastewater can vary rapidly over a range of several units in a short period of time.

3. The flow will change while the pH is changing since the two variables are not related.

4. The change of pH at neutrality can be sensitive to the addition of a reagent so that even slight excesses can cause large deviations in pH from the initial setpoint.

5. Measurement of the primary variable, pH, can be affected by materials which coat the measuring electrodes.

6. The buffer capacity of the waste has a profound effect on the relation between reagent feed and pH and may not remain constant.

7. A relatively small amount of reagent must be thoroughly mixed with a large volume of liquid in a short period of time.

Figure 55 schematically illustrates the components of an automatic pH control system designed to handle a waste having pH which could be either high or low at different times. If pH of the raw waste were only high or only low, the appropriate acid or caustic feed pump head could be eliminated from the schematic flow diagram.

The heart of the control system is the pH probe and analyzer which requires daily maintenance and calibration to ensure that it is generating an accurate reading of the pH in the neutralized waste. A false reading from this device will trigger incorrect dosages of chemicals and result in aggravation of a pH problem instead of correction.

GRAVITY SEDIMENTATION

Gravity sedimentation is a solids separation operation classified as primary treatment. Gravity sedimentation is commonly applied to fruits and vegetables wastewaters as follows: (1) settling ponds or grit chambers for raw wash waters, (2) clarification of screened wastewaters prior to further treatment such as activated sludge or spray irrigation, and (3) solids removal prior to discharge into municipal systems.

Settling Ponds

Settling ponds are commonly used for clarifying raw product wash waters, especially for root crops, mechanically harvested tomatoes, and other relatively dirty raw products. These ponds can be either batch or continuous flow types. Laboratory bench scale testing can be used to rationally determine the detention time required for proper clarification and necessary solids storage. The settleable matter will collect on the bottom of the pond. The ponds are usually built 10 to 15 ft deep in order to store solids for at least one year's operation. The settling pond effluent is commonly recycled to the final wastewater treatment system.

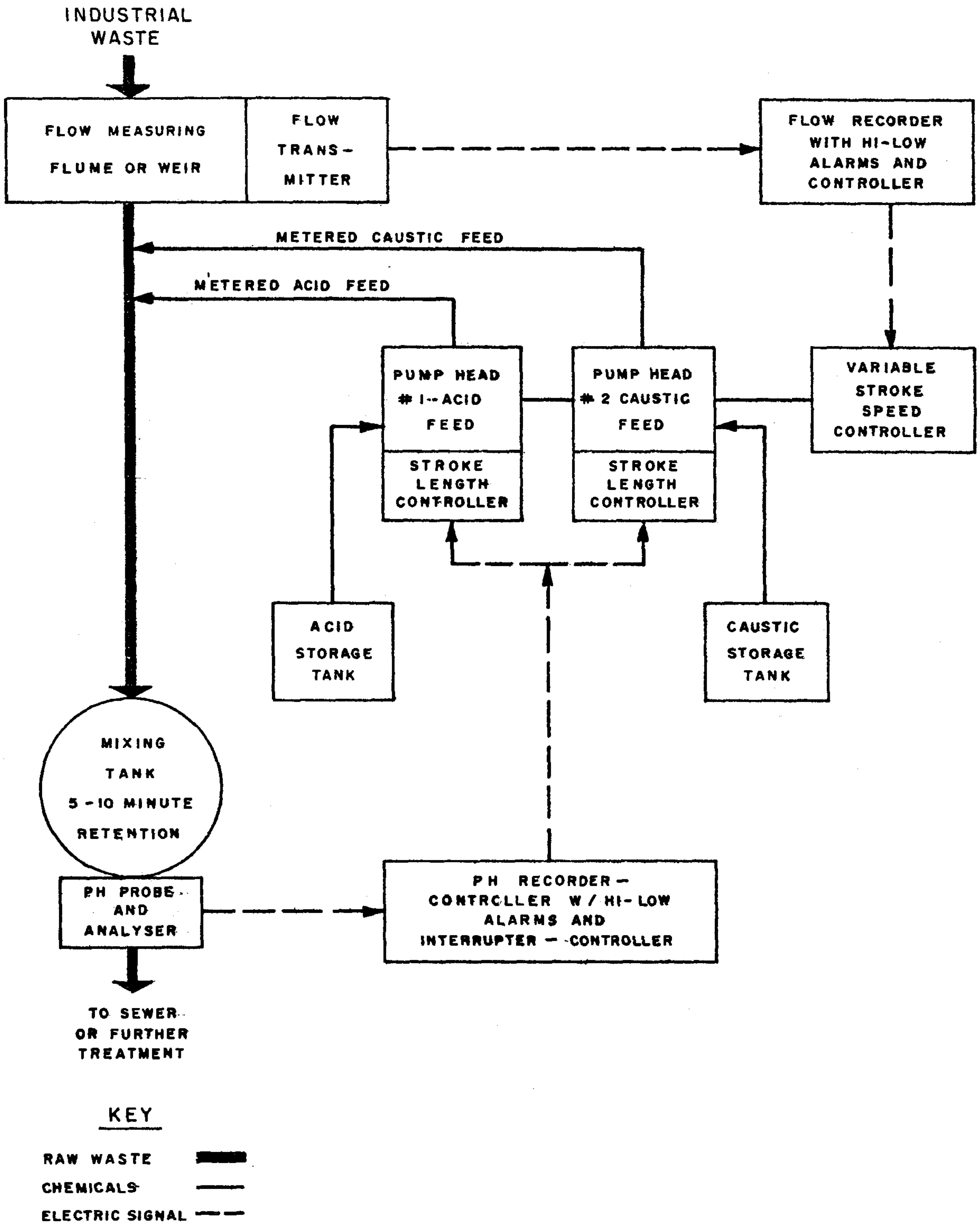
If improperly designed, ponds of this type can develop odors from anaerobic digestion of settled organic material. This problem can be avoided if adequate liquid velocities are maintained to retard settlement of the lighter organic material. Settling ponds are drained and cleaned periodically.

Mechanical Grit Chambers

A mechanical grit chamber, either aerated or unaerated, is excellent for specific grit removal. The settling basin is small because of very short retention times, usually from one to five minutes. The unaerated grit chambers are more economical but may remove organic matter with the grit and make disposal of solids more difficult. Both types of grit chambers use mechanical equipment such as screw conveyers or bucket elevators for transporting settled grit from the settling chamber to a storage

FIGURE 55

SCHEMATIC FLOW DIAGRAM FOR pH CONTROL SYSTEM
TREATING WASTE WITH VARIABLE FLOW
AND BOTH HIGH AND LOW pH



hopper. The main advantages of grit chambers are their compact size and ability to be more selective in what weight suspended solids are settled out.

Gravity Clarifiers

Gravity sedimentation is a primary treatment operation to reduce suspended solids and BOD. Center upflow or rectangular continuous flow clarifiers are normally used. The clarified effluent is discharged over an effluent weir, and the settled solids are moved by scraping or suction to a sludge pump wet well. The sludge is then pumped to sludge handling or digestion facilities as described in another section. Surface skimmers can be used to remove floating material for separate disposal.

Primary Clarifier Design Considerations

Clarifiers for fruits and vegetables primary treatment are usually designed for 25 to 41 cu m/day/sq m (600 to 1,000 gal/day sq ft) as reported by Talburt and Smith (Ref. 15), Filbert (Ref. 16), and Grames and Kueneman (Ref. 17). Grames and Kueneman recommended, because of poor settling, a maximum overflow rate of 25 cu m/day/sq m (600 gal/day/sq ft) and a deep side water depth from 2.75 to 3.66 m (9 to 12 ft). They also recommended the use of rake mechanisms with sludge thickening pickets. This creates a combined clarifier and thickener and produces a sludge of maximum solids concentration.

Primary clarifiers have the objective of removing settleable matter in screened or raw wastewaters. Usually a percentage of suspended solids in the influent can be removed. The concentration of suspended solids and percentage settleable is very waste specific and depends upon the commodity being treated. In screened domestic sewage, approximately 35 percent of the BOD_5 and 65 percent of the suspended solids can be removed by primary sedimentation. With fruits and vegetables wastes, these percentages are often lower. Tomato and tree fruit lye peel wastewaters, for example, settle very poorly. In general, wastewaters from processing of root crop vegetables are high in suspended solids which separate well in primary clarifiers.

Wolski (Ref 18) speculated that fruits and vegetables wastewaters were difficult to treat by most treatment chains because of the constant fluctuation in their composition. He theorized that the fluctuations could be partially stabilized by primary sedimentation. He determined a minimum detention time of 45 to 50 minutes and a maximum overflow rate of 60 cu m/sq m/day (1470 gal/day/sq ft). He found the suspended solids were reduced by greater than 40 percent and the BOD_5 reduced by 17 to 30 percent.

Primary sedimentation is not at present a common operation in most fruits and vegetables treatment chains. For certain commodity wastes, however, this operation has potential in the upgrading of existing biological treatment plants and in accomplishing greater efficiencies with new designs. Streebin, Reid, and Hu (Ref. 19) demonstrated a full-scale, two-stage aeration process for treating vegetable wastes. The demonstrated plant did not have primary clarification. They theorized from laboratory testing that with the addition of a primary clarifier, which in this case would remove approximately 50 percent of the raw BOD, the capacity of the complete system would be doubled.

AIR FLOTATION

Air flotation is normally a primary treatment operation that removes suspended solids in the form of a floating sludge. It also has potential as a tertiary step following lagoons for removal of algae and other suspended solids. Air flotation can be either purely physical or physical-chemical with the addition of chemical coagulants. Air flotation units generate air bubbles, and the buoyancy of the air bubbles rising through the wastewater lifts suspended materials to the surface. The floated sludge is then skimmed from the surface.

Air flotation has been rarely used in fruits and vegetables wastewater treatment. However, this technology should be considered in future treatment trains because of: (1) the characteristically poor settling quality of many fruits and vegetables wastes; (2) the dilute sludges obtained from many primary clarifiers and accompanying dewatering problems; (3) the fairly concentrated sludges obtained from air flotation units; and (4) the compact size of air flotation units resulting from the small detention time necessary.

Three alternative air flotation systems are available: (1) vacuum flotation; (2) dispersed air flotation; and (3) dissolved air flotation.

Air Flotation Design

Design parameters important in dissolved air flotation are: (1) chemical coagulant (qualitative and quantitative optimization is important); (2) air/solids ratio; (3) hydraulic loading in cu m/sq m/min (gal/sq ft/min); and (4) solids loading in kg/sq m/hr (lbs/sq ft/hr).

The NCA (Ref. 20) pilot tested a recycle pressurization, dissolved air flotation system on rinse water from peach caustic peel solution and screened tomato processing effluent. Tables 79 and 80 show the results of the NCA test. Removal of suspended solids from the peach rinse waters ranged from 64.8 to 93.2 percent. The removals were inversely proportional to the influent flow rate. From the screened tomato wastewater, suspended solids removals ranged from 60.7 to 83.5 percent. Again, percent removals were inversely proportional to influent flow rates.

TABLE 79

SUSPENDED SOLIDS REMOVAL FROM PEACH RINSE WATER
BY DISSOLVED AIR FLOTATION FROM NCA (1970)

Influent Raw (gpm)	Influent Recycle (gpm)	Hydraulic Loading (gpm/ft^2)	Influent Solids (mg/l)	Effluent Solids (mg/l)	Percent Removal	Solids Loading ($lbs/hr/ft^2$)
7.5	7.5	1.0	1,400	90	93.2	0.6
15.0	15.0	1.9	1,500	180	87.7	0.7
20.0	20.0	2.6	1,300	340	74.0	1.2
25.0	25.0	3.2	700	190	71.0	0.8
20.0	10.0	1.9	900	230	72.0	0.9
30.0	15.0	2.9	1,500	590	66.1	2.2
30.0	10.0	2.6	200	70	64.8	0.3

TABLE 80

SUSPENDED SOLIDS REMOVAL FROM SCREENED TOMATO WASTEWATER BY DISSOLVED AIR FLOTATION FROM NCA (1970)

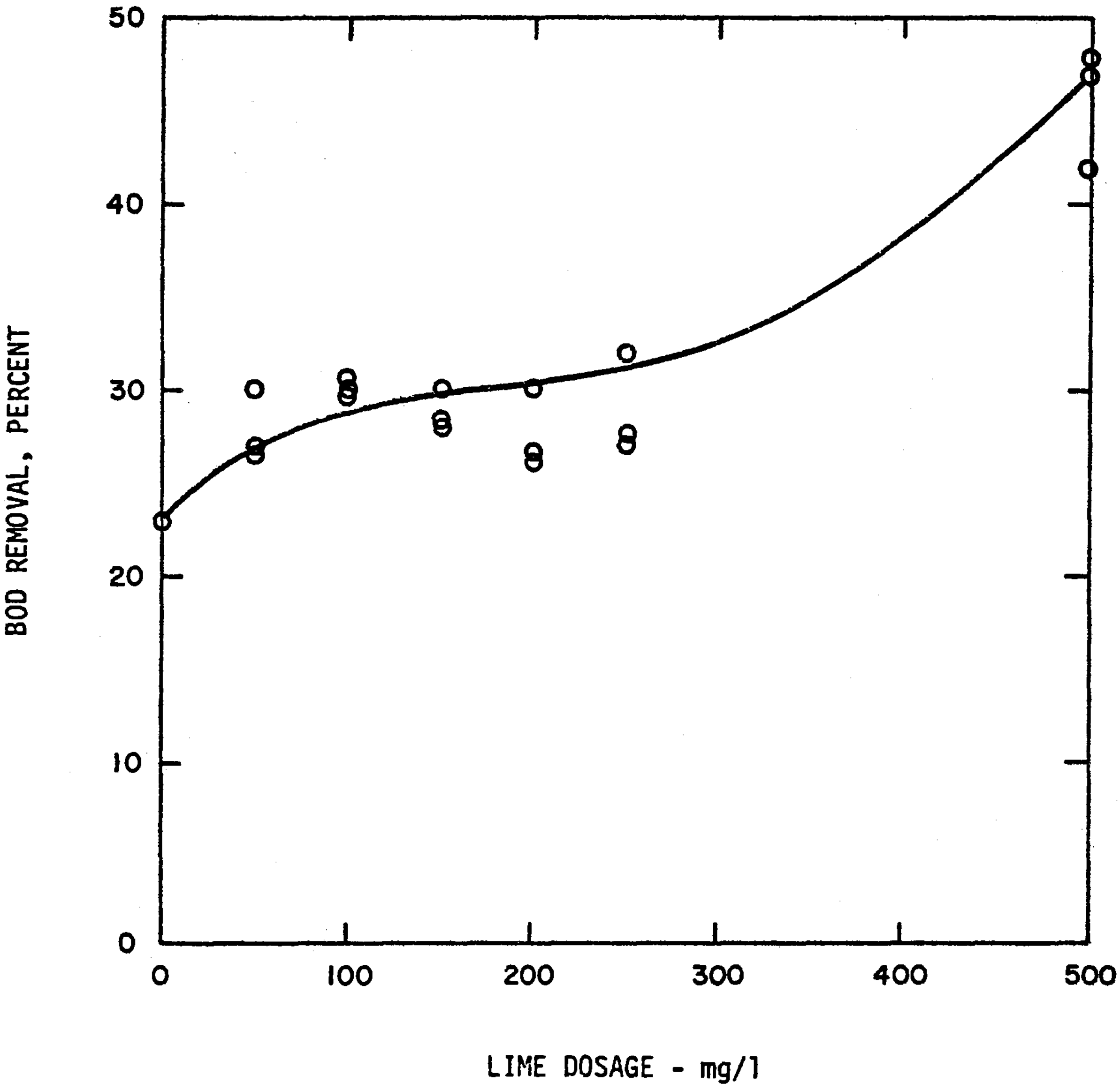
Influent		Hydraulic Loading	Influent Solids	Effluent Solids	Percent Removal	Solids Loading
Raw (gpm)	Recycle (gpm)	(gpm/ft^2)	(mg/l)	(mg/l)		($lbs/hr/ft^2$)
7.5	7.5	1.0	1,100	180	83.5	9.7
15.0	15.0	1.9	1,100	240	77.7	19.5
30.0	15.0	2.9	500	180	60.7	15.9

TABLE 81

CHEMICAL PRECIPITATION OF VEGETABLE PROCESSING WASTES FROM U.S. DEPARTMENT OF INTERIOR (1967)

Waste	Chemicals (mg/l)			Reduction Efficiency %	
	Lime	Alum	$FeSO_4$	SS	BOD
Tomato	8.3	--	--	86.5	39.0
	4.0	1.0	--	--	50.0
Red Beets	9.0		--	90.0	43.0
	10.0	--	4.0	--	59.0
	10.0	--	--	--	48.0
Corn	9.10	--	9-12	--	60.0
	6.0	--	3.25	--	50-75
Carrots	5.0	--	1.0	--	75.0
	3.0	--	--	--	75.0
Peas	7.5	--	3.25	--	50-75
Wax Beans	6.0		2.5	--	50-75

Figure 56 BOD removal by chemical precipitation from peach and tomato wastes from Parker (1969).



There were no chemical additions during the NCA tests described above. Many fruits and vegetables characteristically have low suspended solids concentration relative to dissolved organics, and most oxygen demanding material is in colloidal and soluble forms. A chemical addition system to enhance dissolved air flotation may increase removal efficiency somewhat. Parker (Ref. 21) estimated that with peach and tomato wastes, only 15-25 percent of the BOD5 was associated with suspended solids. Parker also investigated BOD5 removal by chemical precipitation, with results shown in Figure 56. It appears that only 30 percent removal of BOD5 was achieved with reasonable chemical dosages. The U.S. Department of the Interior (Ref. 22) reported the results of various investigators. The results are shown in Table 81. These results correlate well with the NCA study on suspended solids removal. The BOD5 removals, however, are somewhat higher than the Parker results, being in the 40-75 percent removal range.

NUTRIENT ADDITION

In order to maintain optimum process efficiency in biological systems, minimum quantities of nitrogen and phosphorus are required for cell synthesis. Without a proper nutritional balance, soluble BOD5 reduction and liquid-solid separations will be impaired. Virtually all fruit processing wastes are nutritionally deficient along with some vegetable commodities such as potatoes. The nitrogen and phosphorus concentrations that must be maintained are process and commodity specific and must be determined by laboratory or field investigations. Usually the required nitrogen and phosphorus can be related to BOD5 removed.

Table 82 shows the nutrient values in the raw wastewater for various commodities. The minimum nutrient ratios were assumed to be 2 kg of N and 0.5 kg of P per 100 kg BOD5 applied. Using this criteria, the commodities that are nutrient deficient are marked on Table 82. In the cost analysis provided in Section VIII, activated sludge treatment systems for these commodities include nutrient addition.

LAND TREATMENT AND DISPOSAL SYSTEMS

General

With the increasing stringency of regulatory agency effluent limitations and the cost of achieving them, plants in this industry have increasingly turned to land treatment of their wastewater. Among these plants surveyed which do not discharge to municipal systems, 73 percent reported discharge to land via spray irrigation and other types of irrigation or percolation-evaporation ponds. Some of the plants which reported using land treatment may not provide complete containment (zero-discharge) because of "unofficial" run-offs into tailwater ditches.

TABLE 82

NUTRIENT VALUE OF RAW COMMODITIES AND REQUIRED NUTRIENT ADDITION FOR BIOLOGICAL WASTEWATER TREATMENT

NUTRIENTS REQUIRED (1)	COMMODITY	BOD/N/P RATIO	NUTRIENTS REQUIRED (1)	COMMODITY	BOD/N/P RATIO
	CORN	100/2.8/.5	X	GRAPES	100/1.6/.1
X	TOMATOES (2)	100/4/.6		CAULIFLOWER	100/6.8/.9
	PEAS	100/6/.7		OKRA	100/5/.6
	BEETS	100/3.1/3.9		ONION	100/3.1/.5
	BEANS	100/4.4/.8	X	PIMENTO	100/2.8/.3
	CARROTS	100/2.3/.5		RHUBARB	100/3.0/.5
X	PEACH	100/1.4/.3	X	FIGS	100/1.3/.2
X	PINEAPPLE	100/.6/.1	X	PRUNES	100/.7/.2
	SPINACH	100/7.7/.6		ASPARAGUS	100/6.5/1
	SAUERKRAUT	100/4/.5		BROCCOLI	100/7.2/1

(1) Assuming required nutrient ratio BOD/N/P of 100/2/0.5.
(2) Although this commodity achieves the 100/2/0.5 ratio, actual practice has shown that nutrient addition is necessary for successful biological wastewater treatment.

TABLE 82 (continued)

NUTRIENTS REQUIRED(1)	COMMODITY	BOD/N/P RATIO	NUTRIENTS REQUIRED(1)	COMMODITY	BOD/N/P RATIO
X	POTATOES	100/2.4/.4		BRUSSEL SPROUTS	100/7.2/.7
X	PEARS	100/1/.01		ZUCCHINI	100/5/.8
	LIMA BEANS	100/5.4/.6		ARTICHOKES	100/4.4/.8
	SQUASH	100/3.7/.7		DRY BEANS	100/5.4/.6
X	APRICOTS	100/1.6/.23	X	POTATO CHIPS	100/1.1/.2
X	STRAWBERRIES	100/1.6/.3	X	JAMS & JELLIES	100/.1/.01
X	CRANBERRIES	100/.7/.1	X	RAISINS	100/.7/.2
X	CHERRIES	100/1.7/.2	X	SWEET POTATO	100/1.3/.2
X	OLIVES	100/1.2/.1	X	DEHYD. ONION	100/2.1/.004
	MUSHROOMS	100/7/1.9	X	PLUMS	100/.6/.1
X	BLUEBERRIES	100/.9/.1	X	CANEBERRIES	100/1.8/.2
X	PICKLES (avg. sweet & dill)	100/1/.2			

(1) Assuming required nutrient ratio BOD/N/P of 100/2/0.5.

Nevertheless, where conditions are suitable, land treatment is often the simplest, most inexpensive method of treatment. problem.

Land treatment of wastewater is particularly well suited for this industry because of the seasonality of high organic strength of the wastewater. However, large land areas are required for successful operation. Spray irrigation is the most widely used land treatment application method. Other principal methods are ridge-and-furrow irrigation, and flood irrigation. Percolation ponds are covered in the Lagoon subsection of this section. Overland flow and tile-drained fields are land treatment methods system as opposed to a disposal system but are covered in this subsection. Tile drainage may also be required either to improve hydraulic conductivity for irrigated land with poor drainage, or to collect subsurface drainage prior to further treatment in lagoons or second-pass irrigation. Table 83 lists the plants practicing land treatment which were contacted during this study and some data about each. In all these methods, the wastewater is usually at least screened prior to treatment. The extent of additional pretreatment necessary, if any, is dependent upon the treatment methods used, characteristics of wastewater, potential odor problems, pumping requirements, sprinkler nozzle size, and regulatory agency requirements. The National Canners Association has compiled a tabulation of individual state requirements for land treatment showing state requirements vary from none to the equivalent of secondary treatment prior to land treatment.

Experience has shown that land treatment systems must be carefully designed to achieve successful operation. A brief overview of design considerations for each type of system is presented in the following subsections.

Wastewater Characteristics

The characteristics of food processing wastewaters that must be considered with regard to land treatment include BOD_5, total suspended solids, total fixed dissolved solids, pH, heavy metals, and the sodium adsorption ratio (SAR). These characteristics vary widely among food processing wastes. Ranges of values observed at existing land treatment systems for these characteristics are listed in Table 83. The possible effects of these characteristics are discussed in the following paragraphs.

TABLE 83

CHARACTERISTICS OF VARIOUS FOOD PROCESSING WASTEWATERS APPLIED TO THE LAND (Ref.6)

Constituent	Unit	Value Range
BOD_5	mg/l	200-4,000
COD	mg/l	300-10,000
Suspended solids	mg/l	200-3,000
Total fixed dissolved solids	mg/l	less than 1,800
Total nitrogen	mg/l	10-400
pH	--	4.0-12.0
Temperature	deg. C	less than 68

The soil is a highly efficient biological treatment system; therefore, liquid loading rates at land treatment operations are normally governed by the hydraulic capacity of the soil rather than the organic loading rate. This operational independence from BOD_5 loading is a distinct advantage of land treatment systems over conventional treatment systems in treating high-strength wastewaters.

There are limits, of course, to the organic loading that can be placed on the land without stressing the ecosystem in the soil. The effects of organic overloads on the soil include damage to or killing of vegetation, severe clogging of the soil surface, and leaching of undegraded organic materials into the groundwater. Defining the limiting organic loading rate for a system must be done on an individual basis. However, rule-of-thumb rates have been developed based on experience. A maximum BOD_5 loading rate of 224 kg/ha/day (200 lbs/acre/day) has been suggested as a safe loading rate for pulp and paper wastewaters. (Ref. 6) A somewhat higher rate can normally be used with food processing wastewater containing a higher percentage of sugars rather than starchy or fibrous material. Substantially higher loading rates of greater than 672 kg/ha/day (600 lbs/acre/day) have been used on a short-term seasonal basis for infiltration-percolation systems. For overland flow systems, organic loadings in the range of 44.8 - 112 kg/ha/day (40 to 100 lbs/acre/day) have been used successfully.

Suspended solids are generally the major source of operational problems such as clogged sprinklers and clogged soil surface. Pretreatment to remove solids will normally minimize these problems. The soil has a large capacity to adsorb heavy metals. Once this capacity is exceeded, however, the metals may be leached to the groundwater (under acid soil conditions) or inhibit plant growth.

Wastewaters that have a pH between 6.0 and 9.5 are generally suitable for daily application to most crops and soils. Wastewaters with pH below 6.0 have been successfully applied to soils that have a large buffering capacity.

The ratio of sodium to other cations called sodium adsorption ratio (SAR), primarily calcium and magnesium, can adversely affect the permeability of soils, particularly clay soils. Wastewaters with a SAR below 8 are considered safe for most soils.

Spray Irrigation

This is a method of applying wastewater on land through a sprinkler system. If the soil is permeable and terrain flat, most of the wastewater percolates into the ground or is consumed by evapo-transpiration. Pollutants in the wastewater are removed by biological activity or microorganisms in the top of the soil, by the mechanical action of straining through soil, and by nutrient uptake of plants.

The size of spray area required is dependent on the quantity of wastewater applied, schedule of application, waste characteristics, climate, vegetation, soil conditions, and terrain. Spray areas are usually divided into sections, and application of wastewater rotated between sections; e.g., irrigate for 8 hours followed by 40 hours with no irrigation to permit the area to "rest." This "rest" period promotes reaeration and drainage of the soil, microbial degradation, and uptake of mineralized nutrients by plants.

The vegetative cover is an important factor in spray irrigation systems. Dense vegetation reduces soil erosion, improves percolation, aids evapo-transpiration, and harbors microorganisms which consume organics in the wastewater. Selection of suitable cover is governed by the geographical location, soil characteristics, and other factors. Reed canary grass, tall fescue, and red top have been successful in Texas. Mixtures of local grasses and alfalfa have produced good results in Washington; and reed canary grass, and a varied selection of local grasses have been utilized in Pennsylvania.

Loamy, well-drained soil is most suitable for irrigation systems, particularly where consumptive use and crop production is a major goal of the operation. A minimum soil depth of five feet above groundwater is preferred to prevent saturation of the root zone.

Underdrain systems have been used successfully to adapt to high groundwater or impervious subsoil conditions. It is essential that soil and geological testing be conducted of the disposal area to determine its suitability prior to construction of a new system. Drain tile collection systems may be installed some four to eight feet below ground surface at 15.2 to 45.7 m (50 to 150 ft) intervals. The wastewater is applied to the ground surface by spray irrigation or other means at a higher rate than would otherwise be feasible in soils with poor drainage. At one system investigated, the accumulated drain tile volume equalled approximately half of the applied volume to the surface, the remainder presumably being lost to evapo-transpiration.

A properly designed and operated drain tile field can be an excellent treatment unit.

Construction costs are relatively high, as shown in the spray irrigation subsection of Section VIII, but the operational cost is low.

Various problems have occurred using spray irrigation systems. Sprinkler nozzles have plugged due to solids in the wastewater. During winter months, nozzles have plugged due to freezing, and piping has frozen and ruptured. Ponding of wastewater on the wetted areas must be minimized to prevent odor problems.

In the spray irrigation subsection of Section VIII of this report is found a rather comprehensive presentation of the components of a spray irrigation system and their estimated costs.

<u>Ridge and Furrow Irrigation</u>

Ridge-and-furrow systems are usually constructed on level areas with permeable soil. These systems consist of a series of rectangularly shaped furrows which receive wastewater from a main feeder ditch. Raw crops provide consumptive use of the moisture and nutrients applied in the furrows. The irrigation field is usually divided into separate plots and the waste discharged to a different plot each day. Several problems have occurred using ridge-and-furrow irrigation systems. Improperly sloped furrows have caused ponding at the lower end while weed growth in the furrows reduces hydraulic capacity. Hand cutting and spraying minimize this problem. Ineffective screening of wastewater may cause solids accumulation in the furrows which creates odors, reduces hydraulic capacity, and requires maintenance.

<u>Flood Irrigation</u>

Flood irrigation is a misnomer applied to shallow ing basins created by construction of low berms around an area of very permeable soil. Wastewater is intermittently applied at a rate approaching the hydraulic conductivity of the soil, allowed to percolate, and the ground allowed to dry. Occasionally, the bottom of the spreading basin is disced and harrowed to reduce pore clogging and aerate the soil. The method is applicable under very favorable conditions of soil permeability and hot, dry climate; e.g., some localities of the interior valleys of California, Oregon, and Washington. The method is obviously relatively inexpensive in cost and may be considered where conditions are suitable and groundwater quality protection is not a restriction.

Overland Flow

The overland flow technique is a method of land treatment adaptable to impermeable or poorly drained soils. The technique was pioneered in the U.S. in 1954 by the Campbell Soup Company at Napoleon, Ohio, and was studied in depth at the Campbell installation at Paris, Texas. (Ref. 7, 8) This method of land treatment has been used by the city of Melbourne, Australia, for direct application by flood irrigstion of raw domestic sewage (especially during winter months) since 1897 (Ref. 58).

Overland flow differs from spray irrigation primarily in that a substantial portion of the wastewater applied is designed to run off and must be collected and discharged to receiving waters, or in certain cases where wastewater is produced only during part of the year, it is stored for deferred application.

Wastewater is applied by sprinklers to the upper two-thirds of sloped terraces that are 30.5 to 91.4 m (100 to 300 ft) in length. A run-off collection ditch or drain is provided at the bottom of each slope. Treatment is accomplished by bacteria on the soil surface and within the vegetative litter as the wastewater flows down the sloped, grass-covered surface to the run-off collection drains. Ideally, the slopes should have a grade of two to four percent to provide adequate treatment and prevent ponding or erosion. The system may be used on naturally sloped lands or it may be adapated to flat agricultural land by reshaping the surface to provide the necessary slopes.

The hydraulic loading rates possible with the overland flow technique may range between 0.6 to 1.8 cm/day (0.25 to 0.7 in./day) resulting in a land requirement of about 450 to 1350 sq m (50 to 150 acres) plus buffer zone for each mgd applied.

As mentioned previously, the system is especially suited to use with slowly permeable soils such as clays or clay loams, but may also be used on sandy soils with proper application and drainage. With the slowly permeable types of soil (and with properly drained sandy soil),very little water percolates to the groundwater. Most of it appears as surface runoff or is consumed by evapo-transpiration. A cover crop is essential with the overland flow system to provide slope protection and media for the soil bacteria as well as to provide nutrient removal by plant uptake. A water tolerant perennial grass, such as reed canary grass or tall fescue has been found to be suitable to the high liquid loading rates.

Present Practices

Table 84 provides interesting data pertinent to existing spray irrigation systems investigated during this study. Table 85 shows reported costs incurred for construction, operation, and maintenance. Table 86 provides information pertinent to overland flow treatment systems.

LAGOON TREATMENT SYSTEMS

The fruits and vegetables processing industry has utilized lagoons for waste disposal since the early 1930's. The early lagoons were holding lagoons that would hold all the wastes generated by a processor during the processing season. Holding lagoons are still popular within the industry, particularly in the Midwest. Other types of lagoons in use today are percolation-evaporation lagoons, anaerobic lagoons, aerobic lagoons or stabilization lagoons (oxidation ponds), and aerated lagoons.

Percolation-Evaporation Lagoons

In areas where there is very porous soil and hot, dry weather the percolation-evaporation lagoons usually perform efficiently. Most percolation-evaporation lagoons are in the Southwest and California where there is better probability of finding suitable soil and climatic conditions. Thorough site investigations for percolation-evaporation lagoons are necessary. Data should be obtained on percolation rates of surface soils, horizontal and vertical permeability of subsurface soils and possibility of pollution of groundwater aquifiers. The best soil type appears to be a loamy sand soil of approximately 85 percent sand, ten percent silt, and five percent clay with percolation rates up to 4 ft/day.

A percolation-evaporation lagoon is often operated from 15 cm (6 inches) to 30 cm (12 inches) in depth, and raw wastewater is comminuted or screened prior to discharge into the lagoon. Lagoons are usually operated in parallel and alternately filled and allowed to drain. Reed (Ref. 9) reports year around operation is possible in certain areas of Arizona with two weeks of filling followed by a ten-day dry up period in summer and twenty days in winter.

The national trend among state regulatory agencies is to look more closely at waste disposal by percolation then has been the case in the past. Protection of groundwater quality is gradually assuming equal importance with protection of surface water quality and there are few places left where a food processor can indiscriminately percolate wastes into the ground.

Where climatic conditions are suitable, as in the southwest, lined evaporation ponds have been an effective way to dispose of difficult to treat wastes such as olive processing brines. The

TABLE 84

DEMONSTRATED SPRAY IRRIGATION SYSTEMS

Process Code	No. Oper. Days per Year	Avg. Waste Water Volume		Average Influent Conc. (mg/l)		Distance to Field		Size of Irrig. Field		Averate Application Rate	
		mld	mgd	BOD	TSS	KM	MI	HA	AC	cm/day	in/day
PA25	120	1.9	0.5					15	36	1.3	0.5
PE27, CO28	180	2.5	0.7	3,261	1,391			32	80	0.5	0.2
BT28, PE26	90	2.6	0.7			1.5	0.9	24	60	1.0	0.4
PO40		0.3	0.1			0.8	0.5	9.7	24	0.3	0.1
CO82, PE53	120	0.6	0.2			1.6	1	32	80	1.0	0.4
PE 64	180	7.8	2.1			1.9	1.2	115	283	1.2	0.5
CO51	80	0.1	0.04			0.03	0.02	18	45	0.08	0.03
PA80, PI82	180	0.8	0.2	600	475			20	50	0.4	0.15
GR50		0.9	0.2	795	241			6.0	15	1.4	0.5
*M32	150	0.5	0.1	2,390	420	0.2	0.1	7.1	18	0.7	0.3
CE03	190	0.01	0.004	274	49			10	25	0.04	0.02
CT35, PO32	270	38	10			2.7	1.7	120	295	3.2	1.3
TO52	365	1.3	0.3	350	225	2.4	1.5	30	73	3.2	1.2
BW59, PE69	120	1.4	0.4			0.8	0.5	49	120	0.3	0.1
CH57, PL54	150	0.4	0.1	2,300	1,000	0.8	0.5	8.1	20	0.5	0.2
CO69, PO50	180	0.8	0.2			2.4	1.5	10	25	0.8	0.3
ON25, PE30	365	0.4	0.1	800	350	3.2	2	14	35	0.4	0.15

TABLE 85

SUMMARY OF REPORTED COSTS OF CONSTRUCTION AND OPERATION AND MAINTENANCE FOR SPRAY IRRIGATION SYSTEMS

Process Code	Flow Volume		Fields: Distance From Plant		Fields: Size		Const. Cost		Annual Oper. and Maint.
	mgd	mld	MI	KM	AC	HA	$1,000	Year	$1,000
BN42	0.3	1.1			53	21	240	1969-71	
CO28	.4	1.4			80	32	250	1968	12
PE26	1.1-1.2	.4-4.3	1	1.6	60	24	250	1967-70	16
CO82, PE53	0.15	0.5	1	1.6	80	32	75		20
PA80, PI82	0.2	0.7			50	20	30	1972	5
*M32					50	20	100	1962-73	45
CE90	0.01	.4			10	4	36	1966	
CT35, PO32	10	36	1.7	2.7	300	120	300	1951	61
TO52	0.3	1.1	1.5	2.4	75	30	30		8
CH57, PL52	0.1	.36	0.8	1.3	20	8	50		5
BN35, ON35	0.1	.36			35	14	28	1970	27
TO09	3.5	12.6			165	66	500	1960-72	38

TABLE 86

SUMMARY OF OVERLAND FLOW TREATMENT PERFORMANCE

Process Code	Influent Flow		Field Area		Application Rate		Runoff	Influent Avg. Conc.		Effluent Avg. Conc.		Removal Percent	
	mld	mgd	HA	AC	cm/ day	in/ day	% of Infl.	BOD	TSS	BOD	TSS	BOD	TSS
BF 26	1.9	0.5	48	120	0.6	0.25	10	950	140	10	21	99	85
*M30	3.0	0.8	5	12	---	---	60	190	45	65	17	66	62
SL03	13	3.5	154	385	1	0.4	60	490	245	8	24	98	90
TO23	12.5	3.3	100	250	1.3	0.5	10	500	---	12	--	98	--
CE90	0.4	0.1	4	10	0.8	0.3	25	1,040	711	5	25	99	96
*M32	0.4	0.1	20	50	---	---	--	2,780	1,100	170	51	94	95
SL01	15	4	134	335	1.1	0.45	--	500	365	---	--	--	--

amount of evaporation is highly variable depending on location. Data from the local weather bureau can be used to estimate evaporation and rainfall rates and their resulting effect on waste disposal by evaporation.

Holding Lagoons

Holding lagoons are basins large enough to hold all processing wastewaters discharged by a plant during a processing season. Generally, processing within the plant occurs during the summer and fall and the wastes are stored until the next spring and then discharged during high stream flow.

Holding lagoons are a common type of disposal facility in the Midwest and Northeast and have been used for many years. The advantages to the processor are: investments are made in land instead of treatment hardware; fairly good treatment results with little operation; the yearly cycle of fill and draw coincides well with the summer process season and spring high stream flows; and minimal sludge disposal problems. The advantage to regulatory agencies is positive regulation of discharges on a cu. meters/day basis during the time when the assimilative capacity of the receiving water is at its highest. The main disadvantages are possible obnoxious odors, vector breeding, and pollutant percolation into groundwaters.

Holding lagoons are often operated as parallel fill and draw basins. Natural bacteriological activity, primarily facultative and anaerobic and to a limited extent aerobic, stabilizes the organic matter in the stored wastewater. Wind and thermal currents mix the ponds to a limited extent. After a period of from six to eight months, the BOD_5 and suspended solids concentration may be reduced to a suitable level for discharge.

Table 87 lists effluent qualities and operational variables for Wisconsin holding lagoon treatment from O'Leary and Berner (Ref. 10). The raw waste concentrations and flows were not reported so removal efficiencies and detention times are not known. Because the lagoons were reported as holding lagoons, it is assumed the lagoons retained a full year of process flow. The discharged effluents are quite good with BOD_5 concentrations generally below 30 mg/l and suspended solids generally below 70 mg/l.

Many processors with existing holding lagoons are using their holding lagoons as part of a more sophisticated treatment chain in an attempt to meet more stringent discharge standards, and reduce the odor potential of the lagoons themselves. Some of the variations are described below.

Some processors have installed aeration systems in an attempt to convert the holding lagoon into an aerated lagoon with a long retention period. See the section on Aerated Lagoons.

TABLE 87

HOLDING LAGOON EFFLUENT QUALITIES AND OPERATIONAL VARIABLES FROM O'LEARY AND BERNER (1973)

Commodity	Total Pond Volume (million liters)	No. Parallel Ponds.	Effluent		
			Flow liters/min	BOD mg/l	S.S. mg/l
Vegetables	238.6	4	378.5	6	
Sauerkraut	36.8	3	198.2	40	
Peas, Corn	101.5	3	227.1	28	70
Peas, Corn	118.9	3	283.9	37	7
Peas, Corn & Misc. Veg.	194.2	4	473.2	17	22
Peas, Corn & Misc. Veg.	15.4	1	189.3	12	18
Sauerkraut & Carrots	37.9	1	378.5	5.4	14
Peas, Cream Corn & Carrots	6.89	2	378.5	32	56
Sauerkraut	84.3	2	113.6	26	100

Other processors have combined holding lagoons with spray irrigation, before or after the holding lagoon. Advocates of spray irrigation prior to lagooning report that the strength of the waste is sufficiently reduced to minimize odor problems during storage.

One processor slowly discharges holding lagoon contents into the municipal system at a nearby town. The holding lagoon acts as a year long equalization tank, and protects the municipal treatment works against large variations in influent volumes and strength.

Aerobic Lagoons

Aerobic lagoons or stabilization or oxidation lagoons are designed to utilize principals of natural purification. In aerobic or stabilization lagoons wastewater organics are decomposed by a combination of aerobic, facultative, and anaerobic bacteria. The aerobic bacteria are supplied with oxygen by natural surface aeration and an abundance of oxygen releasing algae. Bacteria and algae in aerobic lagoons form a symbiotic relationship which accelerates the treatment of wastewaters. Bacteria aerobically stabilizes the organic matter with the release of carbon dioxide. The carbon dioxide is assimilated by algae in the presence of sunlight, with the production of more algae which release oxygen for use by the bacteria.

In order to control the bacteria-algae interaction, a small degree of engineering design is necessary. The ponds work best at a rather shallow depth but the optimum depth varies with the season, therefore, an effluent drawoff structure that can control depths from three to six feet is desirable. Inlet and outlet locations must harmonize with the pond geometry to give food mixing and prevent short circuiting. Ponds in series are more efficient than single large ponds because they minimize short circuiting and allow sedimentation of spent algae and bacteria before discharge.

Aerobic lagoons have been used extensively in the fruits and vegetables industry. Porges (Ref. 11) reported that the canning industry utilized approximately 29 percent of the total number of aerobic lagoons or stabilization ponds used by industry. The Missouri Basin Engineering Health Council (Ref. 12) reported the median operational parameters and performance for aerobic lagoons or stabilization ponds used by the canning industry as follows: BOD_5 loading - 156 kg/ha/day (139 lbs/acre/day); retention time - 38 days; depth - 1.77 m (5.8 ft); and BOD_5 reduction - 98 percent.

There have been many problems with the use of aerobic lagoons in the fruits and vegetables industry with the primary problem being extreme overloading of the ponds. It appears that optimal design organic loading is very close to domestic sewage design which is

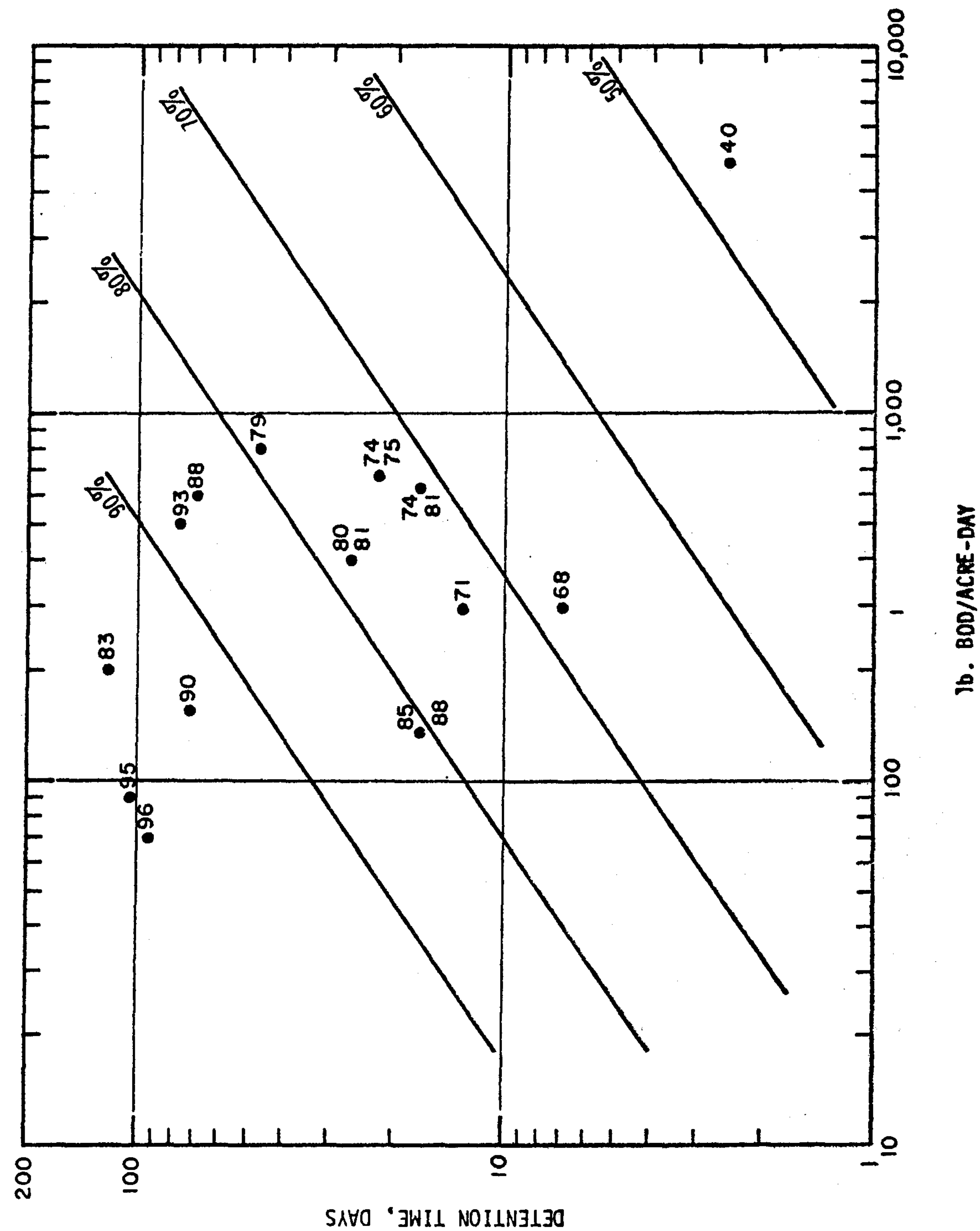
TABLE 88

STABILIZATION LAGOON PERFORMANCE IN TREATING FOOD PROCESSING WASTES

Product	BOD, mg/l in	BOD, mg/l out	BOD lbs/acre/day	Detention days	BOD % removed	Reference
Apricot, peach			90	106	96[a]	Parker (1966)
Apricot, peach			800	47	79[a]	Parker (1966)
Apricot, peach			500	78	93[a]	Parker (1966)
Apricot, peach			600	70	88[a]	Parker (1966)
Cannery			4770	2.5	40	Canham (1949)
Cannery			786	72	90	Canham (1949)
Corn	2936			9.6	59	Eckenfelder (1958)
Corn	774-3700	11-56	(6 ponds in series)			Dicksen (1963)
Pea			70	84	96	Dicksen (1963)
Pea	337-1050	17-58	(6 ponds in series)			Dicksen (1963)
Potato	1000			116	91	Olsen (1964)
Tomato			628	17	74-81[a]	Parker (1966)
Tomato			396	26	80-81[a]	Parker (1966)
Tomato, citrus			662	22	74-75[a]	Parker (1966)
Tomato, citrus			135	17	85-88[a]	Parker (1966)
Soup, tomatoes, poultry[b]		7.8[b]-35	67 (2 ponds in series)		95-99[b]	Gilde (1967)

a - nutrients added   b - centrifuged effluent

Figure 57 BOD removal efficiency relationship for ponds.



56 kg/ha/day (50 lbs BOD5/acre/day) for ponds in warmer climates. For application in colder climates, organic loading should be reduced to compensate for lower rates of microbial activity. Most ponds, however, have been operated at much higher loads as shown in Table 88. The BOD5 removal rates indicate there is a correlation with BOD5 loading. The results of Parker (Ref. 13) are shown in Figure 57.

The advantages of aerobic lagoons are that they reduce the suspended solids and colloidal matter, and oxidize the organic matter. They are simple, requiring minimal attention and they are inexpensive. The major problems of aerobic lagoons within this industry are odor problems which are apparently caused by overloading due to concentrated raw wastes and inadequate capacity for increased production, and high suspended solids due to algae growths. Lagoons are also dependent on climatic conditions including sunlight, wind and temperature.

Anaerobic Lagoons

Anaerobic lagoons degrade organic material in the absence of dissolved oxygen. The ponds are typically deep and heavily loaded with waste. The organic waste is degraded by anaerobic bacteria which have a relatively slow reaction rate. Under anaerobic conditions, organic materials are converted to methane, hydrogen sulfide, ammonia and organic acids. With these conditions, undesirable odors are generally generated. If the odors can be tolerated, the ponds may reduce up to 80 percent of the raw organic load. Another advantage is that sludge from other operations can be mixed in the ponds and stabilized.

Some anaerobic lagoons are reported to be relatively free of obnoxious odors. A common feature of these ponds is a thick mat of solids buildup on the pond surface, not unlike the scum mat which forms in the ordinary anaerobic digester tank in a domestic sewage treatment plant. This mat or a plastic cover of nylon-reinforced Hypalon, polyvinly chloride or styrofoam on the pond surface, helps to prevent odors through containment and prevention of surface agitation. Properly installed covers provide a convenient means for odor control and collection of the by-product methane gas.

Anaerobic lagoons are usually used in a treatment chain as primary treatment of screened cannery wastewaters. Subsequent treatment is usually some type of aerobic biological treatment. Performance data of anaerobic ponds are shown in Table 89. Optimal design criteria appears to be no greater than 320 kg BOD5/ha/day (286 lbs BOD5/acre/day).

TABLE 39

ANAEROBIC LAGOON PERFORMANCE ON SCREENED FOOD WASTES

Product	BOD mg/l	BOD lbs/1000 cu ft/ day	Detention Days	BOD, % Removed	Reference
Cannery		9.6-430	1/6-37 (pilot)	40-95	Agardy, et al (1967)
Citrus	4600	214	1.3*	87	McNary, et al (1953)
Corn		70-104	6-11.3	25-69	Canham (1968)
Corn		70-104	6-11.3**	53	Canham (1968)
Fruit, sewage	360-1200	110-430	1/6-1/4 (lab)	50-70	Norgaard, et al (1960)
Pea		81.5-159	2.8-3.9	22-29	Canham (1968)
Pea		81.5-159	2.8-3.9**	47-49	Canham (1968)
Pea blanch	30000		10	90+	Oliver, et al (1955)
Tomato	550	7.5	7.4	80	Hert (1958,1950)
Tomato		5.1	9.25	82	Hert (1948,1950)
Tomato		.86	37	98	Hert (1948,1950)
Tomato		2.5-9.9	7.5-10	70+	Splittstoesser, et al (1969)
Tomato, lima		1975	2.53	40	Canham (1950)

* Contact anaerobic process

** With added sodium nitrate

Aerated Lagoons

Aerated lagoons are basins in which oxygenation is accomplished mechanically, usually by fixed or floating surface aerators or diffused air piping systems. The lagoon is usually 2 to 4.5 m (7 to 15 ft) deep and relatively small in area when compared to stabilization ponds. Two designs are in practice. The first is the completely mixed basin in which all solids are kept in suspension, and stabilization of organics is entirely aerobic. The second type is much more prevalent and is known as the partially mixed or aerobic-anaerobic aerated lagoon. In the partially mixed aerated lagoon, oxygen transfer requirements are satisfied, but heavier solids settle to the bottom of the basin where they undergo anaerobic biological decomposition. Eckenfelder and O'Connor (Ref. 14) developed many of the theoretical relationships pertinent to aerated lagoon performance. Their work, since substantiated by other investigators, indicates that if sufficient oxygen is being supplied to the process, then BOD_5 removal is primarily a function of detention time, the biological solids concentration, the temperature, and the nature of the waste. It is beyond the scope of this report to discuss in detail the theoretical consideration involved, but general design considerations are discussed below.

Design Considerations - Design considerations for aerated lagoons are generally as follows:

1. BOD_5 removal rate
2. Temperature
3. Oxygen requirements
4. Mixing and geometry
5. Nutrients

BOD_5 Removal Rate - When an aerated lagoon is assumed to be completely mixed, the following relationship can be formulated:

$$R = 1/(1+kt)$$

where: R = BOD_5 removal fraction
t = detention time
k = removal rate

The removal rate is waste specific and temperature sensitive and must be determined by laboratory or pilot testing. Therefore, for a specific waste and temperature, the BOD_5 removal is only a function of detention time (assuming a completely mixed aerobic system).

Temperature - Temperature variations can exert a strong effect on the rate of BOD5 removal in aerated lagoons. How temperature will affect any specific plant design will, of course, depend upon the local climate and the seasonality of the waste generation. The engineer will normally design unit process facilities to meet effluent standards under the worst temperature conditions. In the fruits and vegetables industry, most processing occurs during mild temperatures and thus the temperature effect on lagoons is less important. Also, many north central processors handle waste in long retention lagoons with discharges determined by water quality requirements. Because of the long retention times, temperature effects are insignificant. Nevertheless, temperature may affect the aerated lagoon treatment of some commodities such as dry beans and mushrooms. The effluent limitations and the associated costs reflect the worst temperature effect.

Oxygen Requirements - In an aerated lagoon, the total oxygen requirements are related to the BOD5 removal and the mass of biological solids in suspension. When the biological solids are maintained at a low level, the oxygen requirements are then related only to BOD5 removal. This relationship follows:

mg oxygen/day = a' mg BOD5 rem/day

The coefficient a' can vary from 0.9 to 1.4 for most biodegradable wastes. Frequently an extremely conservative a' coefficient of 1.5 is used for design.

Oxygen is usually transferred to the waste in an aerated lagoon by mechanical aerators. The general oxygen transfer relationship is presented in the Activated Sludge section. Generally, aerator design can be based on a transfer rate of 5.96 kg BOD5/KW/hr (2 lbs BOD5/hp/hr). This value is, however, temperature dependent.

Mixing and Geometry

Aerators serve two functions in biological treatment processes; the transfer of the required oxygen and inducing sufficient mixing to maintain uniform oxygen throughout the basin as in the case of aerobic lagoons, and keeping the biological solids in suspension in the activated sludge process. For activated sludge, the power required for oxygen transfer is usually considerably in excess of that required for mixing. In large aerobic-facultative lagoons or extended aeration systems, however, power for mixing may control the aerator design.

The oxygen transfer efficiency for most aerators is usually lagoon volume dependent while the mixing efficiency is usually geometry dependent. For most organic mixed liquors, the minimum velocity for complete solids suspendsion is 0.12 to 0.15 m/sec (0.4 to 0.5 ft/sec). At a 4.27 m (14 ft) lagoon depth, a power of 3.93 to 5.91 KW/1000 cu m (20 to 30 hp/MG) is required for full suspension.

TABLE 90

REPORTED AERATED LAGOON TREATMENT SYSTEM PERFORMANCE

Process Code	Volume		Influent Qual.		Effluent Qual.		Average Percent Reduction	
	mld	mgd	BOD, mg/l Ave. (Range)	TSS, mg/l Ave. (Range)	BOD, mg/l Ave. (Range)	TSS, mg/l Ave. (Range)	BOD	TSS
GR33	0.8	0.2	1,300 (800-2,500)	400 (40-620)	26 (18-40)	25 (15-35)	98	94
TO51	0.4	0.1	1,000	690	13	44	99	93
TO52	1.1	0.3	1,100	530	13	44	99	92
PK60	0.8	0.2	3,280 (1,500-5,800)	401 (135-825)	26 (8-50)	136 (85-270)	98	68
ST40	0.8	0.2	4,090	270	94	41	98	85
PN26	1.9	0.5	616 (510-710)	130 (88-220)	53 (33-70)	92 (40-120)	91	30

However, for the case where complete mixing is not required, uniform dissolved oxygen dispersion is from 1.0 to 2.0 KW/1000 cu m (6 to 10 hp/MG). A single cell aerated lagoon can obtain good removal of soluble BOD_5, but the effluent will contain suspended solids in the same concentrations as the mixed liquor. Usually a greatly improved effluent can be achieved by following the aerated lagoon with a second polishing lagoon where suspended solids are allowed to settle.

Nutrients - A proper nutritional balance with nitrogen and phosphorus being the most important is essential for efficient biological treatment. This is discussed separately in this section because of its importance in treating nutrient deficient fruit and vegetable wastes.

Study Results - Table 90 on the following page shows treatment results reported on well-designed aerated lagoons which were investigated during the preparation of this document.

TRICKLING FILTER

General

The trickling filter provides a means of secondary biological treatment which allows the wastewater to trickle over the filter media giving opportunity for formation of a zoogleal film on the media. The zoogleal film is composed of bacterial organisms which oxidize and remove suspended and dissolved solids in the wastewater which it contacts. As this film builds up, it will slough off the media and is usually removed in a clarifier where it settles as humus sludge. The settled sludge is either returned to the head of the treatment plant to settle with the primary sludge or is managed separately.

The circular filter media bed, usually 0.9 to 2.4 m (3 to 8 ft) deep, consists of rock, slag, broken stone, coal, bricks, plastic material, or other durable insoluble material with enough pore space to allow good ventilation throughout the bed and permit the wastewater's passage through the bed without "ponding" due to the heavy zoogleal growth. The most popular media today is molded plastic. The bed consists of pre-fab, honeycombed units which are usually stacked relatively high.

When the wastewater completes its flow through the media, it is collected in an underdrainage system. The underdrainage is designed to allow ventilation throughout the filter bed and promote aerobic organisms in the bacterial growth.

The wastewater is uniformly dispersed over the filter-media surface by a rotary type distributor or a fixed nozzle distributor. The rotary type distributor consists of two or more horizontal pipes supported a few inches above the filter bed by a central column. The wastewater enters the column and is fed to each of the horizontal pipes (arms). Each arm has orifices along its length which distribute the wastewater to the media. The jet-like action from these orifices causes the whole distribution system (central column, arms) to rotate, thereby allowing equal dispersion of wastewater over the entire surface area of the bed.

Recirculation is often used to increase the efficiency of trickling filters. A portion of the effluent (from either the trickling filter or final clarifier) is returned to the influent wastewater flow. This increases the contact time between the wastewater and the zoogleal film and seeds the lower portions of the bed with active organisms to promote a more thorough treatment. Recirculation also promotes more continuous and uniform growth sloughings, thereby preventing ponding and enhancing ventilation. In addition, recirculation prevents intermittent drying of the growth.

Design Considerations

There are three classifications of trickling filters; standard rate, high rate, and roughing filters. These differ by hydraulic and organic loadings applied.

The standard rate filter hydraulic range is 1.0 to 4.1 cu m/day/sq m (25 to 100 gal/day/sq ft), and its organic range is 80 to 400 kg BOD5/1000 cu m (5 to 25 lbs BOD5/1000 cu ft) of filter media. Its bed depth is usually 1.8 to 2.4 m (6 to 8 ft). It may or may not use recirculation.

The high-rate filter hydraulic range is 4.091 to 40.91 cu m/day/sq m (100 to 1000 gal/day/sq ft), and its organic loading range is 400 to 4800 kg/ BOD5/1000 cu m (25 to 300 lbs BOD5/1000 cu ft) of filter media. Bed depth is normally 3 to 5 ft. Under most circumstances it will have recirculation.

The roughing filter is actually a high-rate filter with an organic loading exceeding 4800 kg BOD5/1000 cu m (300 lbs BOD5/1000 cu ft) of filter media. Overall BOD5 reductions are lower than a high-rate filter (40 to 70 percent removal efficiency). This type of filter is used primarily to reduce the organic load on subsequent treatment processes (a second trickling filter, activated sludge, etc.). The roughing filter is often used in treatment processes which receive a strong, organic industrial wastewater. Plastic media is often utilized with an extremely deep filter bed, a high recirculation rate, and forced air ventilation.

Some trickling filter treatment processes utilize a two-stage method. That is, two trickling filters in series. As was mentioned in the case of the roughing filter, it could be necessary due to the organic level of the wastewater.

ACTIVATED SLUDGE

General

The activated sludge process is a biological treatment system where wastewater is mixed with an acclimated suspension of microorganisms in an aeration basin or tank. The microorganisms remove the organics from the wastewater and use this food for new cell growth. This process requires the addition of oxygen, usually by either mechanical aerators or by diffused air from air compressors. The microbiological growths are then separated from the treated waste by settling in a secondary clarifier. The settled sludge is then recirculated back to the aeration basin for mixing with the aeration basin influent.

The activated sludge process is presently being used by approximately fifteen to twenty processors in the fruit and vegetable processing industry. Table 91 lists performance data pertinent to the better activated sludge. Plants not listed either lacked performance data, or were not functioning well because of design or operating deficiencies. As can be seen from the table the process is capable of outstanding performance when conservatively designed to anticipate unfavorable variations in waste volume, characteristics, ambient temperature, etc. Pretreatment in the form of pH control, nutrient addition, solid separation, BOD_5 reduction, etc. may be required to insure optimum performance of the activated sludge treatment module.

Design Considerations

Commonly, the industry uses a modification of the standard activated sludge designs utilized for treatment of domestic sewage. The design modifications normally include extended retention times (normally 24 hours or longer), completely mixed aeration basin, and larger secondary clarifiers.

The complete mix method is usually preferred when treating fruits and vegetables wastes because:

1. When completely mixed, the aeration tank partially serves as an equilization basin to smooth out organic load variations which have a harmful effect on a plug flow system;

2. In the completely mixed system, the oxygen utilization rate is constant throughout the tank and aeration equipment can be equally spaced;

3. The lined earthen basins, which are normally used for aeration because they are more economical than reinforced concrete or steel, are easier to design as completely mixed aeration basins.

TABLE 91

REPORTED ACTIVATED SLUDGE TREATMENT SYSTEM PERFORMANCE

Process Code	Average Volume		Influent Qual.		Effluent Qual.		Average Percent Reduction	
	mld	mgd	BOD, mg/l Ave. (Range)	TSS, mg/l Ave. (Range)	BOD, mg/l Ave. (Range)	TSS, mg/l Ave. (Range)	BOD	TSS
GR32	1.9	0.5	4,000 (1,900-9,000)	170 (80-500)	10 (2-32)	5 (1-20)	99	97
BN43	1.5	0.4	370 (240-730)	220 (120-400)	11 (3-18)	10 (3-40)	97	95
BN47	1.1	0.3	320	170	20	19	94	89
TO50	5.7	1.5	500 (30-1,600)	20 (6-40)	11 (3-30)	10 (1-20)	98	50
TO51	6.1	1.6	1,900 (900-2,500)	320 (100-400)	15 (3-90)	15 (5-65)	99	95
SL01	19	5.0	520 (420-600)	360 (200-850)	25	30	95	92
ST01	1.5	0.4	3,900 (1,000-9,000)	1,440 (350-5,100)	165 (50-490)	140 (10-300)	96	90
SD03	1.9	0.5	5,700*	1,200	450*	190	92	84

* Measured as COD

TABLE 91 (Continued)

Process Code	Average Volume		Influent Qual.		Effluent Qual.		Average Percent Reduction	
	mld	mgd	BOD, mg/l Ave. (Range)	TSS, mg/l Ave. (Range)	BOD, mg/l Ave. (Range)	TSS, mg/l Ave. (Range	BOD	TSS
BN26	0.4	0.1	580 (100-1,800)	230 (40-1,000)	15 (6-20)	20 (12-34)	97	92
BD34	0.8	0.2	600 (90-1,800)	450 (80-1,200)	43 (15-90)	45 (25-160)	93	90
*C54	4.6	1.2	260 (20-450)	140 (10-600)	12 (2-90)	20 (2-140)	95	87
CS08	1.9	0.5	3,500 (2,000-6,500)	4,500 (1,700-8,300)	15 (10-30)	35 (20-60)	99	99
PN25	1.9	0.5	210 (20-700)	160 (30-480)	7 (5-21)	36 (15-59)	97	78

* Measured as COD

The principal reasons for the longer detention times are:

1. The wastes are usually higher in BOD_5 than domestic sewage and a longer period of aeration time is required for stabilization.

2. Operational flexibility.

3. Better ability to handle peak and shock loads.

4. Simplification of operation with a minimum of operational control.

The larger secondary clarifiers are generally needed because the aerated mixed liquor often has relatively poor settling characteristics when compared to domestic waste.

The design of an activated sludge process for a fruits and vegetables plant requires knowledge or evaluation of several design parameters. These parameters include:

1. BOD_5 removal chracteristics;
2. Oxygen requirements;
3. Sludge production;
4. Oxygen transfer;
5. Solid-liquid separation;
6. Nutritional requirements;
7. Temperature effects.

BOD_5 Removal Characteristics - A model for BOD_5 removal in a completely mixed activated sludge system is:

$$Se = \frac{(Sa - Se)}{Xakt}$$

Where: Se = effluent soluble BOD5
Sa = influent BOD5
Xa = aeration tank mixed liquor volatile suspended solids (MLVSS)
k = reaction rate
t = aeration detention time

This model is first order and assumes a linear relationship between concentration of BOD_5 remaining and removal rate. With this model the reaction rate can be determined graphically from experimental data.

Oxygen Requirements - In the aeration tank there are two microbiological processes taking place simultaneously that require oxygen, organic growth (synthesis), and organic decay (endogeneous respiration). The total oxygen required can be computed from the following relationship:

$$O_2\text{/day (mg)} = a'\text{BOD5 (mg)/day} + b'\text{ MLVSS (mg)}$$

The coefficient a' can be determined from the slope and b' from the intercept of a plot of lb $\underline{O2}$/(day)/(mg MLVSS) versus mg BOD5 removed/(day)/(mg MLVSS). The data to make the plot would normally be experimental data collected from a bench or pilot scale treatment system.

Sludge Production - Sludge will accumulate in an activated sludge system because of the following:

1. Synthesis of new cells;

2. Accumulation of non-biodegradeable suspended solids present in the influent waste, and;

3. Oxidation of aeration tank volatile suspended solids.

Sludge accumulation can be computed from the following relationships:

$$\text{Sludge (lbs VSS/day)} = \text{F mg VSS/day} + \text{mg } BOD\underline{5} \text{ rem/day} - \text{b mg MLVSS}$$

Where: F = that fraction of the volatile solids in the influent waste that are not biodegraded during the aeration process.
a = fraction of $BOD\underline{5}$ converted to new cells
b = fraction of the total aeration volatile solids oxidized per day

Oxygen Transfer - The rate oxygen is transferred to wastewater in an aeration basin is primarily dependent upon the basin temperature, the dissolved oxygen concentration in the basin and the characteristics of the wastewater which alters the oxygen transfer in comparison to clean water.

Solid-Liquid Separation - To produce low $BOD\underline{5}$ and suspended solids concentrations in the effluent an activated sludge plant must perform solid-liquid separation efficiently. The clarifier following the aeration basin performs this function. When treating fruit and vegetable wastes which are often highly soluble, many activated sludge plants produce a bulking or poor settling mixed liquor. In order to minimize this problem, the following factors should be considered:

1. Clarifier Overflow Rate - Clarifiers within domestic activated sludge plants are usually designed at 32.3 cu m/day/sq m (800 gal/day/ sq ft). For soluble wastes a maximum design criteria of 16.45 cu m/day/sq. m. (400 gal/day/sq ft) is justified.

2. Clarifier Depth - Because the sludge sometimes tends to bulk in a deep clarifier, long detention time is justified. A suggested minimum side water depth of 3.66 m (12 ft) is often required for sludge blanket control.

3. Sludge Removal Mechanism - A suction removal is superior to a scraper unit because of the fluffy nature of the sludge.

4. Sludge Recycle - A minimum capability of 100 percent recycle because of the voluminous nature of the sludge.

5. Sludge Management - The food to microorganisms (F/M) ratio (mg BOD_5/mg MLVSS/day) in the aeration tank should be maintained at a low constant value. Mixed liquor with F/M ratios exceeding 0.2 usually show poor settling characteristics.

6. Nutrients - This was discussed in a previous section.

Activated sludge systems which perform poorly in treating fruit and vegetable wastes usually exhibit very poor liquid-solids separation. The above factors if considered and properly investigated should minimize these problems.

Temperature Effects - Temperature variations can exert an effect on biological treatment processes. The rate of biological reactions will generally increase with temperature up to approximately 30°C. The effect of temperature reduction is to slow bacterial metabolism. The exact degree of slow-down, and it's effect on the process efficiency is waste and process specific. Generally, treatment processes with long detention times (e.g., aerated lagoons), are sensitive to temperature effects and comparatively short term activated sludge treatment stystems are not significantly affected by temperature variations.

MULTI-MEDIA FILTRATION

The action of a rapid sand filter consists of straining, flocculation, and sedimentation. Particles are removed by entrapment between grains of the filter media primarily at the filter's surface. The use of coarser sand or anthracite coal minimizes the premature clogging of the filter surface. Mixed media filters are special versions of rapid sand filters that permit deeper bed-penetration by gradation of particle sizes in the bed. Up-flow filters are also special designs of rapid filters.

Filters are cleaned by reverse flushing or backwashing. Clean water is forced up through the filter media washing away the material that had been removed by the filter's action. The dirty backwash water is returned to a previous step in the treatment process for further treatment. The filters are equipped with an automatic backwash feature which initiates a backwash cycle when a preset pressure difference between the top and bottom of the filter indicates the pores are clogging and solids removal capability rapidly decreasing.

Performance of filters will depend on design, hydraulic flow, wastewater characteristics, and pretreatment of the wastewater prior to filtration. Proper design is specific to the wastewater being treated, and laboratory testing is very important prior to selection of a filter. Often, chemical coagulation is an essential prelude to filtration if the suspended solids are very small, e.g., algae. Chlorination prior to filtration is also frequently necessary to minimize slime growth in the filter which causes clogging and odor problems.

As previously indicated, the use of filters occur mainly as a final step in a treatment chain to remove suspended solids sufficiently to meet regulatory agency criteria. Stabilization ponds, for example, are often very effective in removal of BOD_5 from wastewater but produce effluents with high suspended solids due to algae growth. Experience with domestic wastewater at Lancaster, California, (Ref. 25) indicates that high concentrations of algae can be removed with properly designed filters preceded by chemical coagulation and floculation. A second use for filters is the following unit process to secondary clarifiers of activated sludge systems. Here, the purpose of the filter is to remove suspended solids which have not settled out in the secondary clarifier, a rather common circumstance in the activated sludge treatment of wastes generated by the fruit and vegetable processing industry.

It is believed that sand, anthracite, or mixed media filters will be increasingly used for tertiary treatment of fruit and vegetable processing wastewater in order to remove suspended solids carry-over from secondary treatment processes. Four processors who presently use filters were included in the field investigations conducted for this study.

A slow sand filter is a specially prepared bed of sand or other mineral fines on which doses of wastewater are intermittently applied and from which effluent is removed by an underdrainage system. BOD_5 removal occurs primarily as a function of the degree of solids removal, although some biological action occurs in the top inch or two of sand. Effluent from the sand filter is often of a high quality with BOD_5 and suspended solids concentrations of less than 10 mg/l. Table 92 shows the performance of a rapid sand filter on activated sludge effluent from a processor.

Additional filtration techniques and other treatment methods have been evaluated (Ref. 50, 51) for use in upgrading municipal wastewater stabilization ponds to remove suspended solids,

TABLE 92

RAPID MULTI-MEDIA FILTRATION PERFORMANCE
WITH ACTIVATED SLUDGE EFFLUENT (1)

	Raw Waste Influent BOD5	Activated Sludge Effluent		Multi-Media Filtration Effluent	
		BOD5	TSS	BOD5	TSS
Seasonal Average(2)	4096	20.6	28.1	8.1	8.4
Maximum Month(2)		34.0	78.1	13.0	9.2
Maximum Day(3)		114.0	216.0	32.0	20.0

(1) Grape processing - GR32
(2) Logarithmic averages
(3) Actual maximum values

TABLE 93

EFFLUENT QUALITY FOR VARIOUS TREATMENT PROCESSES

Process	S.S. mg/l	COD mg/l	BOD5 mg/l	Turb. JTU	P mg/l	N mg/l
Chemical Treatment (Solids Contact)	0-7	17	2.9-5	0.2-2.9	0.08-0.9	5-10.7
Granular or Mixed Media Filtration w/Chem.	0-5	13-17	3.1-5.8	0.2-10	0.05	5
Intermittent Sand Filtration	0-3	—	3-5	—	—	—
Sand Filtration w/Chem. Coag.	2-5	26	2-3	0.8-3.5	0.15-1.5	—
Extended Aeration	35	—	20	—	—	—
Total Containment	—	—	—	—	—	—
Activated Carbon	0.6	10-12	1.0	1.2	0.3	6.6
Reverse Osmosis	—	0-1.0	—	0.27	0.2*	3.5**
Electrodialysis	—	8.0	—	—	7.8*	8.2**
Ion Exchange	—	3.7	—	0.0	8.8*	4.2**
Dissolved Air Floatation	6	3	—	—	—	—
Microstraining	5	6	3	—	—	—
Ultrafiltration	0	20	<1	<0.1	—	—

*PO_4 only

**NH_3-NO_3 only

primarily in the form of algae. While raw waste waters treated in this industry are typically more concentrated than domestic sewage, the algae types and BOD5 and TSS concentrations which are produced by stabilization lagoons and oxidation ponds in this industry are largely identical. Therefore, filtration methods considered in these publications as applied to the fruits and vegetables industry would be expected to achieve the same range of effluent quality experienced in municipal application. Table 93 presents the effluent quality and costs for various treatment processes for municipal application. The actual cost for application of these methods in this industry may be different from those presented, however the order of magnitude indicated compares well with that presented in Section VIII of this document.

SLUDGE HANDLING

General

The handling, treatment, and disposal of sludge is a major capital and operating problem associated with the separation of solids in primary clarifiers, secondary clarifiers, air flotation tanks, etc. Due to the relatively high BOD5 and suspended solids levels, the volumes of sludge generated in the treatment of food processing wastes are usually greatly in excess of sludge volumes generated during the treatment of domestic waste for the same wastewater volume treated. Wherever feasible, therefore, the design engineer for a food processing waste treatment facility should use treatment chains which incorporate treatment modules that produce a minimal amount of waste sludge on a continuous basis; e.g., aerated ponds, land disposal, extended aeration activated sludge, etc.

A number of alternate methods are practiced for sludge treatment and disposal, for municipal waste. For the purpose of this study, however, discussion (and cost estimates in Section VIII) will be limited to aerobic digestion, anaerobic digestion, vacuum filtration and sludge handling.

Aerobic Digestion

The aerobic stabilization of biological solids resulting from the treatment of wastewaters is the basis for such modifications of the activated sludge process as "total oxidation" and "extended aeration." However, in many treatment plants separate aerobic digesters are used for the stabilization of mixtures of excess activated and primary sludges. The mechanism of microbial degradation is different for the various mixtures of sludges. The degree of stabilization of the organic solids also varies with sludge type.

Mechanism - The mechanism by which wastewater sludges are stabilized aerobically is dependent upon the type of sludge, i.e., primary, waste activated, or a combination. Aerobic stabilization of primary sludge is a sequential process similar to that of anaerobic sludge digestion. The particulate organic material must be converted to soluble compounds which can be subsequently used by the microbial population as a source of nutrients and energy. Bacterial utilization of the aqueous compounds produces carbon dioxide, water, and cell material.

The aerobic stabilization of primary sludge results in an environment in which the food to microorganism ratio is low. Therefore, the organic material originally in the sludge particle is almost quantitatively converted to bacterial cell material, and the change in the volatile solids concentration is minimal. However, the aerobic stabilization of excess activated sludge may be considered to be a continuation of the activated sludge process. Therefore, little additional cell synthesis occurs, and the primary process involves endogenous respiration of cell mass to water, carbon dioxide, mineralized products, and ash.

Application - the successful application to fruit and vegetable processing wastewater sludges depends on the type of sludge, the organic loading and the detention time. Organic loading and detention time are dependent variables. For a system treating a mixture of activated sludge and primary sludge, the efficiency of volatile solids removal is correlated to sludge age at organic loadings between 640 and 1760 kg/1000 cu m/day (40 to 110 lbs VS/1000 cu ft/day) volatile solids and detention times of 15 to 30 days. The equation describing the relationships between sludge age and efficiency of volatile solids removal is:

Volatile Solids Removal (percent) = 2.84 + 35.07 log (sludge age)

Sludge age is defined as the ratio of the weight of volatile solids in the digestor to the weight of volatile solids added per day. There exists an optimum sludge age beyond which no significant reduction in the concentration of volatile solids occurs.

The recommended loadings for aerobically treated mixtures of primary and activated sludges or primary and trickling filter sludges is less than 1600 kg total solids/1000 cu m/day (100 lbs TS/1000 cu ft/day), and the minimum suggested detention time is 20 days. The recommended detention time for waste activated sludge is about ten days; however, fifteen days is preferred.

Design of the aerobic digestion tanks, either circular or rectangular, will depend on a variety of factors including the following:

1. Influent TSS and BOD_5 concentrations.

2. Percent solids removal in primary and secondary clarifiers.

3. Percent solids to digester from clarifiers.

4. Required retention time.

Major components of aerobic systems include the tank, floating mechanical aerator, and sludge pumps.

Anaerobic Digestion

Anaerobic digestion in separate digestion tanks is a rarity in treating sludge from fruit and vegetable waste treatment because of the seasonal nature of the operation and operational problems associated with anaerobic digestion. Anaerobic digestion is a difficult process to control as temperature, pH, and sludge feed must be closely regulated. Therefore, aerobic digestion, because of its simplicity, appears to be better suited to most fruit and vegetable waste treatment systems.

VACUUM FILTRATION

Vacuum filters have been widely accepted as a mechanical method of sludge dewatering with both domestic wastewaters and industrial wastewaters. The rotary continuous vacuum filter is an economical method of sludge dewatering if the unit is properly designed and the operation is optimized. For some sludges, chemical conditioning is required. This technology is advancing rapidly and should reduce the cost of operating vacuum filtration units for most purposes. (Ref. 23).

A vacuum filter basically consists of a cylindrical drum which rotates partially submerged (usually 25 percent) in a vat or pan of sludge. The filter drum is divided into compartments by partitions or seal strips. A vacuum is applied between the drum deck and filter medium causing filtrate (liquid) to be extracted and filter cake to be retained on the medium during the pickup and cake drying cycle. The discharge cycle varies with the type of filter medium used. An agitator is suspended in the vat to keep the sludge solids in suspension. Four types of vacuum filters are drum-type filters, string discharge filters, belt-type filters and coil-type filters.

The dewatering rate of a vacuum filter sludge cake has been found to be a complex phenomena which cannot be expressed as a convenient equation form. Because of the interaction between the variables affecting final cake moisture content, correlation methods derived from both empirical analysis and theory have been employed. The basic objective of vacuum filtration of sludge is dewatering to the degree required for the particular method employed for sludge cake disposal and to achieve the desired moisture removal at the least possible cost. It is essential that sludge dewatering by vacuum filtration be carried out by an integrated installation that would be reliable, reasonably consistent in performance, and flexible enough to meet the varying conditions normally encountered in handling wastewater sludges.

Specific objectives to be achieved in a given sludge dewatering plant must be a compromise between a number of desirable results, such as a low sludge-cake moisture content, a high filter yield, high-solids recovery, good filtrate clarity, low unit cost of sludge cake production, and ease of vacuum filter operation and maintenance. It is not possible to maximize all of these desirable objectives. Rather, it is the task of the design engineer or plant operator to achieve the optimum balance of these specific objectives for a particular wastewater treatment plant.

Rickter (Ref. 24) reported the use of vacuum filtration for the dewatering of potato waste primary sludge and activated sludge. For this waste, the solids concentration of the primary clarifier-thickener underflow averaged about 48 percent and the vacuum filter cake averaged 62 percent solids without coagulants. When an anionic polymer was added to the silt water entering the clarifier-thickener, the underflow solids increased to about 53 percent, and the filter cake solids increased to about 72 percent.

Final disposal of sludge primarily from vacuum filtration or aerobic digestion, is effected by either land filling of caked solids, or land spreading of digested sludge through irrigation equipment or tank spreaders.

CHLORINATION

The disinfection of domestic and industrial wastewater is usually achieved through chlorination. Chlorine, when added to wastewaters, forms various compounds including HOCl, OCCl, and chloramines. The germicidal effect is believed due to the reaction of the chlorine compounds achieved with essential enzymes of the bacterial cell, thereby stopping the metabolic process. Among the conditions affecting germicidal effectiveness are pH, temperature, contact time, and mixing chlorine dose concentration. Residual pH affects germicidal power through its relation to the formation of HOCl which is many times more effective than OCCl and chloramines.

Chlorine is used principally to disinfect treated effluent prior to its discharge into surface waters. To be effective, chlorine requires a contact time of not less than fifteen minutes at maximum flow rates at which time there should remain a residual of not less than 0.2 to 1.0 mg/l. Under these conditions, chlorination of effluent from secondary treatment will generally result in more than a 99.9 percent reduction in the coliform content of the effluent. The range of chlorine dosage generally required for disinfection varies from 3 to 30 mg/l depending upon the quality of the effluent.

BOD5 can be reduced by the use of chlorine. Approximately two mg/l of BOD5 is satisfied by each mg/l of chlorine absorbed up to the point at which orthotolidine residual is produced. Chlorine alone can reduce BOD5 by as much as 15 to 35 percent. Chlorine for BOD5 reduction, however, is not cost-effective and is not recommended.

An important potential use for chlorine is to kill algae prior to algae removal operations performed on lagoon effluent. Dead algae are much easier to remove by flotation, sedimentation, and filtration than are live algae, according to experience with removal of algae from domestic wastewater lagoon effluents. Chlorination of algae laden lagoon effluents requires high dosages of chlorine (up to 25 mg/l) because chloramines are formed. Chloramines are not as effective a killing agent as the other compounds chlorine forms in water.

Chlorine is also effective in the oxidation of hydrogen sulfide and is used for odor control. It may be applied whenever there is a decomposition odor problem. In general, control will result from the application of 4 to 6 mg/l and without the production of a residual.

Chlorine is available as liquified chlorine, in powdered form, and in solutions. Liquified chlorine in 68 kg (150 pound) and 970 kg (1 ton) cylinders is genrally used for all but the smallest facilities. Chlorination facilities include chlorinators, chlorine handling and storage, mixing, and detention facilities for effluent. Since chlorine is a hazardous substance, special safety precautions in storage and handling are required.

Chlorination is employed for final wastewater disinfection by several fruit and vegetable processors in the U.S, in each case on a secondary effluent prior to direct discharge to surface waters.

CARBON ADSORPTION

Activated carbon has proven its ability to adsorb the organic material in wastewater. Because activated carbon does not rely on bacterial action, it can remove both biodegradable and non-biodegradable material.

Carbon adsorption is an expensive tertiary treatment step, usually following conventional secondary treatment units when high water quality is desired. Because of its relatively high cost and tertiary application, carbon adsorption has not been used for wastewater treatment by fruit and vegetable processors.

Carbon adsorption is a unit operation in which activated carbon adsorbs soluble and trace organic matter from wastewater streams. Either granular or powdered activated carbon can be used to remove up to 98 percent of colloidal and dissolved organics measured as BOD_5 and COD in a wastewater stream. The organic molecules which make up the organic material attach themselves to the surface of the activated carbon and are thereby removed. Larger particles should be filtered from the wastewater in treatment systems upstream from carbon adsorption since its effectiveness is substantially reduced by gross particles of organic matter. Since this technology is well established in the water treatment industry, it presumably can be operated with the properly conditioned feedstream on an efficient and reliable basis.

Operation and maintenance problems do not seem to be significant, particularly if the quality of the feedwater is maintained by appropriate upstream treatment systems. Regeneration is no problem in the packed and expanded bed systems and presumably can be worked out for powdered carbon systems before the mid 1980's.

ELECTRODIALYSIS

Electrodialysis is one of several commercial systems available for removal of TDS. It has not been applied to fruit and vegetable wastewaters, and would be in the future only if less costly methods of dissolved solids removal were not feasible. Probable application then would be on high chloride brine wastes; e.g., from pickle processing. If land is available and climatic conditions suitable, lined evaporation ponds would be normally a more economical solution.

The electrodialysis process incorporates a number of chambers made by alternating anionic and cationic membranes that are arranged with contaminated wastewater solution in the chambers between the differing membranes. Electric current is applied across the membrane chambers causing the cations to move toward the cathode and the anions toward the anode. However, after passing from the chambers containing the wastewater into adjacent brine chambers, the ions can travel no further toward the electrodes. Their path is blocked by a membrane that is impermeable to that particular ionic species. In this manner, the wastewater stream is depleted while the adjacent brine stream is enriched in the ions which are to be removed.

Power costs limit the salinity of the effluent wastewater after treatment in the electrodialysis system to approximately 300 to 500 mg/l of salt. This limitation is imposed because of the increase in electrical resistance in the treated wastewater that would occur at lower concentrations of salt.

The residual pollution from an electrodialysis unit would be the brine solution used and generated in the chambers of the unit. This brine solution might be handled by a blowdown system which removes the quantity of salt added per unit of time. Electrodialysis is an old process in fairly widespread use for the purpose of desalting brackish water. The treatment of wastewater in electrodialysis systems has not been done except on an experimental basis. There is no reported application of the process on wastewater from the fruit and vegetable processing industry. The process, however, does have the potential to be used in this industry for difficult desalting applications.

REVERSE OSMOSIS

Reverse osmosis is a process for removal of dissolved solids in wastewater. Generally used in tertiary applications, this method pressurizes the mineralized feedwater on one side of a semipermeable membrane (more permeable to pure water than to dissolved salts and other ions), forcing the pure solvent through the membrane and leaving a concentrated brine. There are several types of equipment on the market, including tubular, flat, spiral wound, and hollow fiber membranes.

The success of the system is dependent upon selection and maintenance of the membrane. Reverse osmosis has been effective for the treatment of pulp and the paper mill wastes, acid mine drainage, and municipal supplies with a high mineral content. Like electrodialysis, reverse osmosis would find application in this industry primarily for the treatment of high TDS and chloride brine wastes; e.g., pickle brine wastewater.

There has been no direct application of reverse osmosis for treatment of fruit and vegetable processing wastewater. Investigations in the pulp and paper industry indicate that wastes of similar concentration are amenable to reverse osmosis. At these dissolved solids concentrations, the osmotic pressures encountered are high, requiring higher applied pressures. The major advantages of reverse osmosis follow:

1. The equipment is easy to operate.

2. Energy requirements are relatively low.

3. An elevated operating temperature is not required.

4. The process is non-selective in dissolved solids capture, producing a high purity product water.

The principal operating problem appears to be membrane fouling as the pores become plugged with solids, oils, etc. The major disadvantage, however, is treatment and disposal of the concentrated brine waste from the reverse osmosis unit that may constitute up to 25 percent of the total treated volume.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

INTRODUCTION

The estimated costs and power consumption of the various treatment modules described in Section VII are detailed in this section. It is, of course, necessary to make certain simplifying assumptions in preparing general cost estimating data. The assumptions made, and the sources for other cost data are presented in a manner which should allow the reader to understand how the costs were developed.

The cost and energy data for the treatment modules can be summated to estimate the total for various alternate treatment chains. To the summation should be added the cost of land, engineering and contingencies, interest, and increases in cost occuring between June 1974, and the actual estimating date. Examples of the procedure involved are presented in this section.

Non-water quality aspects such as noise and solid waste management are discussed at the end of this section.

APPROACH TO COST ESTIMATION OF TREATMENT MODULES

End-of-pipe treatment processes and operations are costed on a modular basis. The basic approach was to keep the treatment modules as independent as possible to have maximum flexibility in assembling and costing end-of-pipe treatment trains for each of the industry subcategories.

The treatment modules were costed on as realistic and practical a basis as possible. Prime sources of cost information were equipment manufacturers. In many cases, the equipment manufacturers provided estimates and reviews of installation and operation costs. In a further attempt to make the costs realistic, a prominent Los Angeles area contractor specializing in the construction of waste treatment facilities provided valuable information detailing how his firm bids the various components of typical treatment works, e.g., percentage of labor installation costs, power hook-up, overall overhead, etc.

Costs derived from literature were also used, especially several EPA sponsored reports (1,2,3,4,5) which provided cost estimating curves for waste treatment components. Several literature sources provided cost data for specific facilities built to treat fruit and vegetable wastewater, and they were used to cross check the developed cost data.

The capital construction cost data obtained through the field investigation reports was highly variable and often difficult to correlate because of incompleteness. In general, this information again was used as a cross check against the developed cost data. In addition to its incompleteness, the major difficulties with using much of the capital cost data obtained from industry were: (1) treatment facilities had often grown over many years, and no one could really state what the true construction costs were, let alone relate them to 1974 costs, and; (2) very often the majority of the treatment systems had been constructed by plant personnel rather than an outside contractor, resulting in low costs being reported. Typical examples of the second situation were the majority of the spray irrigation systems which had been completely constructed by the processing plant personnel.

All costs were updated to June, 1974, by use of the Engineering News-Record Construction Cost Index, published by McGraw-Hill.

The treatment modules were sized by selecting an appropriate design criterion or a family of criteria if several variances were expected. The modules were then generally sized at flow volume intervals of 0.04 0.38, 1.13, 2.27, 3.78, 11.36, and 18.92 1,000 cu m per day (0.01, 0.1, 0.3, 0.5, 1.0, 3.0, and 5.0 mgd). Other variables found in various tables and figures include BOD_5, TSS, retention time, volumetric capacity, surface area, etc.

Operation and maintenance costs were calculated on a per day basis because of the seasonal nature of the industry and the uncertainties in the number of operating days. The daily operation in hours/day is also variable; however, except where otherwise noted, a 24-hour operating day was assumed for costing operational costs per day.

In summary, the basic assumptions that affect all treatment module costs are:

1. No land costs are included.
2. No engineering costs are included.
3. No construction contingencies are included.
4. Excavation fill or borrow costs were estimated from \$2.00 to \$12.00/cu yd, depending upon the type of construction.
5. Personnel costs for operation were estimated at \$5.00/hr total costs.
6. Electrical power costs were estimated at \$0.02/KWH.
7. All capital construction work is done by an outside contractor using his normal profit margins.
8. Replacement costs included expended parts, supplies, repairs, etc.; it does not mean capital recovery.

SPRAY IRRIGATION

Capital Cost

A typical spray irrigation system for land disposal would include the following components:

1. Pump station.

2. Main transmission pipeline from pump station to irrigation field.

3. Spray field distribution system.

In addition, the total system often might include the following components:

4. Holding lagoon for screened wastewater prior to pump station above.

5. Grit removal and/or primary treatment facility for solids removal.

6. Tailwater holding lagoon for storage of runoff from the field.

7. Drainage tile collection system constructed under the spray irrigation field.

8. Low head pumping station to pump drainage from 6. or 7. above back to the start of the system or sometimes to disposal.

9. Drainage return transmission pipeline.

Figure 58 schematically illustrates the basic system and typical additional components which may be required.

There are, of course, numerous variations of component combinations being used in actual practice. For costing purposes a sequence has been chosen of the following components described above: 1, 2, 3, 4, 6, 8 and 9 and as shown in Figure 58. Table 94 summarizes the total estimated cost for the selected system for various flow volume capacities. Individual subsections following Table 94 provides a comprehensive explanation of how the costs for each component were derived, including tables and curves which can be used to estimate costs based on different sets of assumed conditions. A study of the tables and curves in these subsections and a comparison with other treatment and disposal methods show clearly that when suitable land is available at a reasonable distance, spray irrigation with zero discharge is a cost-effective treatment and disposal method for this industry. Table 94 shows that under the assumed conditions, a typical spray irrigation system will cost from $62,000 for a

FIGURE 58

SCHEMATIC FLOW DIAGRAM OF TYPICAL SPRAY FIELD SYSTEM WITH ZERO DISCHARGE. SOLID LINES DESIGNATE BASIC SYSTEM. DASHED LINES INDICATE ADDITIONAL STRUCTURES OFTEN REQUIRED FOR COMPLETE SYSTEM.

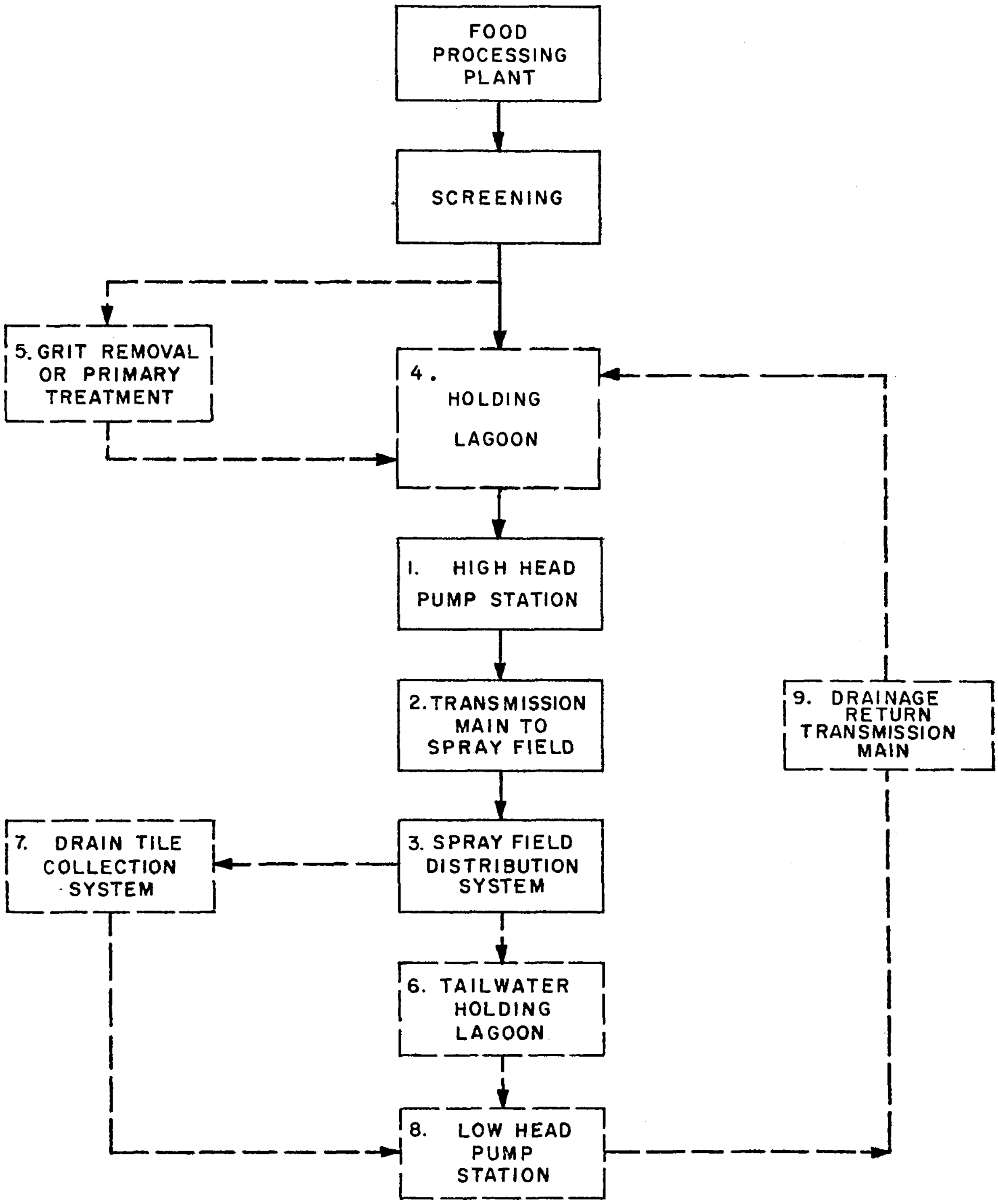
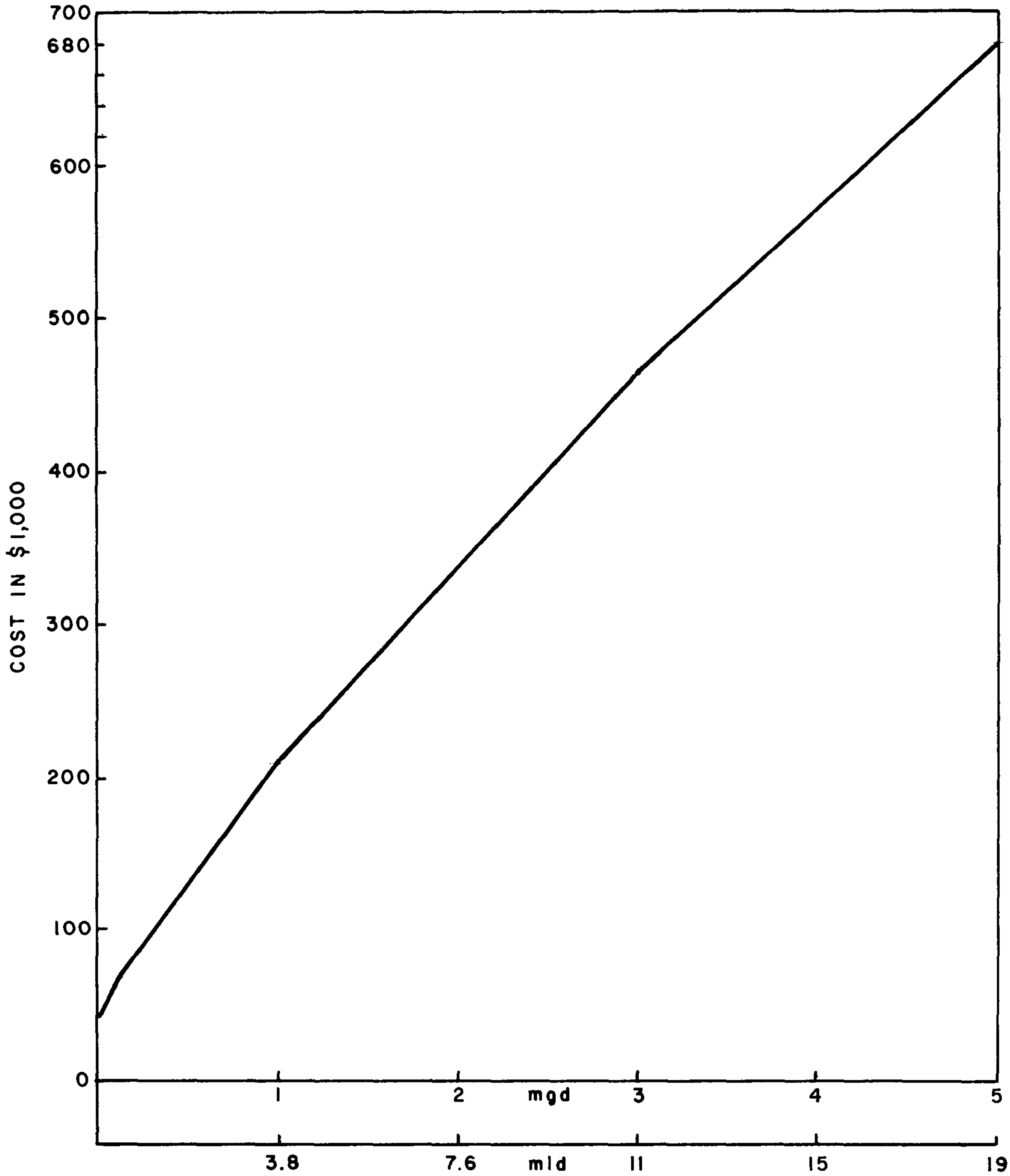


FIGURE 59

ESTIMATED TOTAL CAPITAL COSTS FOR ZERO
DISCHARGE SPRAY IRRIGATION SYSTEMS (1)



(1) Taken from Table 126. Excludes land costs.

TABLE 94

ESTIMATED CAPITAL COST OF ZERO DISCHARGE SPRAY IRRIGATION SYSTEMS

Effluent volume		Cost ($1,000)							
mld	mgd	High head(1) pump station	Holding Lagoon (3)	Transmission(1) main	Spray field(2) distrib. system	Tailwater(3) holding pond	Low head(1) pump station	Return(4) trans. main	Total
0.04	0.01	11	7	1.3	0.7	7	10	0.3	37
0.38	0.1	22	9	4.0	7	8	11	1.0	62
1.13	0.3	31	14	5.3	22	11	14	1.3	99
2.27	0.6	43	21	7.9	44	14	18	2.0	150
3.78	1.0	55	30	11	74	19	22	2.8	210
11.36	3.0	82	63	18	220	39	31	4.5	460
18.92	5.0	100	85	24	370	53	38	6.0	680

(1) Study accompanying text for assumptions made.
(2) Assume application rate of 12.7 mm per day (0.5 in per day).
(3) Assume retention time of 5 days, depth of 10 ft.
(4) Assume @ 25% of cost of transmission main, based on a lesser distance than the transmission main.

system of 0.37 mld (0.1 mgd) up to $680,000 for a system to handle 18.92 mld (5 mgd). Figure 59 shows graphically the cost data presented in Table 94.

Cost of High-Pressure Pump Station

Many different types of arrangements are found in practice for design of the pump stations to supply spray irrigation fields. The major spray systems covering many hundreds of acres may have a very sophisticated pump station including elaborate electrical interlocks and controls with the distribution system. A simple system may consist of one pump installed with no cover and a minimum of accessories. In pricing the pump station, the following assumptions have been made conservative, for a well-designed, medium-size system.

1. Assume two pumps, each of which can pump the entire volume needed separately. In other words, 100 percent standby is provided.

2. Assume pumping head will equal 70,300 kgf/sq m (100 psi) or 70.1 m (230 ft) of head.

3. Assume 85 percent efficiency by pumps.

4. Assume application time of 24 hours. In other words, all daily wastewater generated is pumped during 24 hours.

5. Cost of the pump station includes concrete pad, wet well, electrical connections, pump controls, piping at the pump station, and engineering. No building is included nor is any land cost credited.

Cost of Main Line from Plant to Spray Irrigation Field

Obviously, this cost increment is highly variable since some plants may have available land adjacent to the processing plant, and others would have to transport the waste a long distance. For estimating purposes, the irrigation field is assumed to be located 402 m (1/4 mile) from the processing plant. Other assumptions are as follows:

1. The pipe is buried about 1.2 m (4 ft) deep.

2. Right-of-way costs are zero.

3. The pipe cost equals $1 per inch diameter ft installed.

4. The maximum velocity through the pipe equals 1.5 m/sec (5 ft/sec).

5. The minimum pipe size equals 25 mm (1 in.).

6. The use time is 24 hours daily. In other words, all daily wastewater generated is pumped during 24 hours.

Cost of Spray Irrigation Distribution System

There are a variety of different types of spray irrigation systems used by the industry. These include:

1. Portable laterals with quick-disconnect adapters to tees in a main line.

2. Rotary system on wheels which slowly revolves around central pivot point.

3. Permanently placed laterals on ground surface.

The most common is the last named system which consists of rows of "rainbird" type sprinkler heads mounted on permanent laterals connected to a main line at specific intervals. In pricing the distribution system, costs have been based upon this type of distribution system. The assumptions made are as follows:

1. Rainbird sprinklers are mounted at 48 m (160 ft) intervals on the laterals and cost $8.00 each installed.

2. Laterals are at 61.0 m (200 ft) intervals, are 101.6 mm (4 in.) diameter aluminum pipe, are installed on top of the ground, and cost $2.00/ft installed, including a shut-off valve at the main.

3. The main line feeding the laterals is 254 mm (10 in.) diameter aluminum pipe and costs $8.00/ft installed.

For each ten acres, assuming a 201 m (660 ft) square field, the total cost of the distribution system is calculated as follows:

1. Main line cost = 660 ft x $8.00/ft = $5,280.

2. Number of laterals $== \frac{(660\text{ ft} - ((50\text{ ft.}) \times 2))}{200} = 3.8$

   length of laterals = (660 ft - 50 ft) x 3.8
   = 2318 ft

   cost of laterals = 2318 ft x $2.00/ft - $4,636

3. Number of sprinklers = 4,026 ft/160 ft = 15

   cost of sprinklers = 15 x $8.00 = $120

Total estimated cost of distribution system for each ten acres equals $5,280 + $4,636 + $120 = $10,036 or approximately $1,004/acre = $2,480/hectare.

Figure 60 illustrates the relationship between rate of application in mm/day and acreage required. The rate of application is the average rate; i.e., the actual rate of application on a segment of the spray field may be four times the average rate one day, followed by three days of no irrigation.

Cost of Tailwater and Holding Lagoons

Another section of this report details the cost analysis of various size lagoons. For the purposes of the spray irrigation system cost analysis, the following assumptions have been made:

1. Each lagoon will have a capacity of five days.

2. The lagoon will be 3 m (10 ft) deep with 3 m (10 ft) wide (at the top) berms sloped at 2:1 and no lining; i.e., dirt bottom and sides.

3. The tailwater holding lagoon is size at 50 percent of the capacity of the upstream lagoon due to an assumed 50 percent water loss to evaporation, evapotranspiration and percolation during irrigation.

Cost of Drainage Tiles for Irrigation Field

Drainage tile may be used under the spray irrigation field in cases where it is desired to increase the surface application rate. The optimum drain tile size, spacing, slope, etc. vary between sites depending upon soil conditions, application rates, and other factors. Tile depth varies from 0.61 m (2 ft) to 2.94 m (8 ft), tile spacing from 15.24 m (50 ft) to 45.72 m (150 ft), and pipe slope is generally 0.2 percent.

For the purpose of cost estimation, the following assumptions have been made:

1. A main drain of 381 mm (15 in.) concrete pipe installed at a depth of 2.44 m (8 ft) and costing $49.21/m ($15/ft).

2. Tile drains consisting of 101.6 mm (4 in.) unglazed clay tile installed at 1.82 m (6 ft) depth, 30.48 m (100 ft) spacing, and costing $13.12/m ($4/ft).

3. Gridiron arrangement of tile drains.

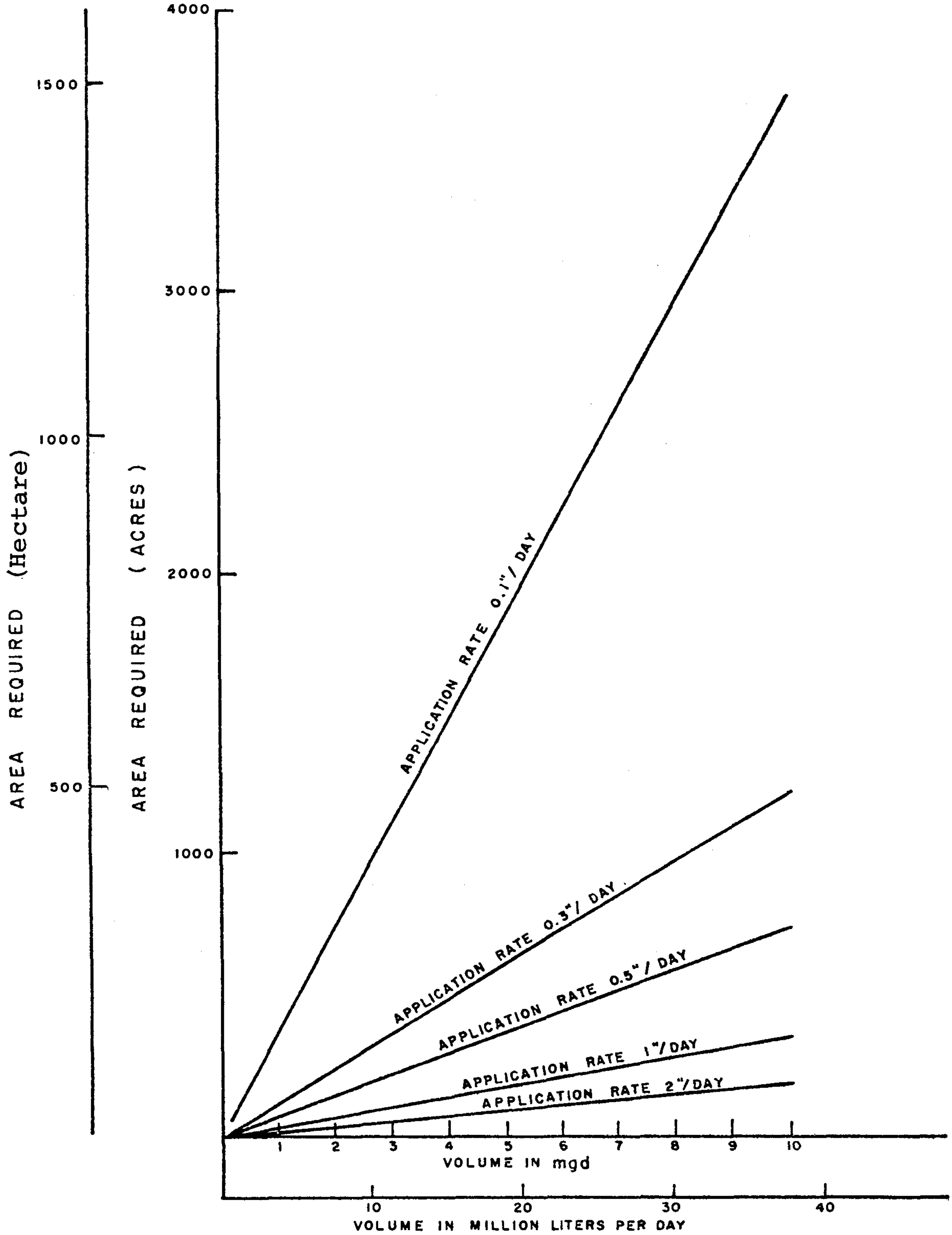
For 4.05 hectare (10 acres), assumed square, at 201.2 m (660 ft) to the side costs are as follows:

Main drain = 660 ft x $15/ft = 9,900

Number of tiles = $\frac{660}{100}$ + 1 = 7.6

FIGURE 60

AREA REQUIRED FOR SPRAY IRRIGATION FIELD
AS A FUNCTION OF APPLICATION RATE



Length of tiles = 7.6 x 660 = 5,000 ft

Cost of tiles = 5,000 x $4 = $20,000

Total cost per acre = $\underline{20,000 + 9,900}$ = $7,413/hectare 10
($3,000/acre for collection system)

Cost of Low-Pressure Pump Station

A wet well and pumping station are usually required to store and pump the drainage from the tile field. The pumps are normally high-volume, low-head to return the drainage water to an adjacent storage lagoon or pump to the point of disposal into a stream. Costs for the drainage pumping facility are based on the following assumptions:

1. A volume pumped equivalent to 50 percent of the water applied to the surface of the field; it is assumed that 50 percent of the applied water is removed by evaporation, transpiration, and percolation.

2. A pumping head of 6.096 m (20 ft) and pump efficiency of 85 percent.

3. A wet well capacity of one-half of one percent of the applied flow per day; e.g., a field with an application of 3.78 mld (1 mgd) would have a wet well of 19,000 l (5,000 gal).

4. Dual pumps with 100 percent standby capacity.

5. 24 hour daily service; i.e., entire daily wastewater generation is handled in 24 hours.

6. To estimate cost of pump station use 50 percent of plant effluent volume shown; e.g., for plant effluent volume 15 mld (4 mgd), use estimated cost of $19,000.

A wet well and pumping station may be required to store and pump the tailwater from the irrigation field drainage from the tiles if tiles are used. The pumps are normally high-volume, low-head to return the drainage water to a storage lagoon. Costs for the low-pressure pumping facility are based on the following assumptions:

1. A volume pumped equivalent to 100 percent of the water applied to the surface of the field; this assumes that on occasion the field is saturated, and run-off equals applied wastewater.

2. A pumping head of 6.096m (20 ft) and pump efficiency of 85 percent.

3. Dual pumps with 100 percent standby capacity.

TABLE 95

ESTIMATED DAILY COST OF OPERATION AND MAINTENANCE FOR SPRAY IRRIGATION SYSTEMS

Plant effluent volume		Direct labor	Expended parts and supplies	High head pump energy cost	Low head pump energy cost	Total O & M cost
mld	mgd	($/day)	($/day)	($/day)	($/day)	($/day)
0.04	0.01	15	4	0.2	0.1	19
0.37	0.1	20	7	2	1	30
1.13	0.3	25	11	5	1	42
2.27	0.6	31	16	11	1	59
3.78	1.0	40	23	17	1	81
11.35	3.0	68	50	48	4	170
18.92	5.0	80	74	86	6	250

Major assumptions:

1. Direct labor and overhead cost is $5.00/hr.
2. Expended parts and supplies equal 4% of capital cost.
3. Energy cost equals $0.02/kw-hr, operation 24 hrs/day.

4. 24 hour daily service; i.e., entire daily wastewater generation is handled in 24 hours.

5. Cost of the pump station includes concrete pad, wet well, electrical connections, pump controls piping at the pump station, and engineering. No building is included nor is any land cost credited.

Operation and Maintenance Cost

Table 95 on the following page summarizes labor, power, and parts replacement costs for various size spray irrigation systems. Assumptions used in generating the cost data are listed at the bottom of the table.

RIDGE AND FURROW IRRIGATION

Capital Cost

Cost components of the typical ridge and furrow irrigation system include:

1. Low head pump station to pump plant effluent to field.

2. Main transmission line from pump station to irrigation field.

3. Furrow distribution system.

In addition, the total system will often include the following components:

4. Holding lagoon for screened wastewater.

5. Tailwater holding lagoon for storage of runoff from the field.

6. Drainage tile collection system constructed under the irrigation field.

7. Low head pumping station to pump drainage from 5. or 6. above back to the start of the system or sometimes to disposal.

8. Drainage return transmission pipeline.

There are, of course, numerous variations of component combinations being used in actual practice. For costing purposes the following sequence of components as described above have been chosen:: 1, 2, 3, 5, 7, and 8, all as described above. Derivations of costs for all system components except the distribution system are developed in Spray Irrigation Costs. A study of these costs and a comparison with other treatment and disposal methods shows clearly that when suitable land is available at a reasonable distance, ridge and furrow irrigation with zero discharge is a cost-effective treatment and disposal method for this industry. A typical ridge and furrow irrigation system will cost from $42,000 for a system of 0.1 mgd up to $247,000 for a system to handle five mgd. Land costs for land taken out of productivity are included for the tailwater holding lagoon but not for the ridge and furrow irrigation distribution system.

LAGOONS

Capital Cost

Costs are estimated for lagoons of various capacities and depths from Figure 61. Costs for lagoon construction will vary widely between locales because the costs are so highly dependent upon the prevailing cost of earth excavation. Our assumed excavation cost of $5.30/cu m ($4.00/cu yd) is a resonable average for the nation; however, actual excavation prices could vary over 100 percent up or down due to local situations (e.g., type of soil, proximity of contractors with large earth-moving equipment, etc.). As with the other treatment systems, the estimated costs in this section do not include land costs. Land costs will be added separately to the estimated costs of treatment chains for the individual commodities.

Estimated costs for aerated lagoons to treat various waste flow volumes and strengths are presented in Table 96.

Major assumptions include the following:

For subcategories with raw wasteloads in excess of 3000 mg/l, primary treatment will be provided to decrease the lagoon influent BOD_5 to less than 3000 mg/l.

Aerator hp required = one hp per hour for every two lbs of BOD_5 in the raw waste.

Retention time required is expressed by the formula

$$T = \frac{E}{(1-E)k}$$

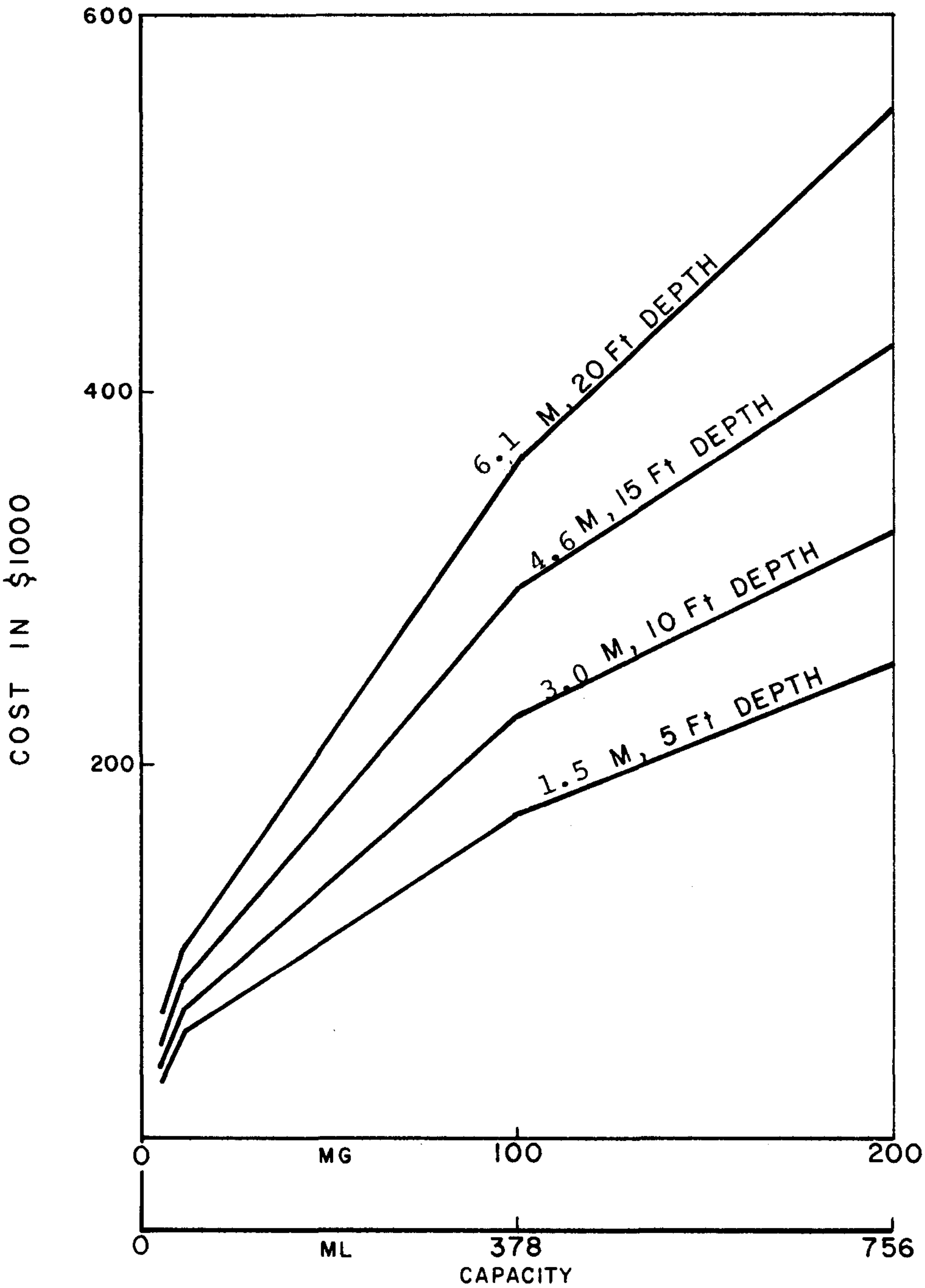
where E equals the percent BOD_5 removal and k equals the reaction constant. k is assumed to equal 0.8. The percent BOD_5 removal desired was assumed to range from 85 percent reduction up to 98 precent reduction.

Operation and Maintenance Costs

In Table 97 are presented estimated operation and maintenance costs for aerated and unaerated lagoons. Assumptions made are listed as footnotes to the table.

FIGURE 61

CAPITAL COST OF LAGOON CONSTRUCTION OF VARYING DEPTH AND CAPACITY



Notes:

- Does not include cost of land
- Assumed excavation cost = $ 5.2/cu m $4 /cu yd)
- Rip-rap lining, sides only = $7.2/sq m ($6/sq yd)

TABLE 96

ESTIMATED CAPITAL COST OF AERATED LAGOONS BASED ON VARYING DAILY WASTE VOLUMES AND STRENGTHS (NOT INLCUDING LAND COSTS)

Average daily volume		Ave. BOD, mg/l	Mechanical aerator		Low head pump cost $1,000	Ret. time days(3)	Total Req'd vol. MG	Lagoon cons't. cost(4) $1,000	Total cost(5) $1,000
mld	mgd		H.P. req'd(1)	Installed cost of aerators $1,000(2)					
0.04	0.01	200	0.4	0.5	10	10	0.1	12	22
		500	0.9	1	10	15	0.15	12	23
		1,000	1.8	2	10	20	0.2	12	24
		2,000	3.7	3	10	25	0.25	13	26
		3,000	5.2	3	10	30	0.3	13	26
	0.1	200	3.5	3	11	10	1	32	46
		500	8.7	4	11	15	1.5	34	49
		1,000	17	6	11	20	2	36	53
		2,000	35	10	11	25	2.5	38	59
		3,000	52	13	11	30	3	42	66
1.13	0.3	200	10	5	14	10	3	42	61
		500	26	8	14	15	4.5	50	72
		1,000	52	13	14	20	6	58	85
		2,000	105	23	14	25	7.5	66	100
		3,000	156	35	14	30	9	77	130
2.27	0.6	200	21	7	18	10	6	58	85
		500	52	13	18	15	9	77	110
		1,000	104	23	18	20	12	90	130
		2,000	208	40	18	25	15	110	170
		3,000	313	56	18	30	18	120	190

TABLE 96 (Continued)

Average daily volume		Ave. BOD, mg/l	Mechanical aerator		Low head pump cost $1,000	Ret. time days (3)	Total req'd vol. MG	Lagoon cons't. cost (4) $1,000	Total cost (5) $1,000
mld	mgd		H.P. req'd (1)	Installed cost of aerators $1,000 (2)					
3.78	1.0	200	35	10	22	10	10	80	110
		500	87	20	22	15	15	110	150
		1,000	174	38	22	20	20	130	190
		2,000	348	70	22	25	25	140	230
		3,000	521	97	22	30	30	150	270
11.36	3.0	200	105	23	31	10	30	150	200
		500	261	56	31	15	45	180	270
		1,000	522	110	31	20	60	200	340
		2,000	1,043	200	31	25	75	240	410
		3,000	1,564	290	31	30	90	260	530
18.92	5.0	200	174	38	38	10	50	190	270
		500	435	83	38	15	75	240	360
		1,000	869	170	38	20	100	280	490
		2,000	1,737	320	38	25	125	320	630
		3,000	2,606	490	38	30	150	360	890

Notes:

(1) Based upon 2 lbs of BOD per H.P. per hour.
(2) Based upon manufacturers estimates, includes power supply and all accessories.
(3) Based upon BOD removals of 85 percent for weak wastes (e.g., 200 mg/l BOD) up to BOD removals of 9 percent for strong wastes (e.g., 3,000 mg/l BOD).
(4) Taken from Figure 15 with 3 m (10 ft) depth, assuming 2 separate lagoons in series to accommodate the required volume.
(5) Does not include land costs.

TABLE 97

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR AERATED LAGOONS

Average Daily Vol.		Ave. BOD				
mld	mgd	mg/l	Energy(1)	Labor(2)	Replacement(3)	Total
0.04	0.01	200	0.2	30	1.8	32
		500	0.4	30	1.9	32
		1,000	0.7	30	2.0	33
		2,000	1.4	30	2.1	34
		3,000	2.0	30	2.1	34
0.38	0.1	200	2.3	40	3.8	46
		500	4.1	40	4.0	48
		1,000	7.1	40	4.4	52
		2,000	12	40	4.8	57
		3,000	20	40	5.4	65
1.13	0.3	200	8.6	40	5.0	54
		500	12	40	5.9	58
		1,000	25	40	7.0	72
		2,000	39	40	8.2	87
		3,000	57	40	11	110
2.27	0.6	200	18	40	6.8	65
		500	27	40	9.0	76
		1,000	49	40	11	100
		2,000	80	40	14	130
		3,000	120	40	16	180
3.78	1.0	200	14	60	9.0	83
		500	32	60	12	100
		1,000	63	60	16	140
		2,000	126	60	19	200
		3,000	188	60	22	270
11.36	3.0	200	42	80	16	140
		500	97	80	22	200
		1,000	190	80	23	300
		2,000	380	80	39	500
		3,000	560	80	48	690

TABLE 97 (cont.)

Average Daily Vol.		Ave. BOD				
mld	mgd	mg/l	Energy(1)	Labor(2)	Replace-ment(3)	Total
18.92	5.0	200	78	80	22	180
		500	160	80	30	270
		1,000	320	80	40	440
		2,000	630	80	56	770
		3,000	940	80	73	1100

(1) Energy cost assumed @ 2¢/KWH, 24 Hr./day operation, For both aerators and low head pump.

(2) Labor cost assumed @ $40/man-day.

(3) Replacement cost assumed @ 3% of capital cost.

pH CONTROL

Capital Cost

Fruit and vegetable processing wastewaters sometimes require extensive pH control due to large pH fluctuation.

Table 98 summarizes estimated capital costs for pH control. Assumptions made in generating these costs are noted at the foot of the table.

Operation and Maintenance Costs

Table 99 summarizes estimated daily operation and maintenance costs for pH control.

CLARIFIERS

Capital Cost

In estimating the capital cost of various diameter clarifiers, the complete clarifier package has been considered, including steel tanks, collector mechanism, inlet structure, outlet weirs and baffles, sludge recirculation pumps, piping, valves, electrical system, and installation. The costs do not include engineering, contingencies, and construction interest because these are added later as a percentage of the complete treatment chain. These estimates are applicable to both primary and secondary clarifiers.

Table 100 itemizes the total estimated capital costs for clarification systems based on physical size only. Figure 62 and Figure 63 show estimated total capital costs based on Table 100 with various overflow rates. The overflow rate is normally estimated on the basis of waste strength as represented by total suspended solids (TSS) concentration. The higher the anticipated TSS concentration, the lower the overflow rate for optimum removal efficiency. Conversely, the lower the incoming TSS concentration, the higher the permissable overflow rate. The cost for sludge handling and treatment is included in the cost estimate for the digestor and vacuum filter.

Operation and Maintenance Costs

Table 101 summarizes estimated operation and maintenance costs for final clarification systems. Assumptions made in generating this data are listed below the table.

AIR FLOTATION

Capital Cost

Some fruit and vegetable wastewater solids have poor settling characteristics (i.e., tomatoes, pears). For these wastes,

TABLE 98

ESTIMATED CAPITAL COST IN $1,000
FOR PH CONTROL

Item	Plant effluent flow (mgd)						
	0.01	0.1	0.3	0.6	1.0	3.0	5.0
. Steel mixing tank(1)	5	15	20	28	31	41	49
. Flow measuring flume (40-2,000 gpm range)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
. Flow transmitter	0.7	0.7	0.7	0.7	0.7	0.7	0.7
. Flow recorder-controller with hi-low alarms	0.8	0.8	0.8	0.8	0.8	0.8	0.8
. pH probe and analyze with ultrasonic cleaner	1.3	1.3	1.3	1.3	1.3	1.3	1.3
. pH recorder with hi-low alarms and interrupter controller	0.9	0.9	0.9	0.9	0.9	0.9	0.9
. Dual head chemical feed pump with compound variable speed and strike length control	2.0	2.0	2.0	2.0	2.0	2.0	2.0
. Chemical storage tanks (acid and caustic)	0.8	0.8	0.8	0.8	1.2	3.0	5.0
. Eye wash fountain and emergency shower	0.3	0.3	0.3	0.3	0.3	0.3	0.3
. Electrical control panel	1.2	1.2	1.2	1.2	1.2	1.2	1.2
. Roofing and fencing	0.4	0.4	0.4	0.4	0.6	0.8	1.0
. Installation(2)	8.9	8.9	8.9	8.9	9.5	12	14
Total cost ($1,000)	23	33	38	46	50	69	79

(1) Cost taken from Ref. 28; cost includes installation.

(2) Installation costs assumed @ 100% of total capital cost (excluding mixing tank).

TABLE 99

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR PH CONTROL

Plant effluent flow		Cost ($/day)				
mld	mgd	Energy (1)	Labor (2)	Replace. (3)	Chem. (4)	Total
0.04	0.01	0.1	7	3	0.2	10
0.38	0.1	0.2	10	4.5	2	17
1.13	0.3	0.5	10	5.2	7	23
2.27	0.6	1.1	10	6.3	14	31
3.78	1.0	1.8	20	6.8	24	53
11.36	3.0	5.4	40	9.5	72	130
18.92	5.0	9.0	40	11	120	180

(1) Assumed @ 2c/kwh for the mixing tank.
(2) Assumed @ $40/man-day.
(3) Assumed @ 5% of capital cost.
(4) Chemical dosage assumed at 100 mg/l and cost at $.03/lb.

TABLE 100

ESTIMATED CAPITAL COST OF CLARIFICATION SYSTEMS

Cost ($1,000)

Tank dia.	Tank (1)	Basic (4) collector	Inlet (4) well	Weirs (4) and baffles	Pump (5) for sludge recirc.	Piping (2) elect., valves	Install.(3)	Total
10	3.3	5.0	8	0.6	7.5	6.1	5.0	35
15	5.8	5.8	8	0.8	7.9	6.8	5.8	41
20	7.6	6.3	8	1.0	8.2	7.2	6.3	45
25	10	6.6	8	1.3	8.5	7.5	6.6	48
30	13	12	8	1.5	8.8	10	12	65
35	16	12	8	1.7	9.3	11	12	70
40	20	12	8	1.9	9.9	11	12	75
45	23	13	8	2.1	10	12	13	81
50	27	13	8	2.3	11	12	13	86
55	32	14	8	2.5	12	13	14	96
60	36	13	8	2.7	13	13	14	100
65	40	14	8.5	2.9	14	14	14	110
70	46	16	8.5	3.1	14	15	16	120
75	52	16	8.5	3.3	16	16	16	130
80	57	17	9	3.5	17	17	17	140
85	63	17	9	3.7	18	18	17	150
90	70	17	9	3.9	19	18	17	150
95	76	18	9	4.1	21	19	18	160

Notes:

(1) Tank of 1/4" steel, 12' deep, cost of $0.70/lb steel includes installation.
(2) Assumed at 50% of collector and pump cost.
(3) Tank installation included in tank price - this figure for installation of accessories only.
(4) Costs taken from prominent manufacturers sales price book.
(5) Cost based on reference 1 with 400 gpd/ft^2 overflow rate.

TABLE 101

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR CLARIFIERS

Plant effluent flow		Cost ($/day)[4]			
mld	mgd	Energy[1]	Labor[2]	Replacement[3]	Total
0.04	0.01	0.1	8	5	13
0.38	0.1	0.2	10	6	16
1.13	0.3	0.3	10	9	19
2.27	0.6	0.4	15	11	26
3.78	1.0	0.6	20	13	34
11.36	3.0	1.4	30	23	54
18.92	5.0	2.4	40	32	74

(1) Assume energy cost @ 2c/kwh, for clarifier rake mechanism.and sludge return pump.
(2) Assume labor cost @ $5/hr or $40/man-day.
(3) Assume replacement parts cost @ 5% of capital cost.
(4) Based on 400 gpd/ft^2 overflow rate system.

FIGURE 62

ESTIMATED CAPITAL COST FOR CLARIFIERS
AT SELECTED OVERFLOW RATES, BASED ON TABLE

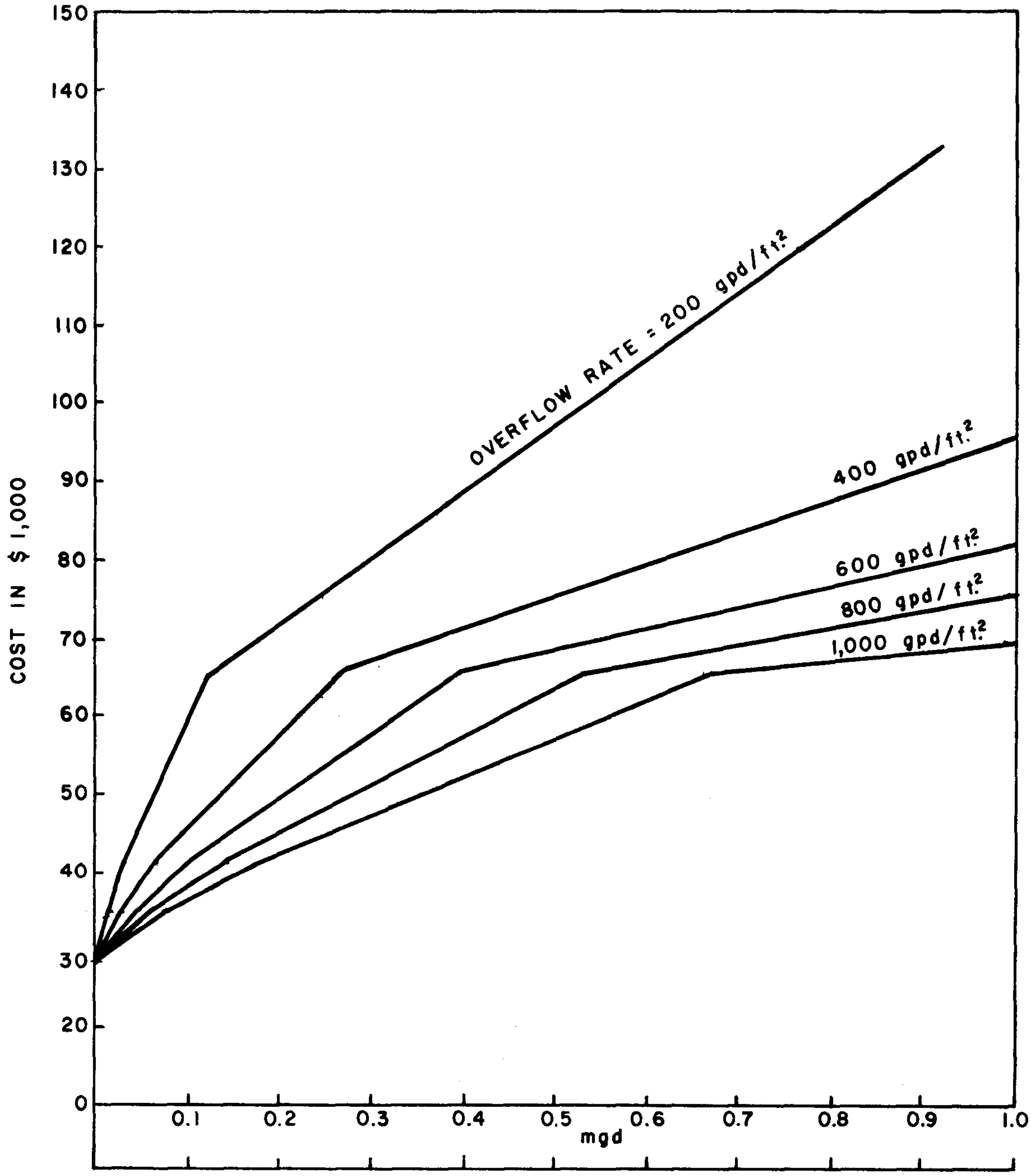
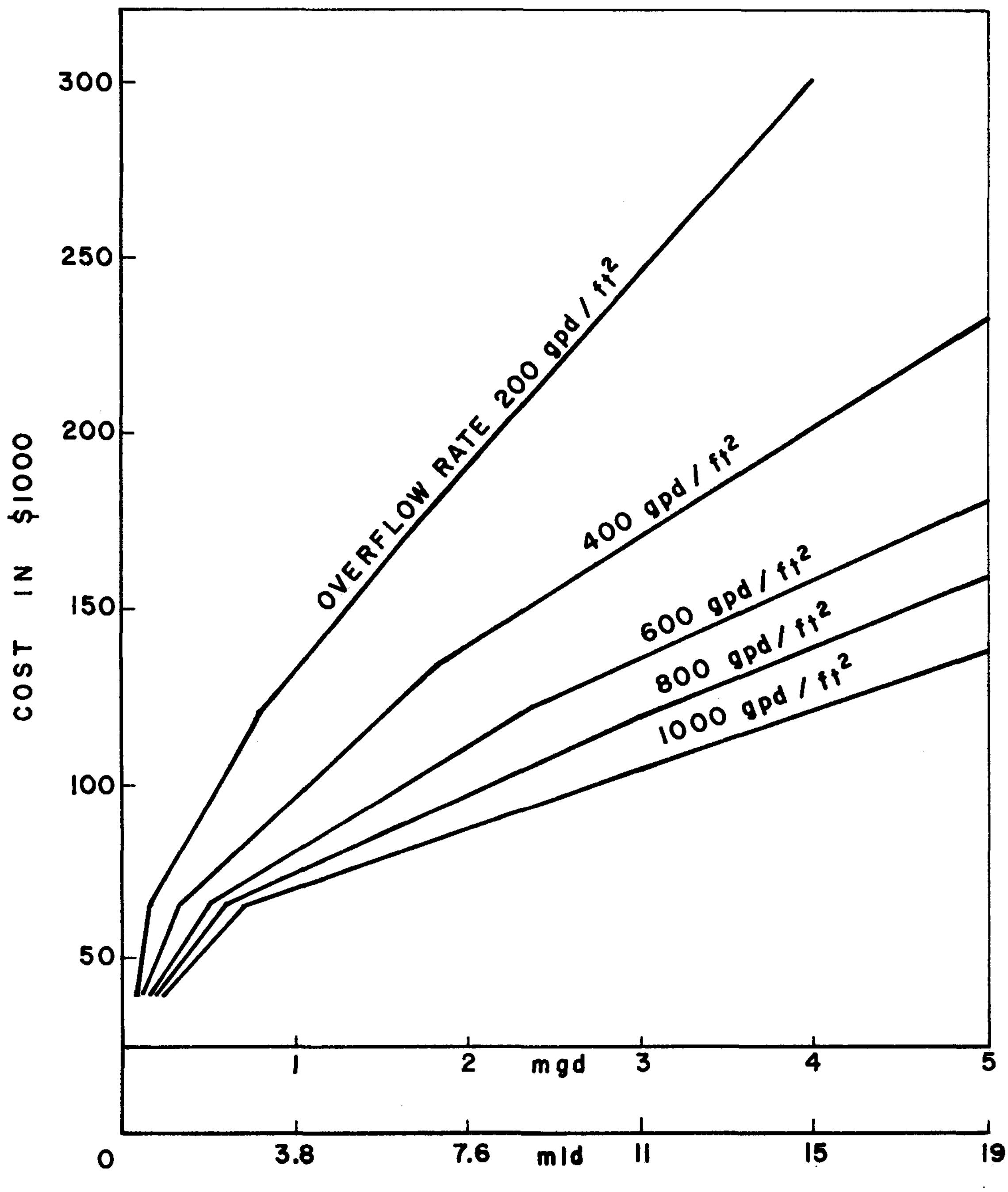


FIGURE 63

ESTIMATED CAPITAL COST FOR CLARIFIERS FOR SELECTED OVERFLOW RATES, BASED ON TABLE



Note:
- Curves are interpolated for lower overflow rates at higher volumes.

dissolved air flotation provides better primary treatment capability than does settling. In addition, wastewater with over 50 mg/l of grease and oil should be treated by flotation before entering biological treatment systems.

Tables 102 and 103 summarize capital costs for pressurized dissolved air flotation systems with and without the addition of chemical flocculants. The cost for sludge handling and treatment is included in the cost estimate for the digestor.

Operations and Maintenance Costs

Table 104 summarizes operation and maintenance costs for dissolved air flotation.

NUTRIENT ADDITION

Capital Cost

The capital cost of a nutrient addition facility includes a proportional pump to add the nutrient proportioned to the flow and storage facilities for the nutrient material. For flows in excess of 1 mgd, the capital cost was estimated at $10,000. For flows less than 1 mgd, the capital cost was estimated at $5,000.

Operation and Maintenance Costs

Figure 64 shows the daily cost of nutrient addition per million gallons as a function of wastewater BOD_5, based upon the assumptions shown at the bottom of the figure. The figure shows that nutrient cost is very significant at the higher levels of BOD_5.

TRICKLING FILTER

Capital Cost

The cost of the plastic media roughing trickling filter includes the trickling filter itself with all its accessories and the recirculating pumps.

Table 105 shows costs of trickling filters with loading rates varying from 200 to 1000 gpd/sq ft.

Operation and Maintenance Costs

Table 106 summarizes estimated operation and maintenance costs for trickling filtration including only the trickling filter and recirculation systems.

TABLE 102

ESTIMATED CAPITAL COST OF AIR FLOTATION
WITH CHEMICAL ADDITION

Daily Volume		Influent TSS less than 1000 mg/l $1000	Influent TSS more than 1000 mg/l $1000
MLD	MGD		
0.04	0.01	27	33
0.38	0.1	36	49
1.13	0.3	53	67
2.27	0.6	65	83
3.78	1.0	78	96
11.36	3.0	117	149
18.92	5.0	146	

Notes:

- Based on hydraulic loading of 2.0 gpm/ft^2 and suspended solids loading of 1.0 lbs/hr/ft^2.

- Costs taken from Ref.[29].

TABLE 103

ESTIMATED CAPITAL COST OF AIR FLOTATION SYSTEMS WITHOUT CHEMICAL ADDITION

Daily Volume		Influent TSS less than 1000 mg/l $1000	Influent TSS more than 1000 mg/l $1000
MLD	MGD		
0.04	0.01	25	30
0.38	0.01	30	44
1.13	0.3	43	57
2.27	0.6	57	71
3.78	1.0	69	84
11.36	3.0	101	129
18.92	5.0	130	168

Notes:

- Based on hydraulic loading of 2.0 gpm/ft^2 and suspended solids loading of 1.0 lbs/hr/ft^2
- Costs taken from Ref. 30.

TABLE 104

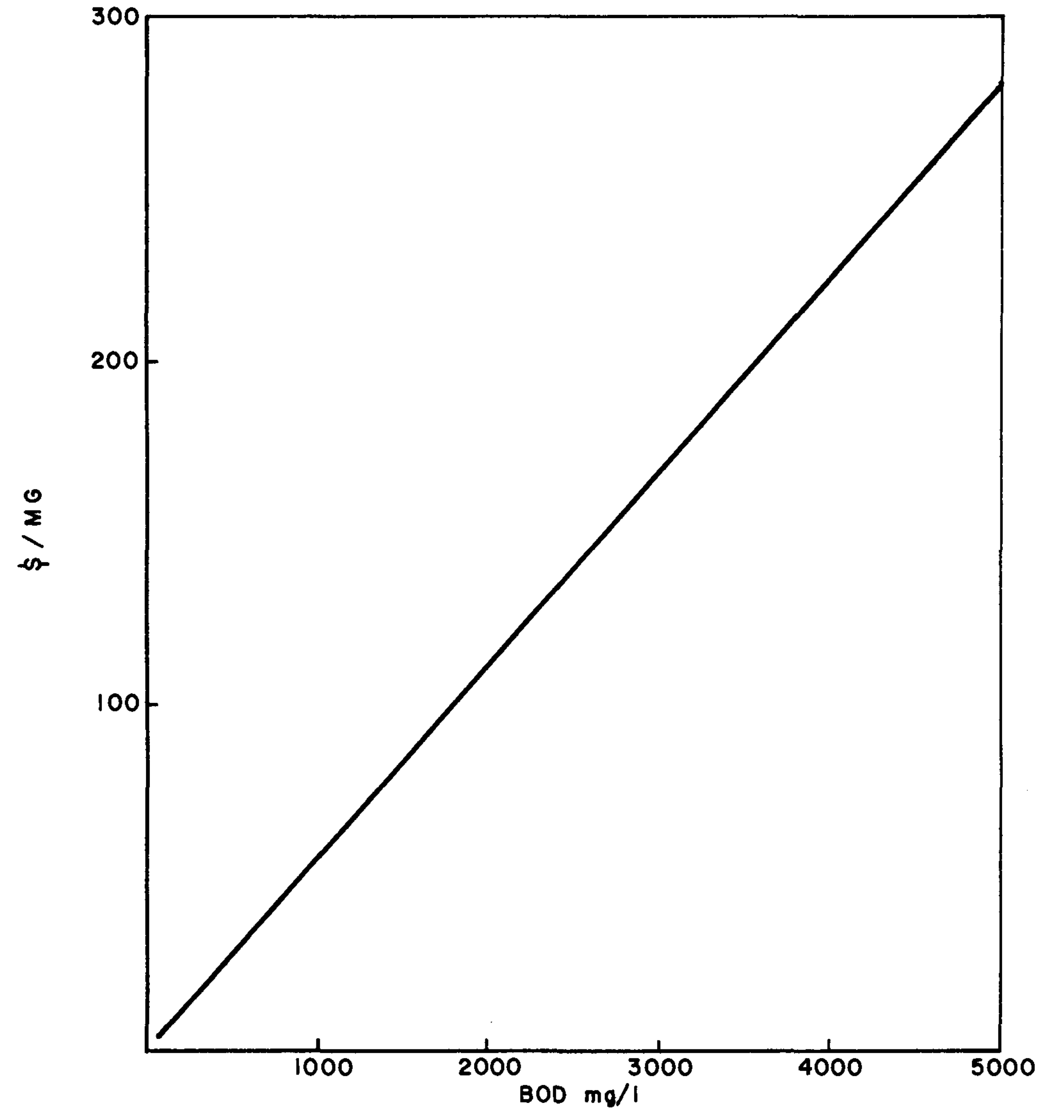
ESTIMATED DAILY OPERATING AND MAINTENANCE COSTS OF AIR FLOTATION SYSTEMS WITH CHEMICAL ADDITION

Plant effluent volume		Cost ($/day)				
mld	mgd	Energy(1)	Chemical(2)	Labor(3)	Replacement(4)	Total
0.04	0.01	0.01	0.05	10	5	15
0.38	0.1	0.05	0.54	10	8.0	19
1.13	0.3	0.14	1.6	10	11	23
2.27	0.6	0.20	3.2	10	14	27
3.78	1.0	0.46	5.4	20	16	42
11.36	3.0	0.93	16	20	24	61
18.92	5.0	1.4	27	30	32	89

(1)Based on $0.02 per kwh, air requirement assumed @ 0.05 cu ft/gal using diffuser type aeration.
(2)Based on dosage of 20 mg/l of lime.
(3)Based on $5.00/hr.
(4)Based on 6 percent of capital cost of the systems with influent TSS > 1,000 mg/l.

FIGURE 64

ESTIMATED COSTS FOR NUTRIENT ADDITION



Note: The following assumptions were made in generating this figure:

(1) BOD:N:P ratio required is 100:5:1.

(2) Nutrients used are aqua ammonia (NH_3) @ \$0.08/lb, and phosphoric acid (H_3PO_4) @ \$0.20/lb.

(3) Raw wastewater is 60% deficient in both nitrogen and phosphorus.

(4) Costs of chemical storage and feed pump are negligible compared to the cost of the chemicals.

TABLE 105

ESTIMATED CAPITAL COSTS FOR TRICKLING FILTERS

Plant effluent volume		Hydraulic load (gpd/ft^2)	Area (ft^2)	Cost(1) (2) ($1,000)
mld	mgd			
0.04	0.01	200	50	6.3
		400	25	5.0
		600	17	4.6
		800	12	4.4
		1,000	10	4.4
0.38	0.1	200	500	22.07
		400	250	14.30
		600	167	11.28
		800	125	9.64
		1,000	100	8.58
1.13	0.3	200	1,500	47.34
		400	750	29.01
		600	500	22.07
		800	375	18.31
		1,000	300	15.93
2.27	0.6	200	3,000	79.25
		400	1,500	47.34
		600	1,000	35.41
		800	750	29.01
		1,000	600	24.92
3.78	1.0	200	5,000	117.57
		400	2,500	69.18
		600	1,667	51.13
		800	1,250	41.51
		1,000	1,000	35.41
11.36	3.0	200	15,000	282.77
		400	7,500	162.0
		600	5,000	117.47
		800	3,750	94.00
		1,000	3,000	79.25
18.92	5.0	200	25,000	431.05
		400	12,500	244.2
		600	8,333	175.90
		800	6,250	140.03
		1,000	5,000	117.57

TABLE 105 (con't.)

(1) All costs taken from "Cost of Wastewater Treatment Processes," Dorr-Oliver, Inc., The Advanced Wastewater Treatment Research Laboratory, FWPCA, Dec. 1968.

(2) Cost includes concrete, distributor, media and underdrainage.

TABLE 106

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR TRICKLING FILTERS

Plant effluent flow		Cost ($/day)			
mld	mgd	Operation(1)	Labor(2)	Replacement(3)	Total
0.04	0.01	0.1	5	1	
0.38	0.1	0.3	10	2	
1.13	0.3	1	20	3	
2.27	0.6	2	30	5	
3.78	1.0	3	40	7	
11.36	3.0	10	80	15	
18.92	5.0	16	120	22	

Notes:

1) Assume power cost @ 2.0c/KWH, with 24 hr/day operation of filter and recirculation pump.
2) Assume labor cost of $5/hr or $40/man-day.
3) Assume replacement cost @ 4% of capital cost for trickling filter with 600 gpd/ft^2 loading and recirculation ratio of 2.

ACTIVATED SLUDGE AERATION BASIN

Capital Cost

Typical activated sludge systems include aeration basin and aeration system (including aerators, piping, and instrumentation), clarifier, and other facilities. Cost estimates for the clarifier and other facilities are included in other subsections.

Table 107 summarizes and Figure 65 depicts aeration basin capital costs at various retention times and flow volumes. Long-term aeration basins (retention time of one to three days) have been selected as more effective and less expensive than conventional activated sludge aeration tanks (retention time of six to twelve hours) for treating this industry's wastewater. The larger aeration period and larger basin size aid in assimilating possible high sludge loads and also in neutralizing minor pH fluctuations. Assumptions used in determining specific costs are listed below the table.

Table 108 delineates mechanical aerator capital costs as a function of waste strength (BOD) and volume (mgd). Aerators were sized to provide one hp per hour per two lbs BOD_5 entering the system.

Basin retention time determinations are summarized in Table 109. The Eckenfelder formula for complete mix activated sludge systems was used to aid in calculating the proper balance between retention time, MLVSS concentration, and raw waste strength to yield the desired BOD_5 removal percentages. The activated sludge subsection of Section VII describes the Eckenfelder formula.

Operation and Maintenance Costs

Table 110 summarizes estimated daily operation and maintenance costs for activated sludge aeration systems. Assumptions made to compute the costs are provided at the bottom of the table.

AEROBIC DIGESTION

Capital Cost

Included in the aerobic digestion cost is an earthen basin (including accessories such as sludge piping, valves, etc.) and the mechanical surface aeration equipment.

Table 111 summarizes costs for aerobic digestion systems as a function of treatment plant influent volume and solids to the digestor.

In estimating costs for aerobic digestion to handle food processing wastes, we have assumed that the sludge-solids concentration is four percent into the aerobic digestor and that the digestor retention time is 15 days. Solids going to the

TABLE 107

ESTIMATED TOTAL CAPITAL COST
OF ACTIVATED SLUDGE AERATION BASINS

Plant Effl. Volume mld	Plant Effl. Volume mgd	Infl. BOD mg/l	Basin Ret'n Time Days	Excav. and Line $1,000	Aera-tors $1,000	Pipe Pump & Instr. $1,000	Total $1,000
0.04	0.01	200	1.0	16	0.5	14	30
		500	1.5	17	1.0	14	31
		800	1.5	17	1.5	14	32
		1,500	2.0	18	2.0	14	34
		2,500	2.5	19	2.8	14	36
		3,000	3.0	20	3.0	15	38
0.38	0.1	200	1.0	24	2.8	15	42
		500	1.5	25	4.1	16	45
		800	1.5	25	4.6	16	46
		1,500	2.0	26	7.9	18	52
		2,500	2.5	28	12	19	59
		3,000	3.0	29	13	20	62
1.13	0.3	200	1.0	29	4.1	20	53
		500	1.5	33	7.8	24	65
		800	1.5	33	12	24	69
		1,500	2.0	39	21	28	88
		2,500	2.5	42	30	30	100
		3,000	3.0	48	38	32	120
2.27	0.6	200	1.0	39	6.3	26	71
		500	1.5	51	13	34	98
		800	1.5	51	18	34	100
		1,500	2.0	60	38	40	140
		2,500	2.5	69	56	46	170
		3,000	3.0	78	70	52	200
3.78	1.0	200	1.0	51	10	34	95
		500	1.5	64	23	46	140
		800	1.5	69	28	46	140
		1,500	2.0	84	56	56	200
		2,500	2.5	91	83	66	240
		3,000	3.0	100	110	76	290
11.36	3.0	200	1.0	100	24	76	200
		500	1.5	135	56	108	300
		800	1.5	135	83	108	330
		1,500	2.0	175	150	140	460
		2,500	2.5	180	250	162	590
		3,000	3.0	220	350	192	760

TABLE 107 (Continued)

Plant Effl. Volume mld	mgd	Infl. BOD mg/l	Basin Ret'n Time Days	Excav. and Line $1,000	Aera-tors $1,000	Pipe Pump & Instr. $1,000	Total $1,000
18.92	5.0	200	1.0	150	38	120	310
		500	1.5	190	83	166	440
		800	1.5	190	140	166	500
		1,500	2.0	240	250	210	700
		2,500	2.5	250	400	248	900
		3,000	3.0	280	570	284	1100

NOTES:

1. Excavation and placement cost assumed for square basins, 12 ft deep, as follows:

MG	$/cu yd
0-2	12
2-4	11
4-6	10
6-10	9
10-15	8

2. Lining cost assumed as follows:

MG	$/sq yd
0-2	9.00
2-4	8.25
4-6	7.50
6-10	6.75
10-15	6.00

3. Aerator size and cost based on completely mixed basins and 2 lb BOD per H.P. per hour.

FIGURE 65

ESTIMATED CAPITAL COSTS OF ACTIVATED SLUDGE AERATION BASINS

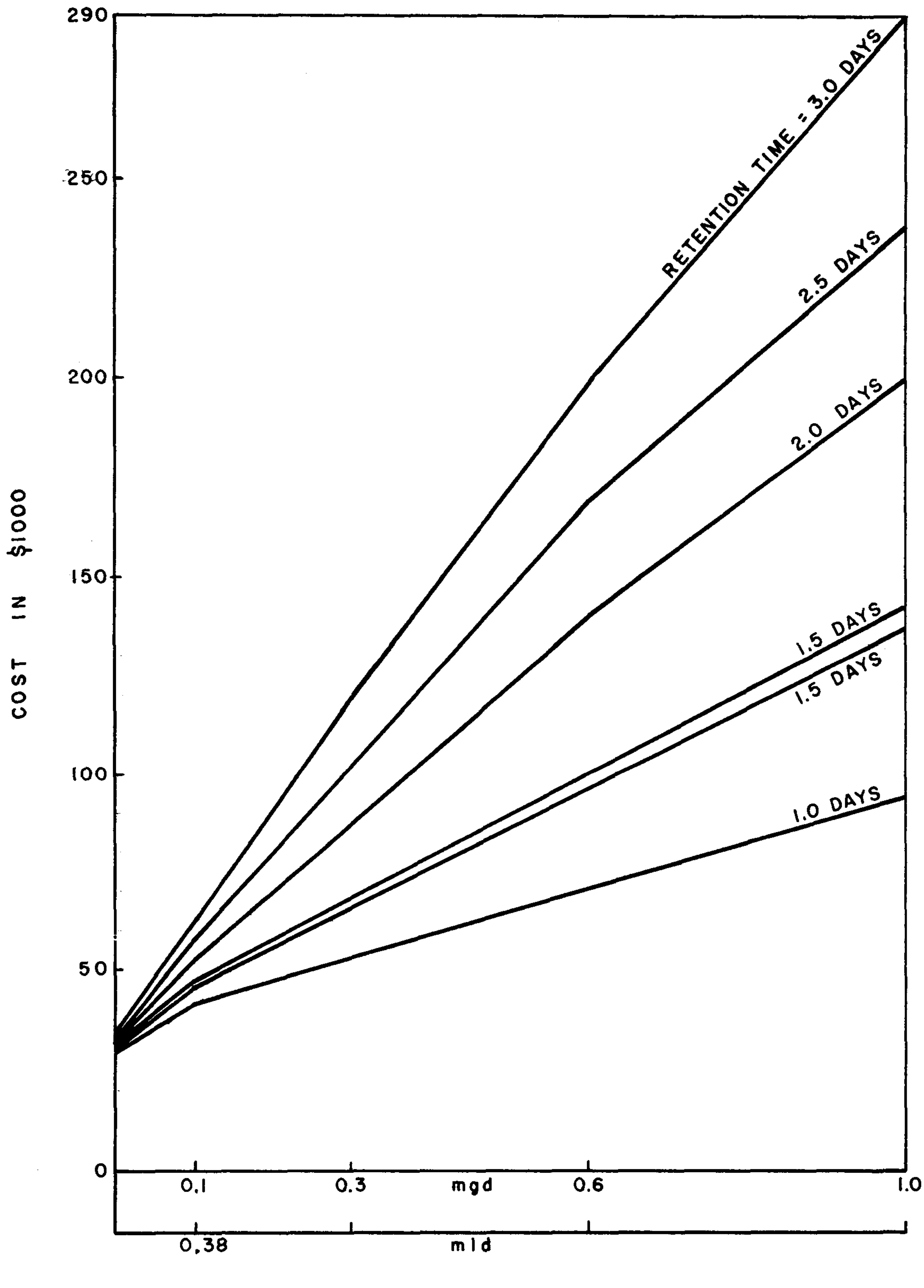


TABLE 108

ESTIMATED CAPITAL COST OF ACTIVATED SLUDGE AERATION

Plant Eff. Vol.		Ave. BOD	Required Ret. Time	Mechanical Aerator			
mld	mgd	(mg/l)	(days) (3)	H.P. Req. (1)	No. of Units	H.P. per Unit	Installed Cost ($1,000) (2)
0.04	0.1	200	1.0	0.35	1	0.5	0.5
		500	1.5	0.87	1	1.0	1.0
		800	1.5	1.4	2	0.75	1.5
		1,500	2.0	2.6	2	1.5	2.0
		2,500	2.5	4.3	2	2.25	2.8
		3,500	3.0	6.1	2	3	3.0
0.38	0.1	200	1.0	3.5	1	5	2.8
		500	1.5	8.7	1	10	4.1
		800	1.5	14	1	15	4.6
		1,500	2.0	26	1	30	7.9
		2,500	2.5	43	1	50	12.0
		3,500	3.0	61	1	60	13.0
1.13	0.3	200	1.0	10	1	10	4.1
		500	1.5	26	1	30	7.9
		800	1.5	42	1	50	12.0
		1,500	2.0	78	2	40	19
		2,500	2.5	130	2	75	28
		3,500	3.0	180	3	60	38
2.27	0.6	200	1.0	21	1	20	6.3
		500	1.5	52	1	60	13
		800	1.5	83	2	50	23
		1,500	2.0	160	2	75	28
		2,500	2.5	260	4	75	56
		3,500	3.0	360	5	75	70

TABLE 108 - Continued

Plant Eff. Vol.		Ave. BOD	Required Ret. Time	Mechanical Aerator			
mld	mgd	(mg/l)	(days) (3)	H.P. Req. (1)	No. of Units	H.P. per Unit	Installed Cost ($1,000) (2)
3.78	1.0	200	1.0	35	1	40	9.6
		500	1.5	87	2	50	23
		800	1.5	140	2	75	28
		1,500	2.0	260	4	75	56
		2,500	2.5	430	6	75	83
		3,500	3.0	600	8	75	110
11.36	3.0	200	1.0	100	2	50	5.5
		500	1.5	260	4	75	56
		800	1.5	420	6	75	83
		1,500	2.0	780	11	75	150
		2,500	2.5	1,300	18	75	250
		3,500	3.0	1,800	25	75	350
18.92	5.0	200	1.0	170	3	60	38
		500	1.5	430	6	75	83
		800	1.5	700	10	75	140
		1,500	2.0	1,300	18	75	250
		2,500	2.5	2,200	29	75	400
		3,500	3.0	3,000	41	75	570

(1) Based upon 2 lbs of BOD per H.P. per hour.
(2) Based upon manufacturers, estimates, includes power supply and all accessories.
(3) Based upon BOD removals of 85 percent for weak wastes (e.g., 200 mg/l BOD) up to BOD removals of 96 percent for strong wastes (e.g., 3,000 mg/l BOD).

TABLE 109

DETERMINATION OF AERATION BASIN RETENTION TIME FOR VARIOUS BOD CONCENTRATIONS TO ACHIEVE REQUIRED BOD REDUCTIONS(1)

Influent BOD mg/l	BOD removal desired percent	Effluent BOD mg/l	MLVSS mg/l	Required retention time days
200	85	30	2,830	1.0
500	91.6	42	3,635	1.5
800	93.0	55	4,515	1.5
1,500	94.7	80	4,437	2.0
2,500	95.6	110	4,345	2.5
3,500	96.3	130	4,320	3.0

(1) Retention time computed from Eckenfelder formula for complete mix activated sludge systems, See Reference 41 , Activated Sludge System Subsection of Section VII of this document.

TABLE 110

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR ACTIVATED SLUDGE AERATION BASINS

Average Daily Vol.		Ave. BOD	Cost ($/Day)			
mld	mgd	mg/l	Energy(1)	Labor(2)	Replace-ment(3)	Total
0.04	0.01	200	0.18	40	4.1	44
		500	0.36	40	4.2	45
		800	0.54	40	4.4	45
		1,500	1.1	40	4.7	46
		2,500	1.6	40	4.9	46
		3,500	7.2	40	5.2	47
0.38	0.1	200	1.8	40	5.8	48
		500	3.6	40	6.2	50
		800	5.4	40	6.3	52
		1,500	11	40	7.1	58
		2,500	16	40	8.1	64
		3,500	21	40	8.5	70
1.13	0.3	200	3.6	40	7.2	51
		500	11	40	8.9	60
		800	18	40	9.4	67
		1,500	33	40	12	85
		2,500	51	40	14	100
		3,500	64	40	16	120
2.27	0.6	200	7.2	40	9.7	57
		500	21	40	13	74
		800	36	40	14	90
		1,500	64	40	19	120
		2,500	100	40	23	160
		3,800	130	40	27	200
3.78	1.0	200	14	40	13	67
		500	36	40	19	95
		800	54	40	19	110
		1,500	110	40	27	180
		2,500	160	40	33	230
		3,500	210	40	40	290

TABLE 110 (cont.)

Average Daily Vol.		Ave. BOD	Cost ($/Day)			
mld	mgd	mg/l	Energy(1)	Labor(2)	Replacement(3)	Total
11.36	3.0	200	36	60	27	120
		500	110	60	41	210
		800	160	60	45	260
		1,500	300	60	63	420
		2,500	480	60	81	620
		3,500	670	60	100	830
18.92	5.0	200	64	80	42	190
		500	160	80	60	300
		800	270	80	68	420
		1,500	480	80	96	590
		2,500	780	80	120	980
		3,500	1100	80	150	1300

(1) Assume energy cost @ 2¢/KWH, 24 hr/day operation.

(2) Assume labor cost @ $40/man-day.

(3) Assume replacement cost @ 5% of capital cost.

TABLE 111

ESTIMATED CAPITAL COSTS OF AEROBIC DIGESTION SYSTEMS

Plant eff. flow		Influent SS (mg/1)(3)	Cost ($1000)			
mld	mgd		Tank	Blower(2)	Acces-sories(1)	Total
0.04	0.01	100	0.68	26.7	1.0	28.38
		300	1.2	26.8	1.0	29.00
		600	1.7	26.8	1.0	29.50
		1,000	2.2	26.9	1.0	29.76
		3,000	4.3	27.3	1.3	32.90
		5,000	5.7	27.6	1.7	35.00
0.38	0.1	100	2.23	27.02	1.00	30.25
		300	4.29	27.40	1.29	32.98
		600	6.57	27.96	1.97	36.50
		1,000	9.16	28.70	2.75	40.61
		3,000	19.74	32.43	5.92	58.09
		5,000	28.83	36.14	8.65	73.62
1.13	0.3	100	4.29	27.40	1.29	32.98
		300	8.54	28.52	2.56	39.62
		600	13.75	30.93	4.13	48.81
		1,000	19.74	32.43	5.92	58.09
		3,000	45.49	43.60	13.65	102.74
		5,000	68.94	54.80	20.68	144.42
2.27	0.6	100	6.57	27.96	1.97	36.50
		300	13.75	30.93	4.13	48.81
		600	22.57	33.55	6.77	62.89
		1,000	33.04	38.01	9.91	80.96
		3,000	79.99	60.39	24.00	164.38
		5,000	123.77	82.76	37.13	243.66
3.78	1.0	100	9.16	28.70	2.75	40.61
		300	19.74	32.43	5.92	58.09
		600	33.04	38.01	9.91	80.96
		1,000	49.57	45.48	14.87	105.92
		3,000	123.77	82.76	37.13	243.66
		5,000	193.44	120.01	58.03	371.48
11.36	3.0	100	19.16	32.43	5.75	58.09
		300	45.49	43.60	13.65	102.74
		600	79.99	60.39	24.00	164.38
		1,000	123.77	82.76	37.13	243.66
		3,000	325.44	182.00	97.63	605.07
		5,000	522.28	297.00	156.68	975.96

TABLE 111 (con't.)

Plant eff. flow		Influent SS (mg/1)(4)	Cost ($1000)			
mld	mgd		Tank(2)	Blower(3)	Acces-sories(1)	Total
18.92	5.0	100	28.83	36.16	8.65	73.62
		300	68.94	54.80	20.68	144.42
		600	123.77	82.76	37.13	243.66
		1,000	193.44	120.01	58.03	371.48
		3,000	522.28	297.00	156.68	975.96
		5,000	841.66	495.00	252.50	1,589.16

(1) Assumed at 30 percent of tank cost and includes inlet structure, supernatant pump, sludge pump, piping, and electric.

(2) Includes blowers, air header and piping, and blower house; air required assumed @ 25 cfm/1000 ft^3 of digester capacity; costs taken from Reference 32.

(3) Number representing solids to digester is equivalent to the solids removed in air flotation (if used) plus 90 percent of the sum of the TSS to the aeration basin and 60 percent of the BOD to the aeration basin.

TABLE 112

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS
FOR AEROBIC DIGESTION

Plant Eff. Flow		COST ($/DAY)			
mld	mgd	Energy[1]	Labor[2]	Replacement[3]	Total
0.04	0.01	0.2	16	4	20
0.38	0.1	1.3	20	6	27
1.13	0.3	4.0	20	8	32
2.27	0.6	8.1	20	11	39
3.78	1.0	13	30	15	58
11.36	3.0	40	40	33	113
18.92	5.0	67	40	51	158

(1) Assume Energy cost at 2¢/KWH.

(2) Assume Labor cost at $40/man-day.

(3) Assume Replacement at 5% of capitol costs, and 1000 mg/l SS concentration in plant influent.

digestor are comprised of all solids removed in dissolved air flotation, if used, plus all solids removed by the secondary clarifier not recirculated as MLVSS to the aeration basin.

Operation and Maintenance Costs

Estimated daily operation and maintenance costs for aerobic digestion are summarized in Table 112.

VACUUM FILTRATION - SLUDGE HANDLING

Capital Cost

Table 113 on the following page summarizes estimated capital costs for vacuum filters. In generating this data, we have assumed that solids entering the digestor are comprised of 60 percent of the solids into the aerobic digestor (the other 40 percent being destroyed in the digestor) plus all solids removed by primary gravity settling (if used).

Operation and Maintenance Costs

Table 114 summarizes daily operation and maintenance costs for vacuum filtration of varying flows with an assumed SS concentration of 1000 mg/l.

Since many processors will not require the use of this dewatering equipment, the capital and operating costs have been developed to adequately cover the cost of other methods of sludge handling, such as land spreading of digested or primary sludge where dewatering is not necessary.

EMERGENCY RETENTION PONDS

Capital Cost

Due to the great fluctuations possible in raw effluent characteristics from fruit and vegetable processing plants, even the best designed biological treatment systems may show erratic performance at times. To safeguard against this, it is advantageous to follow conventional biological treatment systems with an emergency retention pond when fruit and vegetable wastewater is being handled.

As shown in Table 115 retention ponds of short detention periods (here assumed at two days) are relatively inexpensive.

Operation and Maintenance Costs

Table 116 summarizes estimated operation and maintenance costs for aerated polishing ponds.

TABLE 113

ESTIMATED CAPITAL COST OF VACUUM FILTRATION

Plant effluent flow		Influent SS (3) (mg/l)	Dry solids (1,000 lb/ day)	Required filter area (ft^2) (1)	Cost ($1,000) (2)
mld	mgd				
0.04	0.01	100	0.008	0.08	26
		300	0.025	0.26	27
		600	0.050	0.52	27
		1,000	0.083	0.86	27
		3,000	0.25	2.6	28
		5,000	0.42	4.4	30
0.38	0.1	100	0.08	0.8	27
		300	0.25	2.6	28
		600	0.50	5.2	30
		1,000	0.83	8.6	33
		3,000	2.5	26	46
		5,000	4.2	44	60
1.13	0.3	100	.25	2.6	28
		300	.75	7.8	32
		600	1.5	16	39
		1,000	2.5	26	46
		3,000	7.5	78	87
		5,000	13	140	130
2.27	0.6	100	.50	5.2	30
		300	1.5	16	39
		600	3.0	31	50
		1,000	5.0	52	67
		3,000	15	160	150
		5,000	25	260	230
3.78	1.0	100	0.83	8.6	33
		300	2.5	26	46
		600	5.0	52	67
		1,000	8.3	86	93
		3,000	25	260	230
		5,000	42	440	360
11.36	3.0	100	2.5	26	46
		300	7.5	78	87
		600	15	160	150
		1,000	25	260	230
		3,000	75	780	630
		5,000	130	1,400	1,100

TABLE 113 (con't.)

Plant effluent flow		Influent SS (3) (mg/l)	Dry solids (1,000 lb/day)	Required filter area (ft^2) (1)	Cost ($1,000) (2)
mld	mgd				
18.92	5.0	100	4.2	44	60
		300	13	140	130
		600	25	260	230
		1,000	42	440	360
		3,000	130	1,400	1,100
		5,000	210	2,200	1,700

(1) Assume loading rate of 4 $lbs/ft^2/hr$ and 24 hour/day operation.
(2) All costs adapted from Reference 33.
(3) Number representing solids to vacuum filter is equivalent to 60 percent of the solids into the aerobic digester plus all the solids removed by primary gravity settling (if used).

TABLE 114

ESTIMATED DAILY OPERATION AND MAINTENANCE
COSTS FOR VACUUM FILTRATION

Plant effluent flow		Cost ($/day)(4)			
mld	mgd	Energy(1)	Labor(2)	Replacement(3)	Total
0.04	0.01	0.5	15	4.4	20
0.38	0.1	1	20	5.4	26
1.13	0.3	2	20	7.6	30
2.27	0.6	4	25	11	40
3.78	1.0	6	30	15	51
11.36	3.0	15	40	38	93
18.92	5.0	24	40	59	120

(1) Assume:
- Energy cost @ 2c/kwh.
- Energy costs taken from Ref. 34.
- 24 hour/day operation.

(2) Assume labor costs @ $40/man-day.
(3) Assume replacement costs @ 6% of capital cost.
(4) Assume costs are for system with 1,000 mg/l SS influent.

TABLE 115

ESTIMATED CAPITAL COST OF EMERGENCY RETENTION PONDS

Plant Eff. Flow		Cost ($1,000) (2)	
mld	mgd	Lagoon(1) Vol. (MG)	Lagoon(3) Construction Cost
0.04	0.01	0.02	6
0.38	0.1	0.2	7
1.13	0.3	0.6	10
2.27	0.6	1.2	13
3.78	1.0	2.0	17
11.36	3.0	6.0	34
18.92	5.0	10.0	48

(1) Assume 2 day retention.

(2) Assume 200 mg/l influent BOD.

(3) Based on 3m (10 ft) depth, unlined pond.

TABLE 116

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR EMERGENCY RETENTION PONDS

Plant Eff. Flow		Cost ($/Day)	
mld	mgd	Labor (1)	Total
0.04	0.01	3	3
0.38	0.1	5	5
1.13	0.3	6	6
2.27	0.6	8	8
3.78	1.0	9	9
11.36	3.0	11	11
18.92	5.0	12	12

(1) Labor cost assumed @ $40/man-day.

RAPID SAND FILTRATION (MULTI-MEDIA)

Capital Cost

Figure 66 on the following page graphically summarizes estimated capital costs for sand filtration of secondary effluent. Assumptions made in generating the data are listed below the figure.

Operation and Maintenance Costs

Table 117 summarizes estimated operation and maintenance costs for sand filtration. A further breakdown of energy costs is provided in Table 118.

CHLORINATION SYSTEM

Capital Cost

The capital cost of a chlorination system includes the following:

1. Chlorinators to measure and apply the chlorine.

2. Chlorine cylinder storage.

3. Housing for the above.

To simplify the calculations, we are assuming that a chlorine application rate of 20 mg/l is required to disinfect the effluent. Table 119 provides estimated size and cost of the chlorination facility required.

The cost for the chlorine contact basin is included in the cost of the polishing pond.

Operation and Maintenance Costs

The operation and maintenance costs for a chlorination facility are estimated on Table 120. Assumptions made are shown as footnotes to the table.

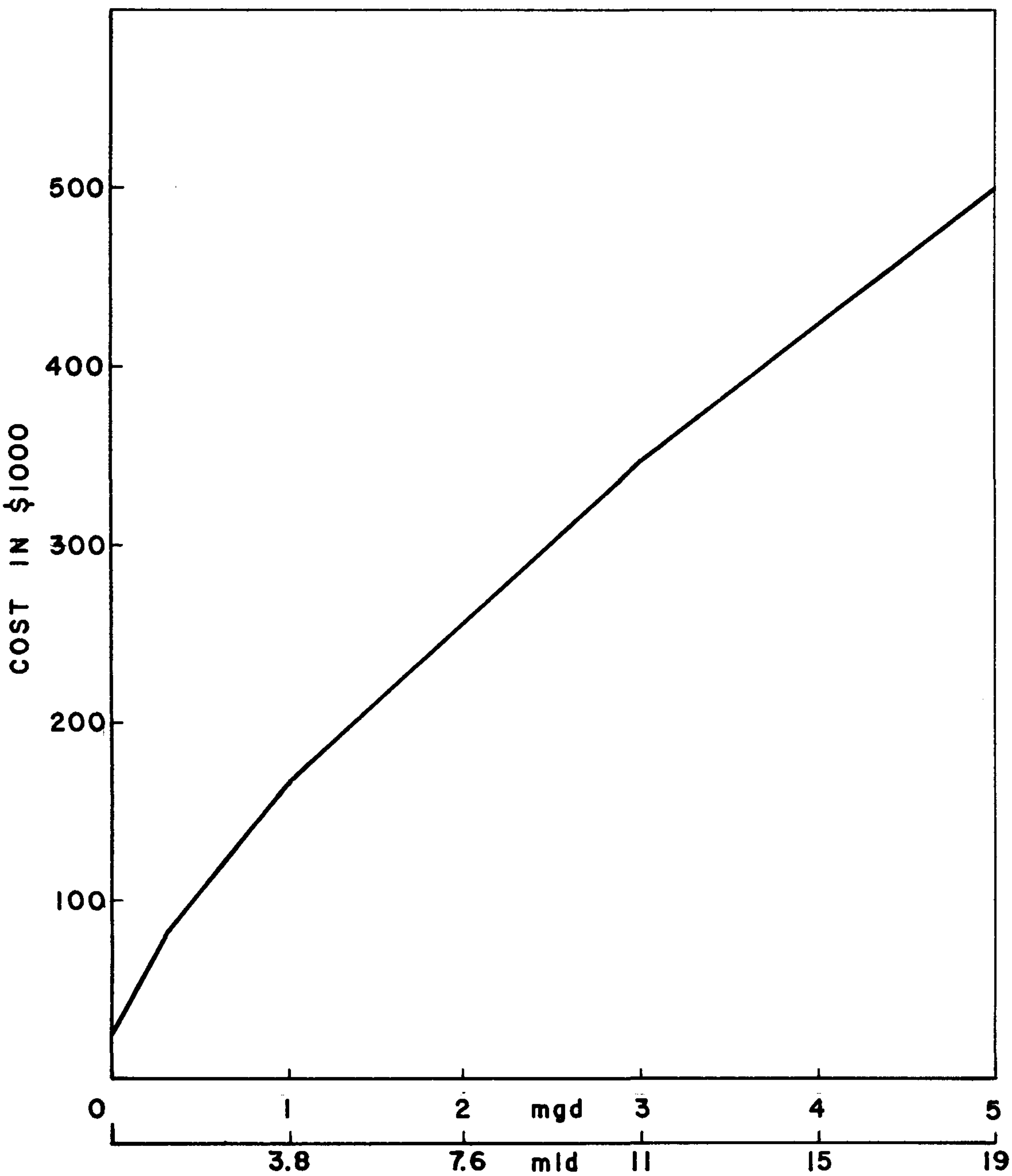
ANAEROBIC DIGESTION

Capital Cost

Table 121 summarizes anaerobic digestion costs as a function of treatment plant influent volume and solids to the digestor(s). In estimating costs for anaerobic digestion to handle food processing wastes, we have assumed that the sludge solids concentration into the digestor is four percent and that the digestor retention time is 40 days. Solids going to the digestor are comprised of all solids removed in dissolved air flotation, if used, plus all solids removed by the secondary clarifier not recirculated as MLVSS to the aeration basin.

FIGURE 66

ESTIMATED CAPITAL COSTS FOR RAPID SAND OR MULTI- MEDIA FILTRATION



Notes:

(1) Assume 4 gpm/ft^2 hydraulic loading rate.

(2) All costs taken from Ref. 35.

TABLE 117

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR RAPID SAND FILTRATION

Plant effluent flow		Cost ($/day)			
mld	mgd	Energy (1)	Labor (2)	Replacement (3)	Total
0.04	0.01	0.1	11	3	14
0.38	0.1	1	16	5	22
1.13	0.3	2	16	11	29
2.27	0.6	5	16	16	37
3.78	1.0	8	25	23	56
11.36	3.0	25	40	48	110
18.92	5.0	41	40	68	150

(1) Assume energy cost at 2c/kwh

(2) Assume labor cost at $40/man-day.

(3) Assume replacement cost at 5% of capital cost.

TABLE 118

ESTIMATED DAILY ENERGY COSTS FOR
RAPID SAND FILTRATION

Plant effluent flow		Energy cost ($/day)(1)			
mld	mgd	Main stream(2) pump	Back wash(3) pump	Surface wash(4) pump	Total
0.04	0.01	0.1	0.01	0.01	0.12
0.38	0.1	0.79	0.03	0.01	0.83
1.13	0.3	2.4	0.09	0.03	2.5
2.27	0.6	4.9	0.20	0.05	5.1
3.78	1.0	7.9	0.29	0.09	8.3
11.36	3.0	24	0.88	0.3	25
18.92	5.0	39	1.5	0.4	41

(1) All costs taken from Ref.36 and based on 4 gpm/ft^2 application rate.

(2) Total dynamic head assumed at 100 ft, 80% pump efficiency.

(3) Backwash assumed at 5% of main stream, 75 ft head, 80% pump efficiency.

(4) Surface wash pump assumed to operate 15 min/day at 1.4 gpm/ft^2, with a head of 300 ft; 80% efficiency is also assumed.

TABLE 119

CAPITAL COST OF CHLORINATION FACILITIES

Daily volume		lbs CL_2 (1) per day	Cost of chlorinators (2) \$1,000	Cost of cylinder storage \$1,000	Cost of housing (3) \$1,000	Total cost \$1,000
mld	mgd					
0.04	0.01	1.7	0.5	0.5	0.5	2
0.38	0.1	17	1	1	1	3
1.13	0.3	51	2	1	2	5
2.27	0.6	100	2	1	2	5
3.78	1.0	170	3	2	2	7
11.36	3.0	500	5	3	3	11
18.92	5.0	840	7	3	4	14

(1) Based on assumed chlorine application rate of 20 mg/l.
(2) Based on 100 percent standby capacity and normal accessories and installation.
(3) Based on \$30/ft^2.

TABLE 120

OPERATION AND MAINTENANCE COST OF CHLORINATION EQUIPMENT

Daily volume		Daily cost			
		Chlorine cost(1)	Labor cost(2)	Replacement parts(3)	Total(4)
mld	mgd	$	$	$	$
0.04	0.01	0.2	20	0.01	20
0.38	0.1	2	20	1	23
1.13	0.3	6	20	2	28
2.27	0.6	11	20	2	33
3.78	1.0	19	20	3	42
11.36	3.0	55	40	5	100
18.92	5.0	92	40	7	139

(1) Based on $0.11/lb in ton cylinders.
(2) Based on $5/hr.
(3) Based on 0.1 percent per day of chlorinator cost only.
(4) Power costs are assumed negligible.

TABLE 121

ESTIMATED CAPITAL COSTS OF ANAEROBIC DIGESTION

Plant effluent flow		SS(5) (mg/l)	Sludge vol.(1) cf^3	Digester vol.(2,4) 1,000 cf^3	Number of tanks	Total cost ($1,000(3)
mld	mgd					
0.38	0.1	100	33	1.3	1	26
		300	100	4.0	1	35
		600	200	8.0	1	46
		1,000	330	13.0	1	60
		3,000	1,000	40.0	1	120
		5,000	1,700	(33.0)	2	210
1.13	0.3	100	100	4.0		35
		300	300	12.0		56
		600	600	24.0		85
		1,000	1,000	40.0		120
		3,000	3,000	40.0	3	370
		5,000	5,000	40.0	5	610
2.27	0.6	100	200	8.0		46
		300	600	24.0		85
		600	1,200	24.0	2	170
		1,000	2,000	40.0	2	240
		3,000	6,000	40.0	6	730
		5,000	10,000			
3.78	1.0	100	330	13.0	1	60
		300	1,000	40.0	1	120
		600	2,000	40.0	2	240
		1,000	3,300	33.0	4	430
		3,000	10,000			
		5,000	17,000			

TABLE 121 (Continued)

Plant effluent flow		SS (mg/l)	Sludge vol. (1) cf^3	Digester vol. (2,4) 1,000 cf^3	Number of tanks	Total cost ($1,000 (3)
mld	mgd					
11.36	3.0	100	1,000	40.0	1	120
		300	3,000	40.0	3	370
		600	6,000	40.0	6	730
		1,000	10,000			
		3,000	30,000			
		5,000	50,000			
18.92	5.0	100	1,700	33.0	2	210
		300	5,000	40.0	5	610
		600	10,000	40.0	10	1,200
		1,000	17,000	39.0	17	2,000
		3,000	50,020	40.0	50	6,100
		5,000	84,000	40.0	84	10,000

(1) Assume 4% solids.
(2) Assume 40 day retention.
(3) Costs based on Reference 1; where capital costs exceed $1,000,000, it has been assumed that an alternate sludge treatment/disposal would be used rather than anaerobic digestion.
(4) Assume 40,000 cu. ft. is maximum digester capacity; larger volumes are accommodated by multiple tanks of identical size.
(5) Number representing solids to digester is equivalent to the solids removed in air flotation (if used) plus 90 percent of the sum of the TSS to the aeration basin and 60 percent of the BOD to the aeration basin.

TABLE 122

ESTIMATED DAILY OPERATION AND
MAINTENANCE COSTS FOR ANAEROBIC DIGESTION

Plant Eff. Vol.		Cost ($/day)			
mld	mgd	Energy(1,4)	Labor(2)	Replacement(3)	Total
0.38	0.1	1.5	40	7	48
1.13	0.3	1.9	40	13	55
2.27	0.6	3.8	40	27	71
3.78	1.0	7.6	40	47	95

(1) Assume energy cost @ 2¢/KWA.
(2) Assume labor cost @ $40./man-day.
(3) Assume replacement cost @ 4% of capital investment, for 1,000 ppm TSS in influent.
(4) Taken from Ref. 37.

Operation and Maintenance Costs

Table 122 summarizes estimated daily operation and maintenance costs for anaerobic digestion. Assumptions made in arriving at these figures are listed below the table.

CARBON ADSORPTION

Capital Cost

Figure 67 summarizes capital costs for carbon adsorption. The construction cost curve is based on carbon towers designed for a surface loading of four gal/min/sq ft. Costs include the towers, initial carbon charge, tower pumps, carbon regeneration furnaces, carbon handling and storage equipment, and all other mechanical and electrical equipment.

Operation and Maintenance Costs

Carbon adsorption for food processing wastewater applications would only be used as a polishing tertiary treatment. Table 123 summarizes operation and maintenance costs which would be added on to primary and secondary system costs. Table 124 summarizes component energy costs for carbon adsorption.

ELECTRODIALYSIS

Capital Cost

Table 125 summarizes capital costs for electrodialysis membranes, electrical equipment, and auxiliary equipment. Assumptions made in generating this data are listed as footnotes of the table.

Other electrical and auxiliary equipment costs are taken from Ref. 38.

Operation and Maintenance Costs

Table 126 summarizes operating and maintenance costs for electrodialysis. Assumptions are listed beneath the table.

REVERSE OSMOSIS

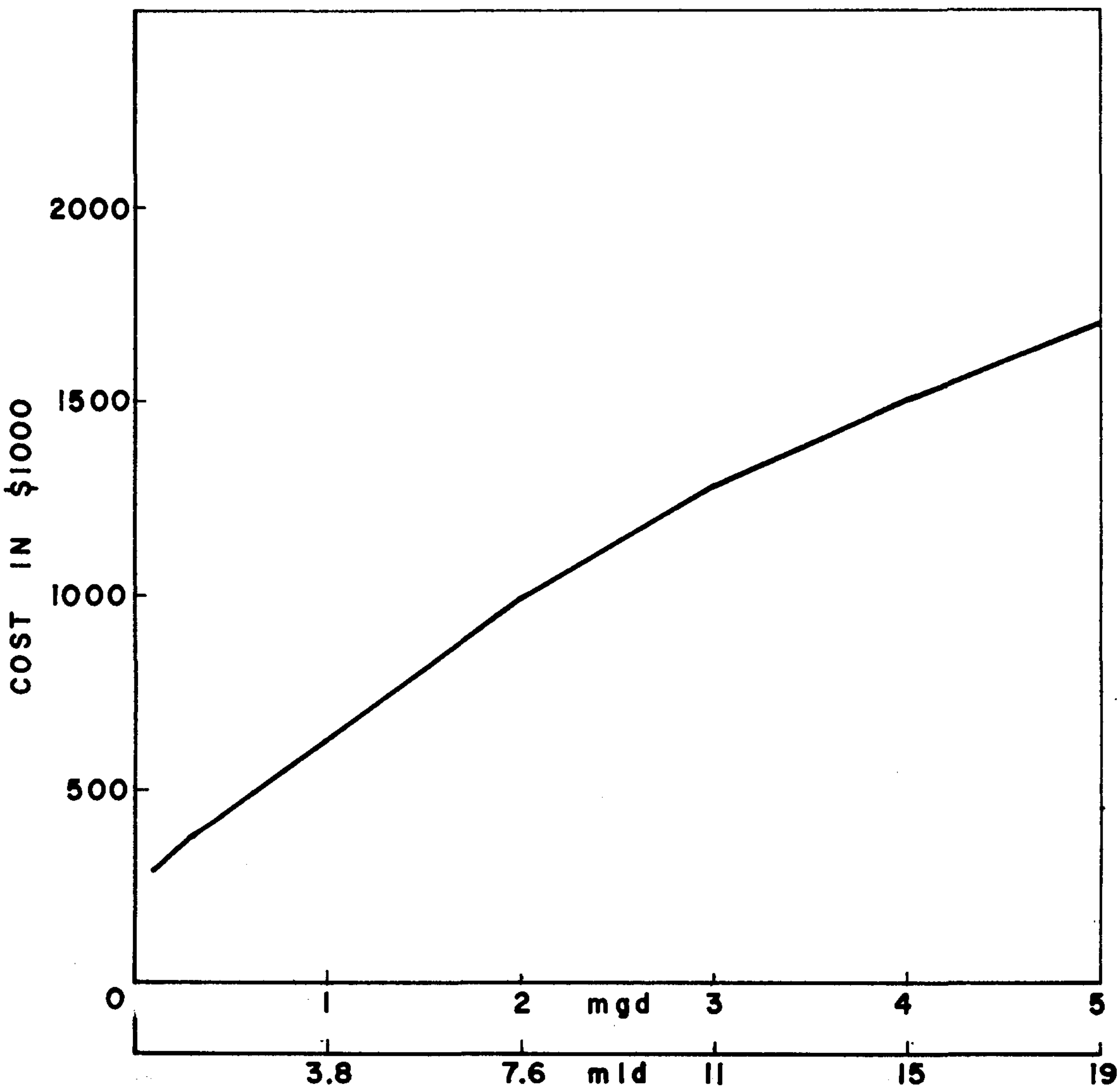
Capital Cost

The capital cost of reverse osmosis is comprised of three major components: the membrane, the feedwater pump, and auxiliary equipment.

Table 127 on the following page summarizes total capital costs for reverse osmosis treatment. Assumptions made are listed below the table.

FIGURE 67

ESTIMATED CAPITAL COST FOR CARBON ADSORPTION



Notes:

- Assume loading rate = 4 gpm/ft^2
- Costs taken from Brown and Caldwell, Lompoc Valley Regional Wastewater Management Study and Preliminary Design, June, 1972.

TABLE 123

ESTIMATED DAILY OPERATION AND
MAINTENANCE COSTS FOR CARBON ADSORPTION

Plant eff. flow		Cost ($/day)			
mld	mgd	Power(1) ($)/day	Labor(2) ($)/day	Replacement(3)	Total ($)
0.38	0.1	0.7	40	49	90
1.13	0.3	2.14	40	62	104
2.27	0.6	4.30	40	80	124
3.78	1	7.17	40	104	151
11.36	3	20.32	40	212	282
18.92	5	33.68	40	279	353

(1)Assumed power cost of 2¢/KWH.
(2)Assumed labor cost of $40/man-day.
(3)Assumed parts replacement cost at six percent of capital investment, includes equipment and carbon.

TABLE 124

ESTIMATED DAILY ENERGY COSTS
FOR CARBON ADSORPTION

Plant eff. flow		Cost ($/day)(1)				
mld	mgd	Main stream	Back wash	Carbon regeneration	Surface spray	Total
0.38	0.1	.61	.02	.06	.01	.70
1.13	0.3	1.83	.07	.22	.02	2.14
2.27	0.6	3.66	.14	.46	.04	4.30
3.78	1.0	6.1	.24	.77	.06	7.17
11.36	3.0	17.32	.71	2.1	.19	20.32
18.92	5.0	28.86	1.18	3.32	.32	33.69

(1)Assume power cost at $0.02/KWH.

TABLE 125

ESTIMATED CAPITAL COST OF ELECTRODIALYSIS(4)

Plant effluent flow		Cost ($1,000)			
mld	mgd	Membrane(1)	Electrical(2) equipment	Aux.(3) equipment	Total
0.38	0.1	7.3	55	31	93
1.13	0.3	22	166	74	262
2.27	0.6	43	332	119	494
3.78	1.0	70	553	175	798
11.36	3.0	188	1,658	400	2,246
18.92	5.0	291	2,764	582	3,637

(1) Assume:
- 6 ft cell length.
- 20 can/sec product stream velocity.
- 1.0 mm cell thickness.

(2) Assume $150/kw required.
(3) Assume product to brine ratio of 3.
(4) All costs taken from Reference 38.

TABLE 126

ESTIMATED DAILY OPERATION AND MAINTENANCE COSTS FOR ELECTRODIALYSIS

Plant effluent flow		Cost ($/day)			
mld	mgd	Energy(1)	Labor(2)	Replacement(3)	Total
0.38	0.1	120	40	18	178
1.13	0.3	366	40	50	456
2.27	0.6	730	40	95	865
3.78	1.0	1,216	80	153	1,449
11.36	3.0	3,646	80	431	4,157
18.92	5.0	6,076	80	698	6,854

(1) Assume energy cost @ 2c/kwh, all costs taken from Reference 40.
(2) Assume labor cost @ $40/man-day.
(3) Assume replacement cost @ 7% of capital cost.

TABLE 127

ESTIMATED CAPITAL COSTS
OF TUBULAR REVERSE OSMOSIS SYSTEMS (1)

Plant Eff. Flow		Cost ($1,000)			
mld	mgd.	Membrane (2) Module	Auxiliary (3) Equip.	Pumping (4) Equip.	Total
0.38	0.1	29	91	37	157
1.13	0.3	86	195	102	383
2.27	0.6	156	325	192	673
3.78	1.0	252	438	308	998
11.36	3.0	714	990	795	2,499
18.92	5.0	1,136	1,396	1,331	3,863

(1) All costs taken from Ref. 41.
See individual component tables for full description of assumptions made.

(2) Includes:
- membrane.
- membrane supports.
- pressure vessels and associated equipment.
- spare membranes.

(3) Includes:
- process instrumentation.
- tank and vessels.
- piping.
- feedwater treatment and chemical injection equipment.
- intake water system.

(4) Includes:
- high pressure pumps and drivers.
- interconnecting pipes and valves.
- process pumps and drivers.
- accessory electrical equipment.

TABLE 128

ESTIMATED DAILY OPERATION
AND MAINTENANCE COSTS OF REVERSE OSMOSIS

Plant Eff. Flow		Cost ($/Day)			
mld	mgd	Energy(1)	Labor(2)	Replacement(3)	Total
0.38	0.1	19	40	30	89
1.13	0.3	58	40	73	170
2.27	0.6	120	40	130	280
3.78	1.0	190	80	190	460
11.36	3.0	580	80	480	1,100
18.92	5.0	970	80	740	1,800

(1) Power cost assumed @ 2¢/KWH, 24 hr./day operation.

(2) Labor cost assumed @ $40/man-day.

(3) Replacement cost assumed @ 7% of capital investment.

TABLE 129

ESTIMATED DAILY ENERGY COSTS FOR REVERSE OSMOSIS

Plant eff. flow		Cost ($/day)				
mld	mgd	Feedwater Pump(1)	Product Water Pump(2)	Reject Brine Pump(3)	Feedwater Process Pump(4)	Total
0.38	0.1	1.0	0.7	0.3	17	19
1.13	0.3	3.1	2.1	0.8	52	58
2.27	0.6	6.2	4.2	1.6	100	120
3.78	1.0	10.0	6.9	2.6	170	190
11.36	3.0	31.0	21.0	7.8	520	580
18.92	5.0	52.0	35.0	13.0	870	970

(1) Assume 60 psi output pressure, 80% pump efficiency.

(2) Assume 80 psi output pressure, 80% efficiency, 0.5 recovery ratio.

(3) Assume 30 psi output pressure, 80% efficiency, 0.5 recovery ratio.

(4) Assume 1,000 psi output pressure, 80% efficiency.

Operation and Maintenance Costs

Table 128 summarizes operating and maintenance costs for reverse osmosis treatment. Energy costs are defined in greater detail in Table 129.

APPROACH TO COST ESTIMATION OF SUBCATEGORY TREATMENT ALTERNATIVES

Treatment costs are given in the following tables (Tables 130-185) for each commodity for eight treatment alternatives. The treatment alternatives include screening, average aerated lagoon treatment and in-plant controls, average activated sludge treatment and in-plant controls, land treatment via spray irrigation, improved aerated lagoon treatment plus additional in-plant controls plus chlorination with and without multi-media filtration and improved activated sludge treatment plus additional in-plant controls plus chlorination with and without multi-media filtration. The effluent quality (BOD_5 and TSS) is given for each treatment alternative with screened raw waste loads given below alternative A. Costs for commodities are given for their typical processing season; costs for some commodities are based on cold temperature conditions. The following subsections summarize the approach used in costing the alternatives for each subcategory.

The basic cost estimating approach consists of taking the average raw waste (flow volume in mgd; BOD_5 in mg/l; and TSS in mg/l) for each subcategory as shown in Section V and treating it sufficiently to meet the effluent guidelines set forth in Section IX or X of this document.

The characteristics of the raw waste loads determined which treatment modules were used and also the loading rates, detention times, etc. at which the units for all treatment chains were operated. Capital and operation and maintenance costs for individual treatment modules were taken directly from the tables and curves presented in the individual treatment module cost subsections of Section VIII.

For treatment alternatives B thru H, screening was assumed to be already installed at plants and was therefore not included in the costs. While most plants currently have some form of lagooning, the entire lagoon system costs were included in the lagoon alternatives.

Spray Irrigation

Cost estimates for each model plant (Table 130-185) for the spray irrigation treatment alternative (D) were taken directly from the total capital cost curve (Figure 59) and the operation and maintenance tabulation (Table 95) developed in the spray irrigation cost subsection of Section VIII. No other modules were used in conjunction with spray irrigation.

TABLE 130

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL APRICOT PLANT
(70 Day Operating Season at 310 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	272	584	648	283	595	583	895
Unit Cost		200	460	310	209	469	449	709
Land Cost		22	4	260	22	4	22	4
Engr. & Cont.		50	120	78	52	122	112	182
TOTAL ANNUAL COST	-	49	119	71	56	126	110	180
Capital Recovery		40	94	63	42	96	91	145
O&M Cost		9	25	8	14	30	19	35
EFFLUENT QUALITY								
BOD5 (kg/kkg)	15.5	1.9	1.9	0	0.6	0.6	0.6	0.6
TSS (kg/kkg)	4.2	3.4	3.4	0	1.1	1.1	0.6	0.6

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 131

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANEBERRY PLANT
(60 Day Operating Season at 19 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	36	177	58	40	181	67	208
Unit Cost		28	140	43	31	143	53	165
Land Cost		1	2	4	1	2	1	2
Engr. & Cont.		7	35	11	8	36	13	41
TOTAL ANNUAL COST	-	8	34	10	10	36	15	41
Capital Recovery		6	28	9	7	29	11	33
O&M Cost		2	6	1	3	7	4	8
EFFLUENT QUALITY								
BOD5 (kg/kkg)	2.8	0.5	0.5	0	0.14	0.14	0.14	0.14
TSS (kg/kkg)	0.6	0.9	0.9	0	0.22	0.22	0.14	0.14

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 132

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL BRINED CHERRY PLANT
(335 Day Operating Season at 11 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	95	227	70	98	230	136	268
Unit Cost		72	180	50	74	182	104	212
Land Cost		5	2	8	5	2	5	2
Engr. & Cont.		18	45	12	19	46	27	54
TOTAL ANNUAL COST	-	30	81	18	38	89	50	101
Capital Recovery		15	37	10	16	38	22	44
O&M Cost		15	44	8	22	51	28	57
EFFLUENT QUALITY								
BOD5 (kg/kkg)	21.8	1.8	1.8	0	0.38	0.38	0.38	0.38
TSS (kg/kkg)	1.4	3.3	3.3	0	0.97	0.97	0.38	0.38

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 133

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL SOUR CHERRY PLANT
(55 Day Operating Season at 50 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	82	252	116	87	257	149	319
Unit Cost		62	200	73	66	204	116	254
Land Cost		4	2	25	4	2	4	2
Engr. & Cont.		16	50	18	17	51	29	63
TOTAL ANNUAL COST	-	16	49	17	18	51	29	62
Capital Recovery		13	41	15	14	42	24	52
O&M Cost		3	8	2	4	9	5	10
EFFLUENT QUALITY								
BOD5 (kg/kkg)	17.2	1.1	1.1	0	0.54	0.54	0.54	0.54
TSS (kg/kkg)	1.0	2.1	2.1	0	0.95	0.95	0.54	0.54

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 134

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL SWEET CHERRY PLANT
(55 Day Operating Season at 78 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	82	252	116	87	257	149	319
Unit Cost		62	200	73	66	204	116	254
Land Cost		4	2	25	4	2	4	2
Engr. & Cont.		16	50	18	17	51	29	63
TOTAL ANNUAL COST	-	16	49	17	18	51	29	62
Capital Recovery		13	41	15	14	42	24	52
O&M Cost		3	8	2	4	9	5	10
EFFLUENT QUALITY								
BOD5 (kg/kkg)	9.7	0.7	0.7	0	0.24	0.24	0.24	0.24
TSS (kg/kkg)	0.6	1.3	1.3	0	0.46	0.46	0.24	0.24

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 135

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CRANBERRY PLANT
(120 Day Operating Season at 28 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	65	202	87	69	206	113	250
Unit Cost		50	160	59	53	163	88	198
Land Cost		3	2	13	3	2	3	2
Engr. & Cont.		12	40	15	13	41	22	50
TOTAL ANNUAL COST	-	16	49	16	20	53	30	63
Capital Recovery		10	33	12	11	34	18	41
O&M Cost		6	16	4	9	19	12	22
EFFLUENT QUALITY								
BOD5 (kg/kkg)	10.0	1.1	1.1	0	0.33	0.33	0.33	0.33
TSS (kg/kkg)	1.4	1.9	1.9	0	0.62	0.62	0.33	0.33

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 136

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL DRIED FRUIT PLANT
(365 Day Operating Season at 26 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	65	202	87	68	205	112	249
Unit Cost		50	160	59	52	162	87	197
Land Cost		3	2	13	3	2	3	2
Engr. & Cont.		12	40	15	13	41	22	50
TOTAL ANNUAL COST	-	28	80	23	37	89	52	104
Capital Recovery		10	33	12	18	41	25	48
O&M Cost		18	47	11	19	48	27	56
EFFLUENT QUALITY								
BOD5 (kg/kkg)	12.4	1.2	1.2	0	0.35	0.35	0.35	0.35
TSS (kg/kkg)	1.9	2.1	2.1	0	0.70	0.70	0.35	0.35

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 137

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL GRAPE JUICE CANNING PLANT
(365 Day Operating Season at 136 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	154	340	147	159	345	240	426
Unit Cost		110	270	90	114	274	179	339
Land Cost		16	2	35	16	2	16	2
Engr. & Cont.		28	68	22	29	69	45	85
TOTAL ANNUAL COST	-	48	117	33	59	128	82	151
Capital Recovery		22	55	18	23	56	36	69
O&M Cost		26	62	15	36	72	46	82
EFFLUENT QUALITY								
BOD5 (kg/kkg)	10.7	0.7	0.7	0.0	0.30	0.30	0.30	0.30
TSS (kg/kkg)	1.2	1.3	1.3	0.0	0.50	0.50	0.30	0.30

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 138

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL GRAPE JUICE PRESSING PLANT
(60 Day Operating Season at 752 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	115	327	170	121	333	221	533
Unit Cost		87	260	100	92	265	172	445
Land Cost		6	2	45	6	2	6	2
Engr. & Cont.		22	65	25	23	66	43	86
TOTAL ANNUAL COST	-	23	65	23	26	68	44	86
Capital Recovery		18	54	20	19	55	35	71
O&M Cost		5	11	3	7	13	9	15
EFFLUENT QUALITY								
BOD5 (kg/kkg)	1.9	0.14	0.14	0.0	0.06	0.06	0.06	0.06
TSS (kg/kkg)	0.4	0.26	0.26	0.0	0.10	0.10	0.06	0.06

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 139

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL OLIVE PLANT
(365 Day Operating Season at 40 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	112	302	208	119	308	231	420
Unit Cost		85	240	120	90	245	180	335
Land Cost		6	2	58	6	2	6	2
Engr. & Cont.		21	60	30	23	61	45	83
TOTAL ANNUAL COST	-	40	107	41	52	119	81	148
Capital Recovery		17	49	24	18	50	36	68
O&M Cost		23	58	17	34	69	45	80
EFFLUENT QUALITY								
BOD5 (kg/kkg)	43.7	3.5	3.5	0.0	1.15	1.15	1.15	1.15
TSS (kg/kkg)	7.5	6.4	6.4	0.0	1.98	1.98	1.15	1.15

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 140

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANNED PEACH PLANT
(75 Day Operating Season at 197 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	188	502	322	196	510	358	672
Unit Cost		140	400	170	146	406	276	536
Land Cost		13	2	110	13	2	13	2
Engr. & Cont.		35	100	42	37	102	69	134
TOTAL ANNUAL COST	-	37	106	40	41	110	70	139
Capital Recovery		28	81	35	29	82	55	108
O&M Cost		9	25	5	12	28	15	31
EFFLUENT QUALITY								
BOD5 (kg/kkg)	14.1	1.2	1.2	0.0	0.51	0.51	0.51	0.51
TSS (kg/kkg)	2.3	2.2	2.2	0.0	0.88	0.88	0.51	0.51

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 141

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL FROZEN PEACH PLANT
(75 Day Operating Season at 476 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	188	502	322	196	510	358	672
Unit Cost		140	400	170	146	406	276	536
Land Cost		13	2	110	13	2	13	2
Engr. & Cont.		35	100	42	37	102	69	134
TOTAL ANNUAL COST	-	37	106	40	41	110	70	139
Capital Recovery		28	81	35	29	82	55	108
O&M Cost		9	25	5	12	28	15	31
EFFLUENT QUALITY								
BOD5 (kg/kkg)	11.7	0.5	0.5	0.0	0.26	0.26	0.26	0.26
TSS (kg/kkg)	1.9	1.1	1.1	0.0	0.31	0.31	0.26	0.26

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 142

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL PEAR PLANT
(60 Day Operating Season at 217 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	178	477	322	196	485	358	647
Unit Cost		140	380	170	146	386	276	516
Land Cost		13	2	110	13	2	13	2
Engr. & Cont.		35	95	42	37	97	69	129
TOTAL ANNUAL COST	-	35	98	39	38	101	67	130
Capital Recovery		28	78	35	29	79	55	105
O&M Cost		7	20	4	9	22	12	25
EFFLUENT QUALITY								
BOD5 (kg/kkg)	21.2	1.1	1.1	0.0	0.37	0.37	0.37	0.37
TSS (kg/kkg)	3.3	2.2	2.2	0.0	0.76	0.76	0.37	0.37

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 143

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL FRESH PICKLE PLANT
(110 Day Operating Season at 27 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	64	214	70	68	218	106	256
Unit Cost		48	170	50	51	173	81	203
Land Cost		4	2	8	4	2	4	2
Engr. & Cont.		12	42	12	13	43	21	51
TOTAL ANNUAL COST	-	15	50	13	18	53	26	61
Capital Recovery		10	35	10	11	36	17	42
O&M Cost		5	15	3	7	17	9	19
EFFLUENT QUALITY								
BOD5 (kg/kkg)	9.5	0.8	0.8	0.0	0.36	0.36	0.36	0.36
TSS (kg/kkg)	1.9	1.4	1.4	0.0	0.53	0.53	0.36	0.36

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 144

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL PROCESS PICKLE PLANT
(250 Day Operating Season at 63 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	119	290	110	124	295	186	357
Unit Cost		90	230	70	94	234	144	284
Land Cost		7	2	22	7	2	7	2
Engr. & Cont.		22	58	18	23	59	35	71
TOTAL ANNUAL COST	-	33	85	23	40	92	56	108
Capital Recovery		18	47	14	19	48	29	58
O&M Cost		15	38	9	21	44	27	50
EFFLUENT QUALITY								
BOD5 (kg/kkg)	18.4	0.9	0.9	0.0	0.32	0.32	0.32	0.32
TSS (kg/kkg)	3.3	1.8	1.8	0.0	0.61	0.61	0.32	0.32

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 145

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL PINEAPPLE PLANT
(210 Day Operating Season at 1,042 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	303	728	1,190	318	743	806	1,231
Unit Cost		220	580	530	232	592	622	982
Land Cost		28	8	530	28	8	28	8
Engr. & Cont.		55	140	130	58	143	156	241
TOTAL ANNUAL COST	-	76	220	150	101	245	206	350
Capital Recovery		45	120	110	47	122	127	202
O&M Cost		31	100	40	54	123	79	148
EFFLUENT QUALITY								
BOD5 (kg/kkg)	10.3	1.2	1.2	0.0	0.55	0.55	0.55	0.55
TSS (kg/kkg)	2.7	2.0	2.0	0.0	0.91	0.91	0.55	0.55

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 146

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL PLUM PLANT
(70 Day Operating Season at 53 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	57	202	76	61	206	99	244
Unit Cost		43	160	53	46	163	76	193
Land Cost		3	2	10	3	2	3	2
Engr. & Cont.		11	40	13	12	41	20	49
TOTAL ANNUAL COST	-	12	41	13	15	44	22	51
Capital Recovery		9	33	11	10	34	16	40
O&M Cost		3	8	2	5	10	6	11
EFFLUENT QUALITY								
BOD5 (kg/kkg)	4.1	0.4	0.4	0.0	0.15	0.15	0.15	0.15
TSS (kg/kkg)	0.4	0.8	0.8	0.0	0.22	0.22	0.15	0.15

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 147

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL RAISIN PLANT
(365 Day Operating Season at 149 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	64	202	95	68	206	118	256
Unit Cost		50	160	64	53	163	93	203
Land Cost		2	2	15	2	2	2	2
Engr. & Cont.		12	40	16	13	41	23	51
TOTAL ANNUAL COST	-	26	77	24	35	86	51	102
Capital Recovery		10	33	13	11	34	19	42
O&M Cost		16	44	11	24	52	32	60
EFFLUENT QUALITY								
BOD5 (kg/kkg)	6.1	0.3	0.3	0.0	0.11	0.11	0.11	0.11
TSS (kg/kkg)	1.6	0.6	0.6	0.0	0.28	0.28	0.11	0.11

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 148

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL STRAWBERRY PLANT
(35 Day Operating Season at 49 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	68	227	119	73	232	135	294
Unit Cost		52	180	75	56	184	106	234
Land Cost		3	2	25	3	2	3	2
Engr. & Cont.		13	45	19	14	46	26	58
TOTAL ANNUAL COST	-	13	42	16	15	44	26	55
Capital Recovery		11	37	15	12	38	22	48
O&M Cost		2	5	1	3	6	4	7
EFFLUENT QUALITY								
BOD5 (kg/kkg)	5.3	1.1	1.1	0.0	0.33	0.33	0.33	0.33
TSS (kg/kkg)	1.4	1.9	1.9	0.0	0.52	0.52	0.33	0.33

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 149

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL PEELED TOMATO PLANT
(90 Day Operating Season at 930 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	300	848	770	311	859	661	1,209
Unit Cost		220	670	360	229	679	509	959
Land Cost		25	8	320	25	8	25	8
Engr. & Cont.		55	170	90	57	172	127	242
TOTAL ANNUAL COST	-	59	180	85	68	189	133	254
Capital Recovery		45	140	73	47	142	104	199
O&M Cost		14	40	12	21	47	29	55
EFFLUENT QUALITY								
BOD5 (kg/kkg)	4.1	0.8	0.8	0.0	0.24	0.24	0.24	0.24
TSS (kg/kkg)	6.2	1.3	1.3	0.0	0.37	0.37	0.24	0.24

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 150

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL TOMATO PRODUCT PLANT
(90 Day Operating Season at 1,602 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	286	826	712	297	837	622	972
Unit Cost		210	660	330	219	669	479	739
Land Cost		24	6	300	24	6	24	6
Engr. & Cont.		52	160	82	54	162	119	227
TOTAL ANNUAL COST	-	55	164	78	63	172	122	231
Capital Recovery		43	130	67	45	132	97	184
O&M Cost		12	34	11	18	40	25	47
EFFLUENT QUALITY								
BOD5 (kg/kkg)	1.3	0.3	0.3	0.0	0.18	0.18	0.18	0.18
TSS (kg/kkg)	2.7	0.5	0.5	0.0	0.25	0.25	0.18	0.18

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 151

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL ASPARAGUS PLANT
(60 Day Operating Season at 33 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	110	264	276	118	271	268	421
Unit Cost		83	210	150	89	216	209	336
Land Cost		6	2	88	6	2	6	2
Engr. & Cont.		21	52	38	23	53	53	83
TOTAL ANNUAL COST	-	19	53	35	22	56	48	82
Capital Recovery		16	43	31	17	44	41	68
O&M Cost		3	10	4	5	12	7	14
EFFLUENT QUALITY								
BOD_5 (kg/kkg)	2.1	0.6	0.6	0.0	0.16	0.16	0.16	0.16
TSS (kg/kkg)	3.4	0.9	0.9	0.0	0.21	0.21	0.16	0.16

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 152

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL BEET PLANT
(120 Day Operating Season at 284 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	349	502	198	355	508	467	620
Unit Cost		270	400	100	275	405	365	495
Land Cost		11	2	60	11	2	11	2
Engr. & Cont.		68	100	28	69	101	91	123
TOTAL ANNUAL COST	-	75	111	26	80	116	102	138
Capital Recovery		55	81	20	56	82	74	100
O&M Cost		20	30	6	24	34	28	38
EFFLUENT QUALITY								
BOD5 (kg/kkg)	19.7	0.5	0.5	0.0	0.25	0.25	0.25	0.25
TSS (kg/kkg)	3.9	1.3	1.3	0.0	0.72	0.72	0.25	0.25

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 153

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL BROCCOLI PLANT
(270 Day Operating Season at 56 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	115	314	300	123	322	285	484
Unit Cost		87	250	160	93	256	223	386
Land Cost		6	2	100	6	2	6	2
Engr. & Cont.		22	62	40	24	64	56	96
TOTAL ANNUAL COST	-	36	102	49	47	113	84	150
Capital Recovery		17	51	33	18	52	44	78
O&M Cost		19	51	16	29	61	40	72
EFFLUENT QUALITY								
BOD5 (kg/kkg)	9.8	2.3	2.3	0.0	1.0	1.0	1.0	1.0
TSS (kg/kkg)	5.6	3.7	3.7	0.0	1.4	1.4	1.0	1.0

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 154

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL BRUSSELS SPROUT PLANT
(90 Day Operating Season at 102 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	148	354	412	157	363	369	575
Unit Cost		110	280	210	117	287	287	457
Land Cost		10	4	150	10	4	10	4
Engr. & Cont.		28	70	52	30	72	72	114
TOTAL ANNUAL COST	-	29	76	74	35	89	74	128
Capital Recovery		22	57	67	24	59	58	93
O&M Cost		7	19	7	11	30	16	35
EFFLUENT QUALITY								
BOD5 (kg/kkg)	3.4	0.8	0.8	0.0	1.0	1.0	1.0	1.0
TSS (kg/kkg)	10.8	1.3	1.3	0.0	1.3	1.3	1.0	1.0

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 155

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CARROT PLANT
(200 Day Operating Season at 109 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	125	364	188	131	370	243	482
Unit Cost		93	290	110	98	295	188	385
Land Cost		9	2	50	9	2	9	2
Engr. & Cont.		23	72	28	24	73	46	95
TOTAL ANNUAL COST	-	34	95	31	41	102	65	126
Capital Recovery		18	59	22	19	60	37	78
O&M Cost		16	36	9	22	42	28	48
EFFLUENT QUALITY								
BOD5 (kg/kkg)	19.5	1.1	1.1	0.0	0.5	0.5	0.5	0.5
TSS (kg/kkg)	12.0	2.2	2.2	0.0	1.0	1.0	0.5	0.5

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 156

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CAULIFLOWER PLANT
(180 Day Operating Season at 37 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	134	316	380	143	325	331	513
Unit Cost		100	250	200	107	257	257	407
Land Cost		9	4	130	9	4	9	4
Engr. & Cont.		25	62	50	27	64	65	102
TOTAL ANNUAL COST	-	32	85	55	41	94	81	134
Capital Recovery		20	51	41	22	53	53	84
O&M Cost		12	34	14	19	41	28	50
EFFLUENT QUALITY								
BOD5 (kg/kkg)	5.3	1.3	1.3	0.0	1.5	1.5	1.5	1.5
TSS (kg/kkg)	2.6	2.0	2.0	0.0	1.9	1.9	1.5	1.5

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 157

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANNED CORN PLANT
(70 Day Operating Season at 229 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	133	327	158	138	332	226	420
Unit Cost		100	260	94	104	264	174	334
Land Cost		8	2	40	8	2	8	2
Engr. & Cont.		25	65	24	26	66	44	84
TOTAL ANNUAL COST	-	26	66	22	29	69	45	85
Capital Recovery		20	54	19	21	55	35	69
O&M Cost		6	12	3	8	14	10	16
EFFLUENT QUALITY								
BOD5 (kg/kkg)	14.4	0.5	0.5	0.0	0.12	0.12	0.12	0.12
TSS (kg/kkg)	6.7	1.0	1.0	0.0	0.22	0.22	0.12	0.12

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 158

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL FROZEN CORN PLANT
(70 Day Operating Season at 77 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	133	327	158	138	332	226	420
Unit Cost		100	260	94	104	264	174	334
Land Cost		8	2	40	8	2	8	2
Engr. & Cont.		25	65	24	26	66	44	84
TOTAL ANNUAL COST	-	26	66	22	29	69	45	85
Capital Recovery		20	54	19	21	55	35	69
O&M Cost		6	12	3	8	14	10	16
EFFLUENT QUALITY								
BOD_5 (kg/kkg)	20.2	1.2	1.2	0.0	0.56	0.56	0.56	0.56
TSS (kg/kkg)	5.6	2.4	2.4	0.0	0.93	0.93	0.56	0.56

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 159

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL DEHYDRATED ONION AND GARLIC PLANT
(160 Day Operating Season at 228 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	215	524	455	225	534	463	772
Unit Cost		160	420	220	168	428	358	618
Land Cost		15	4	180	15	4	15	4
Engr. & Cont.		40	100	55	42	102	90	150
TOTAL ANNUAL COST	-	49	128	59	59	138	108	187
Capital Recovery		33	85	45	35	87	74	126
O&M Cost		16	43	14	24	51	34	61
EFFLUENT QUALITY								
BOD5 (kg/kkg)	6.5	1.6	1.6	0.0	0.59	0.59	0.59	0.59
TSS (kg/kkg)	5.9	2.4	2.4	0.0	0.87	0.87	0.59	0.59

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 160

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL DEHYDRATED VEGETABLE PLANT
(335 Day Operating Season at 149 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	184	429	368	193	438	380	612
Unit Cost		140	340	190	147	347	297	497
Land Cost		9	4	130	9	4	9	4
Engr. & Cont.		35	85	48	37	87	74	111
TOTAL ANNUAL COST	-	57	143	64	71	157	119	205
Capital Recovery		28	69	39	29	70	60	101
O&M Cost		29	74	25	42	87	59	104
EFFLUENT QUALITY								
BOD5 (kg/kkg)	7.9	1.9	1.9	0.0	0.9	0.9	0.9	0.9
TSS (kg/kkg)	5.7	2.9	2.9	0.0	1.3	1.3	0.9	0.9

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 161

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL DRY BEAN PLANT
(365 Day Operating Season at 21 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	85	227	92	89	231	139	281
Unit Cost		63	180	62	66	183	106	223
Land Cost		6	2	14	6	2	6	2
Engr. & Cont.		16	45	16	17	46	27	56
TOTAL ANNUAL COST		31	81	24	40	90	56	106
Capital Recovery		13	37	13	14	38	22	46
O&M Cost		18	44	11	26	52	34	60
EFFLUENT QUALITY								
BOD_5 (kg/kkg)	15.4	1.6	1.6	0.0	0.7	0.7	0.7	0.7
TSS (kg/kkg)	4.4	2.8	2.8	0.0	1.1	1.1	0.7	0.7

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 162

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL LIMA BEAN PLANT
(40 Day Operating Season at 79 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	149	340	258	155	346	293	472
Unit Cost		110	270	140	115	275	225	385
Land Cost		11	2	83	11	2	11	2
Engr. & Cont.		28	68	35	29	69	57	85
TOTAL ANNUAL COST	-	25	62	30	27	64	51	88
Capital Recovery		22	55	28	23	56	46	79
O&M Cost		3	7	2	4	8	5	9
EFFLUENT QUALITY								
BOD5 (kg/kkg)	13.9	2.4	2.4	0.0	0.9	0.9	0.9	0.9
TSS (kg/kkg)	10.4	4.0	4.0	0.0	1.3	1.3	0.9	0.9

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 163

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL MUSHROOM PLANT
(300 Day Operating Season at 12 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	62	177	76	68	181	106	221
Unit Cost		47	140	53	50	143	82	175
Land Cost		3	2	10	3	2	3	2
Engr. & Cont.		12	35	13	13	36	21	44
TOTAL ANNUAL COST	-	22	61	19	30	69	43	82
Capital Recovery		10	28	11	11	29	18	36
O&M Cost		12	33	8	19	40	25	46
EFFLUENT QUALITY								
BOD5 (kg/kkg)	8.7	1.9	1.9	0.0	0.63	0.63	0.63	0.63
TSS (kg/kkg)	4.8	3.2	3.2	0.0	0.95	0.95	0.63	0.63

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 164

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANNED ONION PLANT
(300 Day Operating Season at 13 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	56	214	81	60	218	103	261
Unit Cost		43	170	56	46	173	80	207
Land Cost		2	2	11	2	2	2	2
Engr. & Cont.		11	42	14	12	43	21	52
TOTAL ANNUAL COST	-	24	74	19	32	82	45	95
Capital Recovery		9	35	11	10	36	17	43
O&M Cost		15	39	8	22	46	28	52
EFFLUENT QUALITY								
BOD5 (kg/kkg)	22.6	2.1	2.1	0.0	0.9	0.9	0.9	0.9
TSS (kg/kkg)	9.4	3.7	3.7	0.0	1.7	1.7	0.9	0.9

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 165

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANNED PEA PLANT
(80 Day Operating Season at 75 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	130	314	195	136	320	248	432
Unit Cost		98	250	110	103	255	193	345
Land Cost		8	2	57	8	2	8	2
Engr. & Cont.		24	62	28	25	63	47	85
TOTAL ANNUAL COST	-	26	65	26	29	68	49	88
Capital Recovery		20	51	22	21	52	39	70
O&M Cost		6	14	4	8	16	10	18
EFFLUENT QUALITY								
BOD5 (kg/kkg)	22.1	1.8	1.8	0.0	0.7	0.7	0.7	0.7
TSS (kg/kkg)	5.4	3.3	3.3	0.0	1.3	1.3	0.7	0.7

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 166

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL FROZEN PEA PLANT
(80 Day Operating Season at 102 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	130	314	195	136	320	248	432
Unit Cost		98	250	110	103	255	193	345
Land Cost		8	2	57	8	2	8	2
Engr. & Cont.		24	62	28	25	63	47	85
TOTAL ANNUAL COST	-	26	65	26	29	68	49	88
Capital Recovery		20	51	22	21	52	39	70
O&M Cost		6	14	4	8	16	10	18
EFFLUENT QUALITY								
BOD5 (kg/kkg)	18.3	1.3	1.3	0.0	0.54	0.54	0.54	0.54
TSS (kg/kkg)	4.9	2.5	2.5	0.0	0.93	0.93	0.54	0.54

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 167

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL PIMENTO PLANT
(100 Day Operating Season at 17 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	76	227	102	80	231	132	283
Unit Cost		58	180	67	61	183	103	225
Land Cost		4	2	18	4	2	4	2
Engr. & Cont.		14	45	17	15	46	25	56
TOTAL ANNUAL COST	-	18	51	17	21	54	32	65
Capital Recovery		12	37	14	13	38	22	47
O&M Cost		6	14	3	8	16	10	18
EFFLUENT QUALITY								
BOD5 (kg/kkg)	27.3	2.6	2.6	0.0	1.3	1.3	1.3	1.3
TSS (kg/kkg)	2.9	4.6	4.6	0.0	2.0	2.0	1.3	1.3

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 168

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL SAUERKRAUT CANNING PLANT
(365 Day Operating Season at 43 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	77	190	61	81	194	112	225
Unit Cost		56	150	45	59	153	84	178
Land Cost		7	2	5	7	2	7	2
Engr. & Cont.		14	38	11	15	39	21	45
TOTAL ANNUAL COST	-	26	71	17	34	79	45	90
Capital Recovery		11	31	9	12	32	17	37
O&M Cost		15	40	8	22	47	28	53
EFFLUENT QUALITY								
BOD5 (kg/kkg)	3.5	0.3	0.3	0.0	0.14	0.14	0.14	0.14
TSS (kg/kkg)	0.6	0.6	0.6	0.0	0.26	0.26	0.14	0.14

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 169

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL SAUERKRAUT CUTTING PLANT
(60 Day Operating Season at 175 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	37	164	53	40	167	65	192
Unit Cost		27	130	40	29	132	49	152
Land Cost		3	2	3	3	2	3	2
Engr. & Cont.		7	32	10	8	33	13	38
TOTAL ANNUAL COST	-	8	32	9	10	34	15	39
Capital Recovery		6	26	8	7	27	11	31
O&M Cost		2	6	1	3	7	4	8
EFFLUENT QUALITY								
BOD5 (kg/kkg)	1.2	0.1	0.1	0.0	0.02	0.02	0.02	0.02
TSS (kg/kkg)	0.2	0.1	0.1	0.0	0.04	0.04	0.02	0.02

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 170

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANNED SNAP BEAN PLANT
(70 Day Operating Season at 96 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	90	252	195	96	258	208	370
Unit Cost		68	200	110	73	205	163	295
Land Cost		5	2	57	5	2	5	2
Engr. & Cont.		17	50	28	18	51	40	73
TOTAL ANNUAL COST	-	18	51	25	21	54	41	74
Capital Recovery		14	41	22	15	42	33	60
O&M Cost		4	10	3	6	12	8	14
EFFLUENT QUALITY								
BOD_5 (kg/kkg)	3.1	0.8	0.8	0.0	0.49	0.49	0.49	0.49
TSS (kg/kkg)	2.0	1.2	1.2	0.0	0.66	0.66	0.49	0.49

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 171

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL FROZEN SNAP BEAN PLANT
(70 Day Operating Season at 93 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	90	252	195	96	258	208	370
Unit Cost		68	200	110	73	205	163	295
Land Cost		5	2	57	5	2	5	2
Engr. & Cont.		17	50	28	18	51	40	73
TOTAL ANNUAL COST	-	18	51	25	21	54	41	74
Capital Recovery		14	41	22	15	42	33	60
O&M Cost		4	10	3	6	12	8	14
EFFLUENT QUALITY								
BOD5 (kg/kkg)	6.1	1.4	1.4	0.0	0.67	0.67	0.67	0.67
TSS (kg/kkg)	3.0	2.3	2.3	0.0	0.99	0.99	0.67	0.67

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 172

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANNED SPINACH PLANT
(180 Day Operating Season at 68 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	117	302	322	125	310	287	472
Unit Cost		88	240	170	94	246	224	376
Land Cost		7	2	110	7	2	7	2
Engr. & Cont.		22	60	42	24	62	56	94
TOTAL ANNUAL COST	-	30	81	47	37	88	71	122
Capital Recovery		18	49	35	19	50	45	76
O&M Cost		12	32	12	18	38	26	46
EFFLUENT QUALITY								
BOD5 (kg/kkg)	8.2	2.0	2.0	0.0	0.53	0.53	0.53	0.53
TSS (kg/kkg)	6.5	3.1	3.1	0.0	0.76	0.76	0.53	0.53

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 173

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL FROZEN SPINACH PLANT
(180 Day Operating Season at 88 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	117	302	322	125	310	287	472
Unit Cost		88	240	170	94	246	224	376
Land Cost		7	2	110	7	2	7	2
Engr. & Cont.		22	60	42	24	62	56	94
TOTAL ANNUAL COST	-	30	81	47	37	88	71	122
Capital Recovery		18	49	35	19	50	45	76
O&M Cost		12	32	12	18	38	26	46
EFFLUENT QUALITY								
BOD5 (kg/kkg)	4.8	1.1	1.1	0.0	0.65	0.65	0.65	0.65
TSS (kg/kkg)	2.0	1.8	1.8	0.0	0.88	0.88	0.65	0.65

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 174

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL SQUASH PLANT
(70 Day Operating Season at 216 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	116	327	172	122	333	222	433
Unit Cost		88	260	100	93	265	173	345
Land Cost		6	2	47	6	2	6	2
Engr. & Cont.		22	65	25	23	66	43	86
TOTAL ANNUAL COST	-	23	64	23	26	67	44	85
Capital Recovery		18	53	20	19	54	35	70
O&M Cost		5	11	3	7	13	9	15
EFFLUENT QUALITY	-							
BOD5 (kg/kkg)	16.8	0.6	0.6	0.0	0.16	0.16	0.16	0.16
TSS (kg/kkg)	2.3	1.3	1.3	0.0	0.30	0.30	0.16	0.16

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 175

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL SWEET POTATO PLANT
(100 Day Operating Season at 228 kkg/day)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	435	712	149	440	717	521	798
Unit Cost		340	570	90	344	574	409	639
Land Cost		10	2	37	10	2	10	2
Engr. & Cont.		85	140	22	86	141	102	157
TOTAL ANNUAL COST	-	88	152	22	92	156	108	172
Capital Recovery		69	120	18	70	121	83	134
O&M Cost		19	32	4	22	35	25	38
EFFLUENT QUALITY								
BOD5 (kg/kkg)	30.1	0.5	0.5	0.0	0.26	0.26	0.26	0.26
TSS (kg/kkg)	11.5	1.5	1.5	0.0	0.86	0.86	0.26	0.26

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 176

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CANNED WHITE POTATO PLANT
(150 Day Operating Season at 59 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	312	452	100	316	456	368	508
Unit Cost		240	360	64	243	363	285	405
Land Cost		12	2	20	12	2	12	2
Engr. & Cont.		60	90	16	61	91	71	101
TOTAL ANNUAL COST	-	64	101	18	68	105	80	117
Capital Recovery		49	73	13	50	74	59	83
O&M Cost		15	28	5	18	31	21	34
EFFLUENT QUALITY								
BOD5 (kg/kkg)	27.3	0.9	0.9	0.0	0.26	0.26	0.26	0.26
TSS (kg/kkg)	37.4	1.9	1.9	0.0	0.80	0.80	0.26	0.26

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 177

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL BABY FOOD PLANT
(365 Day Operating Season at 246 kkg/day)
(Costs based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	218	379	247	224	385	349	510
Unit Cost		160	300	130	165	305	265	405
Land Cost		18	4	85	18	4	18	4
Engr. & Cont.		40	75	32	41	76	66	101
TOTAL ANNUAL COST	-	58	127	46	70	139	103	172
Capital Recovery		33	61	26	34	62	54	82
O&M Cost		25	66	20	36	77	49	90
EFFLUENT QUALITY								
BOD5 (kg/kkg)	4.6	0.7	0.7	0.0	0.27	0.27	0.27	0.27
TSS (kg/kkg)	1.6	1.1	1.1	0.0	0.44	0.44	0.27	0.27

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 178

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL CORN CHIP PLANT
(365 Day Operating Season at 35 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	124	314	92	128	318	178	368
Unit Cost		90	250	62	93	253	133	293
Land Cost		12	2	14	12	2	12	2
Engr. & Cont.		22	62	16	23	63	33	73
TOTAL ANNUAL COST	-	41	101	24	50	110	66	126
Capital Recovery		20	50	13	21	51	29	59
O&M Cost		21	51	11	29	59	37	67
EFFLUENT QUALITY								
BOD5 (kg/kkg)	35.2	1.2	1.2	0.0	0.7	0.7	0.7	0.7
TSS (kg/kkg)	30.0	2.7	2.7	0.0	1.4	1.4	0.7	0.7

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 179

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL POTATO CHIP PLANT
(365 Day Operating Season at 11 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	92	290	76	96	294	134	332
Unit Cost		67	230	53	70	233	100	263
Land Cost		8	2	10	8	2	8	2
Engr. & Cont.		17	58	13	18	59	26	67
TOTAL ANNUAL COST	-	32	98	21	41	107	55	121
Capital Recovery		14	47	11	15	48	21	54
O&M Cost		18	51	10	26	59	34	67
EFFLUENT QUALITY								
BOD5 (kg/kkg)	37.0	2.2	2.2	0.0	0.9	0.9	0.9	0.9
TSS (kg/kkg)	42.2	4.2	4.2	0.0	1.6	1.6	0.9	0.9

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 180

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL TORTILLA CHIP PLANT
(365 Day Operating Season at 20 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	124	314	92	128	318	178	368
Unit Cost		90	250	62	93	253	133	293
Land Cost		12	2	14	12	2	12	2
Engr. & Cont.		22	62	16	23	63	33	73
TOTAL ANNUAL COST	-	41	101	24	50	110	66	126
Capital Recovery		20	50	13	21	51	29	59
O&M Cost		21	51	11	29	59	37	67
EFFLUENT QUALITY								
BOD5 (kg/kkg)	29.7	1.9	1.9	0.0	1.0	1.0	1.0	1.0
TSS (kg/kkg)	36.1	3.6	3.6	0.0	1.7	1.7	1.0	1.0

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 181

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL ETHNIC FOOD PLANT
(365 Day Operating Season at 82 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	138	314	163	144	320	244	420
Unit Cost		100	250	95	105	255	185	335
Land Cost		13	2	44	13	2	13	2
Engr & Cont.		25	62	24	26	63	46	83
TOTAL ANNUAL COST	-	41	106	34	52	117	79	144
Capital Recovery		20	51	19	21	52	37	68
O&M Cost		21	55	15	31	65	42	76
EFFLUENT QUALITY								
BOD5 (kg/kkg)	6.8	1.1	1.1	0.0	0.44	0.44	0.44	0.44
TSS (kg/kkg)	2.4	1.9	1.9	0.0	0.70	0.70	0.44	0.44

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 182

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL JAM & JELLY PLANT
(365 Day Operating Season at 29 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	64	202	53	67	205	92	230
Unit Cost		49	160	40	51	162	71	182
Land Cost		3	2	3	3	2	3	2
Engr. & Cont.		12	40	10	13	41	18	46
TOTAL ANNUAL COST	-	24	73	15	32	81	42	91
Capital Recovery		10	33	8	11	34	15	38
O&M Cost		14	40	7	21	47	27	53
EFFLUENT QUALITY								
BOD5 (kg/kkg)	5.9	0.3	0.3	0.0	0.12	0.12	0.12	0.12
TSS (kg/kkg)	1.0	0.5	0.5	0.0	0.27	0.27	0.12	0.12

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 183

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL MAYONNAISE & SALAD DRESSING PLANT
(365 Day Operating Season at 165 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	130	327	92	134	331	184	381
Unit Cost		94	260	62	97	263	137	303
Land Cost		12	2	14	12	2	12	2
Engr. & Cont.		24	65	16	25	66	35	76
TOTAL ANNUAL COST	-	41	115	21	50	124	66	140
Capital Recovery		19	53	10	20	54	28	62
O&M Cost		22	62	11	30	70	38	78
EFFLUENT QUALITY								
BOD5 (kg/kkg)	5.5	0.2	0.2	0.0	0.13	0.13	0.13	0.13
TSS (kg/kkg)	2.6	0.5	0.5	0.0	0.28	0.28	0.13	0.13

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 184

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL SOUP PLANT
(365 Day Operating Season at 618 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	840	1,820	1,560	858	1,838	1,478	2,458
Unit Cost		560	1,450	660	574	1,464	1,074	1,964
Land Cost		140	10	740	140	10	140	10
Engr. & Cont.		140	360	160	144	364	264	484
TOTAL ANNUAL COST	-	209	550	221	263	604	418	759
Capital Recovery		110	290	130	113	293	213	393
O&M Cost		99	260	91	150	311	205	366
EFFLUENT QUALITY								
BOD5 (kg/kkg)	14.9	2.7	2.7	0.0	1.4	1.4	1.4	1.4
TSS (kg/kkg)	9.8	4.5	4.5	0.0	2.2	2.2	1.4	1.4

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

TABLE 185

ESTIMATED TREATMENT COSTS ($1000) FOR A TYPICAL
TOMATO-STARCH-CHEESE CANNED SPECIALITIES PLANT
(365 Day Operating Season at 37 kkg/day)
(Costs Based on Cold Temperature Conditions)

	TREATMENT ALTERNATIVE							
	A	B	C	D	E	F	G	H
TOTAL CAPITAL COST	-	134	264	130	139	269	208	338
Unit Cost		100	210	80	104	214	159	269
Land Cost		9	2	30	9	2	9	2
Engr. & Cont.		25	52	20	26	53	40	67
TOTAL ANNUAL COST	-	40	94	30	50	104	70	124
Capital Recovery		20	43	16	21	44	32	55
O&M Cost		20	51	14	29	60	38	69
EFFLUENT QUALITY								
BOD5 (kg/kkg)	4.8	1.1	1.1	0.0	0.45	0.45	0.45	0.45
TSS (kg/kkg)	2.6	1.8	1.8	0.0	0.65	0.65	0.45	0.45

ALTERNATIVE A: Screening
ALTERNATIVE B: Average Aerated Lagoon Treatment and In-plant Controls
ALTERNATIVE C: Average Activated Sludge Treatment and In-plant Controls
ALTERNATIVE D: Land Treatment via Spray Irrigation
ALTERNATIVE E: Improved Aerated Lagoon Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE F: Improved Activated Sludge Treatment Plus Additional In-plant Controls Plus Chlorination
ALTERNATIVE G: Alternative E Plus Multi-Media Filtration
ALTERNATIVE H: Alternative F Plus Multi-Media Filtration

Aerated Lagoon

Cost estimates for each model plant (Table 130-185) for the aerated lagoon treatment alternatives (B, E and G) were taken directly from the total capital cost curves (Table 96) and the operation and maintenance tabulation (Table 97) developed earlier in the aerated lagoon cost section.

For all subcategories except sweet and white potatoes, the aerated lagoons were the only treatment module used in costing this alternative. Due to the high suspended solids and BOD_5 of sweet and white potato processing wastewater, however, it was necessary to add primary settling and vacuum filtration to the white potato chain and primary settling, a roughing filter, vacuum filtration, and increased aeration basin retention time to the sweet potato chain. The purpose of this additional primary treatment was to reduce the BOD_5 and TSS concentrations in the influent to the aerated lagoon. The vacuum filter was necessary to handle the solids from the gravity settling operation.

Activated Sludge

The activated sludge treatment alternatives (C, F and H) listed in Tables 130-185 consisted of a core of five treatment modules (activated sludge aeration basin, secondary clarifier, emergency retention pond, aerobic digestor, and sludge handling) to which one or more of the following modules could be added, depending on the subcategory raw wasteload characteristics: primary gravity settling, air flotation, nutrient addition, and/or trickling filtration.

For each treatment module, costs were taken directly from the capital cost curves and operation and maintenance tabulations found in the corresponding subsections of Section VIII for the appropriate flow volume, TSS, or BOD_5 concentration to the unit. Following are general descriptions of the major design considerations and assumptions made in costing individual modules for treatment chains for each subcategory.

- Primary Treatment. Primary treatment was comprised of either gravity sedimentation or dissolved air flotation. Gravity settling was assumed required when the raw wastewater TSS concentration exceeded 800 mg/l. Settling was replaced by air flotation for those commodities with significant oil and grease concentrations in their raw wastewater. It was assumed that either gravity settling or air flotation removed 30 percent of the incoming BOD_5 and 70 percent of the incoming TSS. Solids removed by primary treatment were pumped directly to the vacuum filtration unit, bypassing the aerobic digestor.

- Trickling Filter. A plastic media trickling filter was utilized as a "roughing" filter in situations where the influent BOD_5 to the aeration basin would have exceeded 2,000 mg/l. If primary treatment was necessary and in itself reduced the BOD_5 to below 2,000 mg/l, then the roughing filter was not used. It was assumed that the roughing filter achieved a 30 percent reduction in BOD_5 while the TSS concentration was not affected.

- Aeration Basin. Long-term (1.0 to 3.0 day retention time), completely mixed aeration basins were the heart of the activated sludge treatment chain. It was assumed that the combination of aeration basin and secondary clarifier, effectively removed 85 to 90 percent of the incoming BOD_5 for weak wastes (less than 500 mg/l BOD_5) and up to 98 percent for strong wastes with raw waste BOD_5 concentrations of up to 7,500 mg/l. (BOD_5 removal discussion was presented in Section VII.) As previously discussed, the strong waste treatment chain often included primary and roughing filter treatment to aid in the BOD_5 and TSS reduction.

- Secondary Clarification. The secondary clarifier was included in every activated sludge treatment chain. The clarifier was sized and loaded according to the excess solids concentration coming from the aeration basin. The return activated sludge MLVSS recirculation from clarifier to aeration basin was assumed as a constant factor to which the effect of varying wastewater solids loads were added to effectively size the clarification system. Wasted solids (sludge) from the secondary clarifier to the aerobic digestor were assumed to equal 60 percent by weight of the BOD_5 entering the aeration basin and 100 percent by weight of the TSS entering the aeration basin.

- Aerobic Digestion. The aerobic digestors were included in every activated sludge treatment chain and were sized to provide an ultimate 40 percent destruction of volatile solids over a 15-day retention period. The solids load into the digestor was computed as the waste sludge from the secondary clarifier (as described above) plus the solids removed by the dissolved air flotation unit, if one was included in the treatment chain.

- Solids Handling. Solids handling followed the aerobic digestor on each activated sludge treatment chain. Sufficient allowance in cost has been made to cover land disposal of digested and/or primary sludge, or vacuum filtration where required.

- Aerated Polishing Pond. The aerated polishing pond with two-day retention received the effluent from the secondary clarifier and served as a safety factor to stabilize or "polish" the final effluent should any upsets of the biological treatment system occur. No additional BOD_5 removal was credited to the aerated polishing pond.

Multi-Media Filtration

Cost estimates for each subcategory (Tables 130-185) for the multi-media filtration were taken directly from the capital cost curve (Figure 66) and the operation and maintenance tabulation (Table 117).

Chlorination

Cost estimates for each subcategory (Tables 130-185) for chlorination were taken directly from the capital cost curve (Table 119) and the operation and maintenance tabulation (Table 120).

MULTI-PRODUCT PLANT TREATMENT COSTS

The majority of the fruits and vegetables plants process more than one commodity during the year, and often, more than one commodity concurrently.

Two models are developed in this section to demonstrate costing of aerated lagoon, activated sludge and spray irrigation treatment facilities (Alternatives B, C and D) for multi-product plants. The first model consists of a plant that processes peas and corn consecutively; the second, of a plant that processes peas followed by corn and lima beans run concurrently. The listing below displays the process seasons.

First plant: Peas - 80 days, then corn - 70 days

Second plant: Peas - 80 days, then corn and lima beans - 40 days, then corn only - 40 days.

The general procedure for costing the wastewater treatment facilities for multi-product plants was to design for the strongest waste in terms of BOD_5, TSS, and flow. Tables 186 and 187 present a breakdown of this procedure for the two model plants. As shown in the tables for the "Corn and Pea" plant, different elements of the treatment chains were dependent on which system was more complex. For example, the irrigation and aerated lagoon systems for peas were used for the "Corn and Pea" plant while a mixture of corn and pea components was used to cost activated sludge for the multi-product plant. The second model (pea and corn and lima bean) shows that the heaviest waste load occurs when corn and lima beans were processed concurrently. Therefore, the treatment facility was designed for the combined corn and lima beans flow, BOD_5, and TSS. It should be pointed out that the aeration basin for lima beans and corn is sufficient so that a roughing filter is not needed for the multi-product "corn only" processing plant.

TABLE 186

ESTIMATED TREATMENT COSTS BASED ON SPRAY IRRIGATION, AERATED LAGOON, OR ACTIVATED SLUDGE TREATMENT FOR TYPICAL CASE, PEAS AND CORN

Average Daily Volume (mgd) 0.39(P),0.27(C)
Operating Season June to Oct = 150 days
Nutrient Deficient: yes ___ no X
pH Control: yes ___ no X

Average Raw Waste Loads Parameters

BOD (mg/l)	TSS (mg/l)
810 (P)	230 (P)
1800 (C)	560 (C)

A. CAPITAL AND LAND COSTS

Unit Process Influ. Conc. BOD mg/l SS mg/l	Treatment Chain	Design Parameter Unit	Design Parameter Quan.	Unit Cap'l Cost $1,000	Land Cost $1,000	Engr. and Cont. $1,000	Total Cap'l Cost $1,000
PEAS	1. Spray Irrigation	mgd	0.39	90	60	22	170
PEAS	2. Aerat. Lagoon	days	20	98	8	24	130
CORN & PEAS	3. Activated Sludge			290	2	72	360
	a. pH Control	mgd					
	b. Prim. Settling	gpd/sq ft					
	c. Dis. Air Flot.	TSS					
	d. Nutrient Add.	mgd					
CORN	e. Roughing Filter	gpd/sq ft	800	22			
CORN	f. Aeration Basins	days	2.0	83			
PEAS	g. Final Clarifier	gpd/sq ft	400	70			
CORN	h. Aer. Digestor	TSS mg/l	1200	56			
CORN	i. Vacuum Filter	TSS mg/l	720	39			
PEAS	j. Aer. Pol. Pond	mgd	0.39	23			
PEAS	4. Multi-Med. Filt.	mgd	0.39	90	-	22	110
PEAS	5. Chlorination	mgd	0.39	5	-	1.2	6.2

TABLE 186 - (Continued)

B. OPERATION AND MAINTENANCE COST

PEAS Treatment Chain	Cost Parameter Unit	 Quan.	Est. Daily O & M Cost $/day	Est. Oper. Season Days	Tot. An'l O. & M Cost $1,000
1. Spray Irrigation	mgd	0.39	46	80	3.7
2. Aerated Lagoon	mgd	"	70	"	5.6
3. Activated Sludge			190	"	15
a. pH Control	mgd				
b. Primary Settling	mgd				
c. Dis. Air Flot.	mgd				
d. Nutrient Addition	BOD				
e. Roughing Filter	mgd				
f. Aeration Basins	mgd	"	70		
g. Final Clarifier	mgd	"	22		
h. Aerobic Digestor	mgd	"	36		
i. Vacuum Filter	mgd	"	34		
j. Aerated Polishing Pond	mgd	"	28		
4. Multi-Media Filter	mgd	"	30	"	2.4
5. Chlorination	mgd	"	30	"	2.4

TABLE 186 (Continued)

B. OPERATION AND MAINTENANCE COST

CORN Treatment Chain	Cost Parameter Unit	 Quan.	Est Daily O & M Cost $/day	Est. Oper. Season Days	Tot. An'l O & M Cost $1,000
1. Spray Irrigation	mgd	0.27	38	70	2.7
2. Aerated Lagoon	mgd	"	60	"	4.2
3. Activated Sludge			190	"	13
a. pH Control	mgd				
b. Primary Settling	mgd				
c. Dis. Air Flot.	mgd				
d. Nutrient Addition	BOD				
e. Roughing Filter	mgd	"	25		
f. Aeration Basins	mgd	"	60		
g. Final Clarifier	mgd	"	18		
h. Aerobic Digestor	mgd	"	30		
i. Vacuum Filter	mgd	"	29		
j. Aerated Polishing Pond	mgd	"	25		
4. Multi-Media Filter	mgd	"	26	"	1.8
5. Chlorination	mgd	"	27	"	1.9

C. TOTAL ESTIMATED ANNUAL TREATMENT COST

PEAS & CORN Treatment Chain	Annual Capital Recovery $1,000	Annual O & M $1,000	Total Annual Cost $1,000
1. Spray Irrigation	18	6.4	24
2. Aerated Lagoon	21	9.8	31
3. Activated Sludge	58	31	89
4. Multi-Media	18	4.2	22
5. Chlorination	1.0	4.3	5.3

TABLE 187

ESTIMATED TREATMENT COSTS BASED ON SPRAY IRRIGATION, AERATED LAGOON, OR ACTIVATED SLUDGE TREATMENT FOR TYPICAL CASE, PEAS & CORN & LIMA BEANS

Average Daily Volume (mgd) 0.39(P), 0.27(C), 0.84(C&LB)
Operating Season June to Oct = 150 days
Nutrient Deficient: yes ___ no X
pH Control: yes ___ no X

Average Raw Waste Loads Parameters	
BOD (mg/l)	TSS (mg/l)
810(P)	230(P)
1800(C)	560(C)
790(C&LB)	330(C&LB)

A. CAPITAL AND LAND COSTS

Unit Process Influ. Conc. BOD mg/l	SS mg/l	Treatment Chain	Design Parameter Unit	Quan.	Unit Cap'l Cost $1,000	Land Cost $1,000	Engr. and Cont. $1,000	Total Cap'l Cost $1,000
CORN & LIMA		1. Spray Irrigation	mgd	0.84	150	120	38	310
CORN & LIMA		2. Aerat. Lagoon	days	20	160	15	40	220
		3. Activated Sludge			360	4	90	450
		a. pH Control	mgd					
		b. Prim. Settling	gpd/sq ft					
		c. Dis. Air Flot.	TSS					
		d. Nutrient Add.	mgd	(1)				
		e. Roughing Filter	gpd/sq ft					
CORN & LIMA		f. Aeration Basins	days	1.5	120			
"		g. Final Clarifier	gpd/sq ft	400	90			
"		h. Aer. Digestor	TSS mg/l	590	73			
"		i. Vacuum Filter	TSS mg/l	350	45			
"		j. Aer. Pol. Pond	mgd	0.84	31			
CORN & LIMA		4. Multi-Med. Filt.	mgd	0.84	140	-	35	180
"		5. Chlorination	mgd	0.84	6.5	-	1.6	8.1

(1) Though roughing filter would be needed for "corn only" processing plant, the aeration system designed to handle the added flow from lima beans can sufficiently remove the BOD from "corn only" processing without the use of a roughing filter.

TABLE 187 (Continued)

B. OPERATION AND MAINTENANCE COST

CORN Treatment Chain	Cost Parameter Unit	Quan.	Est. Daily O & M Cost $/day	Est. Oper. Season Days	Tot. An'l O. & M Cost $1,000
1. Spray Irrigation	mgd	0.27	38	30	1.1
2. Aerated Lagoon	mgd	"	60	"	1.8
3. Activated Sludge			160	"	4.8
a. pH Control	mgd				
b. Primary Settling	mgd				
c. Dis. Air Flot.	mgd				
d. Nutrient Addition	BOD				
e. Roughing Filter	mgd				
f. Aeration Basins	mgd	"	60		
g. Final Clarifier	mgd	"	18		
h. Aerobic Digestor	mgd	"	30		
i. Vacuum Filter	mgd	"	29		
j. Aerated Polishing Pond	mgd	"	25		
4. Multi-Media Filter	mgd	"	26	"	0.8
5. Chlorination	mgd	"	27	"	0.8

TABLE 187 (Continued)

B. OPERATION AND MAINTENANCE COST

PEAS Treatment Chain	Cost Parameter Unit	 Quan.	Est. Daily O & M Cost $/day	Est. Oper. Season Days	Tot. An'l O. & M Cost $1,000
1. Spray Irrigation	mgd	0.39	46	80	3.7
2. Aerated Lagoon	mgd	"	70	"	5.6
3. Activated Sludge			220	"	18
a. pH Control	mgd				
b. Primary Settling	mgd				
c. Dis. Air Flot.	mgd				
d. Nutrient Addition	BOD				
e. Roughing Filter	mgd		27		
f. Aeration Basins	mgd	"	70		
g. Final Clarifier	mgd	"	22		
h. Aerobic Digestor	mgd	"	36		
i. Vacuum Filter	mgd	"	34		
j. Aerated Polishing Pond	mgd	"	28		
4. Multi-Media Filter	mgd	"	30	"	2.4
5. Chlorination	mgd	"	30	"	2.4

TABLE 187 (Continued)

B. OPERATION AND MAINTENANCE COST

CORN & LIMA BEANS Treatment Chain	Cost Parameter Unit	Quan.	Est. Daily O & M Cost $/day	Est. Oper. Season Days	Tot. An'l O & M Cost $1,000
1. Spray Irrigation	mgd	0.84	70	40	2.8
2. Aerated Lagoon	mgd	"	100	"	4.0
3. Activated Sludge			260	"	10
a. pH Control	mgd				
b. Primary Settling	mgd				
c. Dis. Air Flot.	mgd				
d. Nutrient Addition	BOD				
e. Roughing Filter	mgd				
f. Aeration Basins	mgd	"	93		
g. Final Clarifier	mgd	"	31		
h. Aerobic Digestor	mgd	"	52		
i. Vacuum Filter	mgd	"	47		
j. Aerated Polishing Pond	mgd	"	38		
4. Multi-Media Filter	mgd	"	48	"	1.9
5. Chlorination	mgd	"	40	"	1.6

C. TOTAL ESTIMATED ANNUAL TREATMENT COST

PEAS & CORN & LIMA BEANS Treatment Chain	Annual Capital Recovery $1,000	Annual O & M $1,000	Total Annual Cost $1,000
1. Spray Irrigation	31	7.6	39
2. Aerated Lagoon	33	11	44
3. Activated Sludge	73	30	100
4. Multi-Media	29	5.1	34
5. Chlorination	1.3	4.8	6.1

TABLE 188
ESTIMATED TOTAL CAPITAL COST FOR SINGLE AND MULTI-PRODUCT MODEL PLANTS

PLANT COMMODITIES	TOTAL CAPITAL COST ($1,000)		
	Spray Irrigation	Aerated Lagoons	Activated Sludge
Peas	$170	$130	$330
Corn	$140	$120	$350
Lima Beans	$230	$130	$350
Peas & Corn	$170	$130	$360
Peas & Corn Lima Beans	$310	$220	$450

TABLE 189
ESTIMATED TOTAL ANNUAL COSTS FOR SINGLE AND MULTI-PRODUCT MODEL PLANTS

PLANT COMMODITIES	TOTAL ANNUAL COST ($1,000)		
	Spray Irrigation	Aerated Lagoons	Activated Sludge
Peas	22	26	68
Corn	19	22	70
Lima Beans	24	23	63
Peas & Corn	24	31	89
Peas & Corn Lima Beans	39	44	100

Table 188 summarizes the total capital costs for the three basic treatment alternatives (B, C and D) for typical pea, corn, pea and corn, and pea and corn and lima bean model plants. Table 189 summarizes the total annual cost for the same model plants.

ENERGY REQUIREMENTS

Electrical energy is required to treat food processing wastes primarily for aeration and pumping. The aeration horsepower is a function of the wasteload, and the horsepower for pumping depends on wastewater flow rate.

The differences that exist in raw waste loads between subcategories result in highly variable electrical demands for treatment chains for the various subcategories. Cost estimates for electrical consumption for each treatment module are presented in the respective operation and maintenance cost tabulations earlier in Section VIII of this document. Electrical consumption for each treatment chain can be computed for each of the subcategories as follows:

- The operation and maintenance cost tabulations for each treatment module in Section VIII show the cost of energy for that module.

- Commodity cost tables (Tables 130-185) show the modules included within alternative treatment chains for each of the subcategories and the length of the processing season.

- Using these two sets of tables, the electrical cost for various treatment chains for each of the subcategories can be computed.

- The electrical demand in terms of KWH can be computed for alternative treatment chains by dividing the total energy costs by the unit cost of $0.02 per KWH.

Table 190 shows comparative daily energy costs for the three treatment chains for a medium strength waste. Generally, spray irrigation energy costs are about one-third the energy costs of aerated lagoons and one-fifth the energy costs of activated sludge treatment. Since the spray irrigation energy costs remain essentially the same regardless of waste strength, the energy cost of spray irrigation compared to biological treatment increases with reduced waste strength and decreases with higher waste strength.

SOLID WASTES

The handling, reuse, and/or disposal of solid residuals are important considerations in the processing of fruits and vegetables. Residuals are the food and non-food materials left over from a plant's production processes. This category is made

TABLE 190

ESTIMATED COMPARATIVE DAILY ENERGY COST FOR TREATMENT SYSTEMS (1,2)

Plant Effl. Volume		Spray Irri.	Aerated Lagoons	Activated Sludge	Multi-Media Filter	Chlorination
mld	mgd	$/day	$/day	$/day	$/day	$/day
.38	0.1	3	7	10	1	1
1.1	0.3	7	21	32	2	1
2.3	0.6	13	36	61	4	1
3.8	1.0	20	64	94	6	1
11	3.0	58	190	270	15	2
19	5.0	96	320	473	24	2

(1) Costs based on BOD range of 800-1,000 mg/l.

(2) See operation and maintenance cost tables for individual treatment modules elsewhere in Section VIII.

up of wastes which can be reused (by-products) and those which cannot be reused (solid waste).

Great strides have been made by the industry to reuse their wastes to the maximum extent possible. New uses for solid wastes are being investigated continually in order to decrease the amount requiring disposal and increase potential income.

Most by-products from fruit and vegetable processors go into animal feed. In a report by the National Canners Association in 1968, it was noted that 97 percent of all food byproducts went into animal feed. Other uses for by-products include the production of charcoal, alcohol, vinegar, and other items. Some residuals can be burned to recover their heat value, and still others are used as landscaping mulch (cherry pits) and decorative items and trinkets (carved peach pits).

Handling and Storage

Two general methods are used to handle solid residuals in processing plants: dry and wet. In the dry method, the wastes are collected without the use of water and put into containers. An example is trimmings deposited into a barrel. The wet method employs water to flush the solids from the processing area. Usually sub-floor gutters are used, and as solids accumulate, they are continuously or intermitently carried away by water. Previously-used process water is frequently used in these wet systems. Some plants use a combination wet and dry method; but in cases where water is used, a separation of solid and liquid is made before final disposal. When this is necessary, screening of the plant's wastewater is the most common separation method used.

The wet method of handling solid waste affects a plant's wastewater characteristics. As solids are conveyed in a water medium, soluble solids are leached and become a part of the wastewater load. Virtually all wastewater parameters are degraded when this method of solid waste handling is employed.

Storage of solid waste on-site is normally of a temporary nature. Residuals are stored in moveable containers, fixed hoppers, trucks, or (rarely) in stockpiles. Wastes in these containers are generally moved to a loading area where they are transferred to a truck for delivery to a disposal site.

In the previously mentioned NCA report, it was noted that for the reported year (1968), solid waste from the industry was disposed of primarily by three methods with approximate tonnages as shown:

1. Filling (not necessarily sanitary landfilling) - 780,000 tons.

2. Spreading on open fields - 825,000 tons.

3. Burning - 18,000 tons.

As enforcement of regulations against open dumping and burning become stricter, more of these wastes will be delivered to sanitary landfills. The costs associated with this type of disposal will further encourage processors to use greater and greater percentages of the raw commodity.

Problems associated with the disposal of solid wastes at fill sites include insects, rodents, and odors, in that order. At spread sites, odors replaced rodents as the second most prevalent problem. Odor was reported as the major problem at burn sites. Water pollution was not considered a major problem at any of the three types of disposal sites.

In addition to solid wastes generated within the plant and through screenings, there is the problem of disposal of sludge generated by waste treatment processes. The amount of this sludge varies with the type of treatment processes used and the characteristics of the raw waste. The methods of disposal for the treatment sludge are normally the same as for the plants' other solid wastes.

AIR POLLUTION

Fruit and vegetable processors contribute little to the nation's air pollution problem. In "Pollution Problems in Selected Food Industries," Washington, D.C., 1971, the National Industrial Pollution Council estimated that less than one percent of all industrial air pollution is created by the food industry as a whole.

Some air pollution is produced by the fruit and vegetable industry. Major problem areas are particulate matter and particulate matter is often dispersed into the air during the dry cleaning of raw products. Processes contributing to this problem are agitation by mechanical devices or air jets used to remove loose dirt and other debris. Air-borne peach fuzz was particularly irritating to the employees of one plant. The problem was remedied by wetting the rollers over which the fruit was being conveyed. Other dust problems were noted where leafy vegetables were air cleaned before being washed. These and most other particulate problems were confined to the processing plant and none affected the general public.

Another potential source of particulate pollution is smoke from incinerators. However, it appears that few fruit and vegetable processors are using on-site incinerators for the disposal of waste solids.

Odors are often associated with food processing; however, these apparently are not a serious problem in those segments of the fruit and vegetable industry included in this study. Some odors are generated in the cooking of these commodities, but these are normally confined to the processing plant where exhaust and ventilating fans remove or disperse the odors to the point where they are not objectionable to employees.

Wastewater treatment facilities are other sources of odor. If designed and operated properly, these operations should not be offensive. However, when poorly sited or overloaded, odors can be generated. An example of the former situation was an anaerobic lagoon built just across a highway from a housing development. Equipment which is designed to operate under anaerobic conditions should have facilities to properly handle the odor problem. These could include a cover and gas collector. The generated gas can be flared or collected and used for its heating value in maintaining optimum operating temperatures. Other sources of odor problems are some aerobic treatment facilities. Air flotation systems appear to be prone to these problems. This is particularly true if there is a delay in the disposal of skimmings or any solids which contain grease. Again, proper design and operation will help eliminate the source of odors. This approach is more effective in the long run than any attempt to control odors after they are generated.

NOISE POLLUTION

Fruit and vegetable processors generate little noise that affects the general public. Most noise produced in the processing is dissipated within the plant itself. This noise, however, can be bothersome to employees. Sources of noise noted during this study were the operations in which empty cans were being moved within the plant and filled, and the full cans sealed, thermo-processed, and packed in shipping containers.

Noise associated with wastewater treatment is most often created by air flotation systems or aerated lagoons. Air compressors, blowers, and large pumps may generate noise levels in excess of the Occupational Safety and Health Administration standards. Noise from such equipment housed in inexpensive buildings is concentrated and could be detrimental to employees' health. The noise pollution problem should be addressed in any future design of waste treatment facilities; however, it is not considered to be a serious problem in the fruit and vegetable processing industry.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

INTRODUCTION

The wastewater effluent limitations which must be achieved by July 1, 1977, specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. Best Practicable Control Technology Currently Available is based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within this industrial subcategory. This average is not based upon a broad range of plants within the canned and preserved fruits and vegetables industry, but based upon performance levels achieved by exemplary plants.

Consideration has also been given to the following:

- The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application.

- The size and age of equipment and facilities involved.

- The processes employed.

- The engineering aspects of the application of various types of control techniques.

- Process change.

- Non-water quality environmental impact (including energy requirements.)

Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of canning, freezing, or dehydrating processes, but includes the control technologies within the process itself when the latter are considered to be normal practice within the industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction of the control facilities.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The wastewater effluent limitations guidelines for the canned and preserved fruits and vegetables industry are based on the information contained in Sections III through VIII of this report. The commodity description information in Section III and the waste characterization data in Section V were used to develop the three segments and 58 commodity subcategories listed in Section IV. Separate limitations have also been established for three sizes of plants due to potential economic impacts as discussed in Section IV. The treatment and control technology information in Section VII, along with cost and other aspects of the technologies in Section VIII, were used to develop effluent limitations for pollutants selected in Section VI and characterized in Section V. Based on this information, a determination has been made that the quality of effluent attainable through the application of the Best Practicable Control Technology Currently Available (BPCTCA) is as listed in the tables below.

The BPCTCA limitations can be achieved by end-of-pipe biological treatment, either activated sludge or aerated or aerobic lagoons. These biological treatment systems are primarily designed for organic ($BOD\underline{5}$) removal. The anticipated effectiveness of $BOD\underline{5}$ removal is based on results from processing plants with end-of-pipe treatment using aerated lagoons. These systems are also effective in removal of raw suspended solids, although the effluent suspended solids level from activated sludge is usually lower in concentration than from aerated lagoons. As noted in Section VII, algae growth in lagoon systems has been a problem in this industry, resulting in consistently higher levels of effluent suspended solids. Thus, the suspended solids limitations have been developed using results from processing plants with aerated lagoons, so that either activated sludge or aerated lagoons could be employed to achieve the effluent limitations. Furthermore, the ratios between the maximum day and maximum 30 day average $BOD\underline{5}$ and TSS and the annual average $BOD\underline{5}$ or TSS have been investigated for both activated sludge and aerated lagoon systems. The maximum day and maximum 30 day average to annual average <u>ratios</u> for both $BOD\underline{5}$ and TSS are higher for activated sludge than for aerated lagoons. However, since the maximum day, maximum 30 day average, and annual average effluent $BOD\underline{5}$ <u>concentrations</u> are all higher for aerated lagoons than for activated sludge, the aerated lagoon values have been used as the basis for calculation of the effluent limitations.

Land treatment is widely practiced throughout the industry and is a highly effective technology for treating wastes from plants processing fruits and vegetables. The effectiveness of removing $BOD\underline{5}$ and suspended solids through land treatment is greater than either form of biological treatment. Land treatment technologies described in Section VII should be selected for treating these wastewaters in instances where appropriate land is economically available to the processor. However, because of the difficulty of having adequate land at all plants, land treatment is not the best practicable technology for all processors, and effluent limitations guidelines are based on biological treatment, either activated sludge or aerated lagoons, not land treatment.

It is emphasized that the effluent limitations are based on the performance of aerated or aerobic lagoons, and therefore either activated sludge or aerated lagoons or land treatment can be utilized to achieve the limitations. Furthermore, none of these technologies nor any other specific in-plant or end-of-pipe facilities are of themselves required. Due to economics, space, or other factors, many plants may choose to use any combination of alternative in-plant and/or end-of-pipe technologies. Some plants may choose technologies in addition to biological treatment. A specific processing plant may select biological treatment, land treatment, or any other technology as the most effective method of meeting the limitations.

The BPCTCA effluent limitations guidelines tabulated below are proposed for medium size plants and promulgated (interim final) for large plants. Small plants are excluded and therefore not required to meet these limitations as a result of potential economic impacts identified by a separate study which is discussed in Section IV of this document. Definitions of small, medium, and large size plants also appear in Section IV.

BOD5 Effluent Limitations

Commodity (Fruits)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
	Metric units (kg/kkg of raw material)		
	English units (lb/1000 lb of raw material)		
Apricots	2.98	1.94	1.26
Caneberries	0.78	0.51	0.33
Cherries			
Sweet	1.09	0.71	0.47
Sour	1.70	1.09	0.74
Brined	2.77	1.81	1.19
Cranberries	1.68	1.09	0.71
Dried Fruit	1.83	1.19	0.78
Grape Juice			
Canning	1.02	0.67	0.45
Pressing	0.22	0.14	0.09
Olives	5.31	3.47	2.29
Peaches			
Canned	1.81	1.18	0.78
Frozen	0.80	0.52	0.36
Pears	1.71	1.12	0.75
Pickles			
Fresh Pack	1.19	0.78	0.51
Process Pack	1.39	0.91	0.62
Salt Stations	0.20	0.14	0.10
Pineapples	1.78	1.16	0.75
Plums	0.68	0.44	0.29
Raisins	0.41	0.27	0.18
Strawberries	1.75	1.13	0.73
Tomatoes			
Peeled	1.20	0.78	0.50
Products	0.48	0.31	0.19

TSS Effluent Limitations

Commodity (Fruits)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of raw material) English units (lb/1000 lb of raw material)			
Apricots	4.68	3.35	2.60
Caneberries	1.21	0.85	0.68
Cherries			
Sweet	1.78	1.32	0.96
Sour	2.82	2.11	1.50
Brined	4.48	3.29	2.43
Cranberries	2.67	1.92	1.47
Dried Fruit	2.92	2.12	1.60
Grape Juice			
Canning	1.70	1.28	0.91
Pressing	0.36	0.26	0.19
Olives	8.64	6.36	4.67
Peaches			
Canned	2.93	2.15	1.59
Frozen	1.38	1.07	0.71
Pears	2.90	2.21	1.52
Pickles			
Fresh Pack	1.93	1.41	1.04
Process Pack	2.38	1.82	1.24
Salt Stations	0.43	0.38	0.19
Pineapples	2.82	2.03	1.56
Plums	1.07	0.78	0.59
Raisins	0.72	0.55	0.37
Strawberries	2.69	1.88	1.52
Tomatoes			
Peeled	1.85	1.30	1.04
Products	0.71	0.48	0.41

BOD5 Effluent Limitations

Commodity (Vegetables)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of raw material)			
English units (lb/1000 lb of raw material)			
Asparagus	0.85	0.55	0.34
Beets	0.81	0.54	0.39
Broccoli	3.61	2.34	1.47
Brussels Sprouts	1.25	0.81	0.51
Carrots	1.73	1.14	0.76
Cauliflower	1.98	1.28	0.81
Corn			
Canned	0.70	0.46	0.32
Frozen	1.89	1.24	0.83
Dehydrated Onion/Garlic	2.40	1.55	0.98
Dehydrated Vegetables	2.91	1.88	1.19
Dry Beans	2.46	1.60	1.05
Lima Beans	3.64	2.36	1.52
Mushrooms	2.99	1.94	1.24
Onions (Canned)	3.17	2.07	1.35
Peas			
Canned	2.74	1.79	1.18
Frozen	2.03	1.33	0.88
Pimentos	3.97	2.58	1.69
Sauerkraut			
Canning	0.49	0.32	0.21
Cutting	0.07	0.04	0.03
Snap Beans			
Canned	1.16	0.75	0.47
Frozen	2.12	1.37	0.88
Spinach			
Canned	3.02	1.95	1.23
Frozen	1.77	1.14	0.72
Squash	0.86	0.57	0.40
Sweet Potato	0.78	0.53	0.40
White Potato (Canned)	1.30	0.86	0.60

TSS Effluent Limitations

Commodity (Vegetables)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of raw material)			
English units (lb/1000 lb of raw material)			
Asparagus	1.26	0.85	0.73
Beets	1.55	1.27	0.74
Broccoli	5.37	3.65	3.12
Brussels Sprouts	1.85	1.26	1.08
Carrots	2.91	2.19	1.53
Cauliflower	2.93	1.99	1.70
Corn			
Canned	1.28	1.03	0.63
Frozen	3.16	2.37	1.67
Dehydrated Onion/Garlic	3.56	2.42	2.07
Dehydrated Vegetables	4.32	2.93	2.51
Dry Beans	3.92	2.83	2.15
Lima Beans	5.64	3.99	3.17
Mushrooms	4.59	3.21	2.59
Onions (Canned)	5.09	3.71	2.78
Peas			
Canned	4.44	3.26	2.40
Frozen	3.33	2.47	1.79
Pimentos	6.35	4.62	3.47
Sauerkraut			
Canning	0.78	0.57	0.43
Cutting	0.12	0.10	0.06
Snap Beans			
Canned	1.73	1.17	1.00
Frozen	3.25	2.27	1.84
Spinach			
Canned	4.49	3.05	2.60
Frozen	2.62	1.78	1.52
Squash	1.57	1.25	0.78
Sweet Potato	1.67	1.48	0.74
White Potato (Canned)	2.39	1.93	1.18

BOD5 Effluent Limitations

Commodity (Specialties)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of final product)			
English units (lb/1000 lb of final product)			
Added Ingredients	1.30	0.80	0.33
Baby Food	1.00	0.65	0.42
Chips			
Potato	3.35	2.19	1.47
Corn	1.84	1.22	0.85
Tortilla	2.88	1.89	1.26
Ethnic Foods	1.74	1.13	0.73
Jams/Jellies	0.39	0.26	0.17
Mayonnaise and Dressings	0.34	0.23	0.15
Soups	4.10	2.66	1.71
Tomato-Starch-Cheese Canned Specialities	1.77	1.14	0.72

TSS Effluent Limitations

Commodity (Specialties)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of final product)			
English units (lb/1000 lb of final product)			
Added Ingredients	0.00	0.00	0.00
Baby Food	1.56	1.11	0.87
Chips			
Potato	5.60	4.22	2.96
Corn	3.34	2.67	1.66
Tortilla	4.79	3.59	2.54
Ethnic Foods	2.70	1.91	1.51
Jams/Jellies	0.68	0.53	0.35
Mayonnaise and Dressings	0.60	0.47	0.31
Soups	6.34	4.47	3.56
Tomato-Starch-Cheese Canned Specialities	2.62	1.78	1.52

For medium and large plants in all fruit, vegetable and specialty subcategories, pH shall at all times remain within the range of 6.0 to 9.5. For the medium and large plants in the specialty product subcategories, oil and grease concentrations shall not exceed 20 mg/l. Within the vegetables segment, the limitations for the cauliflower subcategory are in terms of kilograms (kg) of pollutants per 1000 kilograms (kkg) of final product. Within the specialties segment, the limitations for the soups subcategory are in terms of kilograms (kg) of pollutants per 1000 kilograms (kkg) of raw ingredients.

Any medium or large fruit, vegetable, or specialty product processing plant which continuously or intermittently discharges process wastewater during the processing season shall meet the annual average, maximum thirty day average, and maximum day effluent limitations for BOD_5 and TSS. Processing plants employing long term waste stabilization, where all or a portion of the process wastewater discharge is stored for the entire processing season and released at a controlled rate with state approval, shall meet only the annual average effluent limitations for BOD_5 and TSS.

IDENTIFICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The suggested BPCTCA for the 58 subcategories is biological treatment, either aerated or aerobic lagoons or activated sludge. In addition to biological treatment, BPCTCA for some commodities may include primary settling, air flotation, or nutrient addition. For the sweet potatoes, white potatoes, beets, and brined cherries subcategories, a roughing filter is suggested with activated sludge for BPCTCA. Primary settling is suggested with either aerated or aerobic lagoons or activated sludge for BPCTCA for white potatoes or sweet potatoes, and air flotation is suggested with activated sludge for potato chips, corn chips, soups, mayonnaise and dressings, and tomato-starch-cheese specialties. Nutrient addition is suggested for BPCTCA for 22 subcategories.

The application of the best practicable control technology does not require major changes in existing industrial processes for any subcategory. Incorporation of control measures can be accomplished with the adoption of water conservation programs, programs for finding alternate uses for products currently wasted, and steps for improving house keeping and product handling practices. All of these control measures are normal practices and are being utlized by many plants in the industry.

Either aerated or aerobic lagoons or activated sludge can be utilized to achieve BPCTCA, and are being utilized to achieve the effluent limits. Many other plants are also achieving the limitations through land disposal techniques. Land application practices such as spray irrigation, ridge and furrow irrigation, and flood irrigation can be economically feasible and technically satisfactory methods of achieving the effluent limitations.

ENGINEERING ASPECTS OF CONTROL TECHNIQUE APPLICATIONS

The effluent limitations for the 58 industry subcategories are based on effluent data from 27 biological treatment systems including thirteen aerated lagoon systems and fourteen activated sludge systems. The results of these systems have been utilized to develop a series of mathematical expressions which relate organic waste strengths to achievable effluent levels. The effluent levels were then applied to the raw waste load from each subcategory to determine the effluent limitations guidelines.

The first step in the development of effluent limitations from existing treatment data was a thorough analysis of the effluent data. The BOD_5 and TSS effluent concentrations for each treatment plant were separated into thirty day and annual periods. The annual average BOD_5 and TSS concentration were calculated from the BOD_5 and TSS for the entire discharge period on a annual basis; the maximum thirty day BOD_5 and TSS concentrations were determined from comparisons of the average

BOD5 and TSS for each thirty day period; and the maximum day BOD5 and TSS concentrations were determined from comparisons of BOD5 and TSS concentrations for each day during the discharge period. Thus, three concentrations representing the annual average, the maximum thirty day average, and the maximum day were determined for each plant. It must be pointed out that several years of data existed for a few plants (four), a full season's data for most plants (seventeen) and less than a full season for some plants (six). Thus, annual averages, maximum thirty day, and daily maximum values were available and calculated for twenty-one plants and annual averages without maximum thirty day and daily maximums were obtained for six plants.

Logarithmic averages and arithmetic averages were calculated because statistical analyses indicated some plant effluent data was more accurately described by a log-normal distribution than by a normal distribution. However, a comparison of seasonal average BOD5 and TSS data showed the effluent results were similar. For example, the arithmetic and logarithmic averages of the annual average BOD5 and TSS discharge concentrations from aerated lagoons were 34 mg/l BOD5 and 68 mg/l TSS versus 30 mg/l BOD5 and 61 mg/l, repsectively. For activated sludge plants, the arithmetic averages were 21 mg/l BOD5 and 43 mg/l TSS, and the logarithmic averages were 19 mg/l BOD5 and 31 mg/l TSS. There were similar differences for the maximum thirty day averages but the maximum day effluent concentrations were identical for each distribution. Based on the similarity of effluent values, it was determined that both distributions adequately described the data and thus, there was not sufficient justification for using the lower logarithmic concentrations which required increased mathematical efforts on the part of plant personnel and enforcement groups. Accordingly, arithmetic determinations of annual averages and maximum thirty day averages have been utilized.

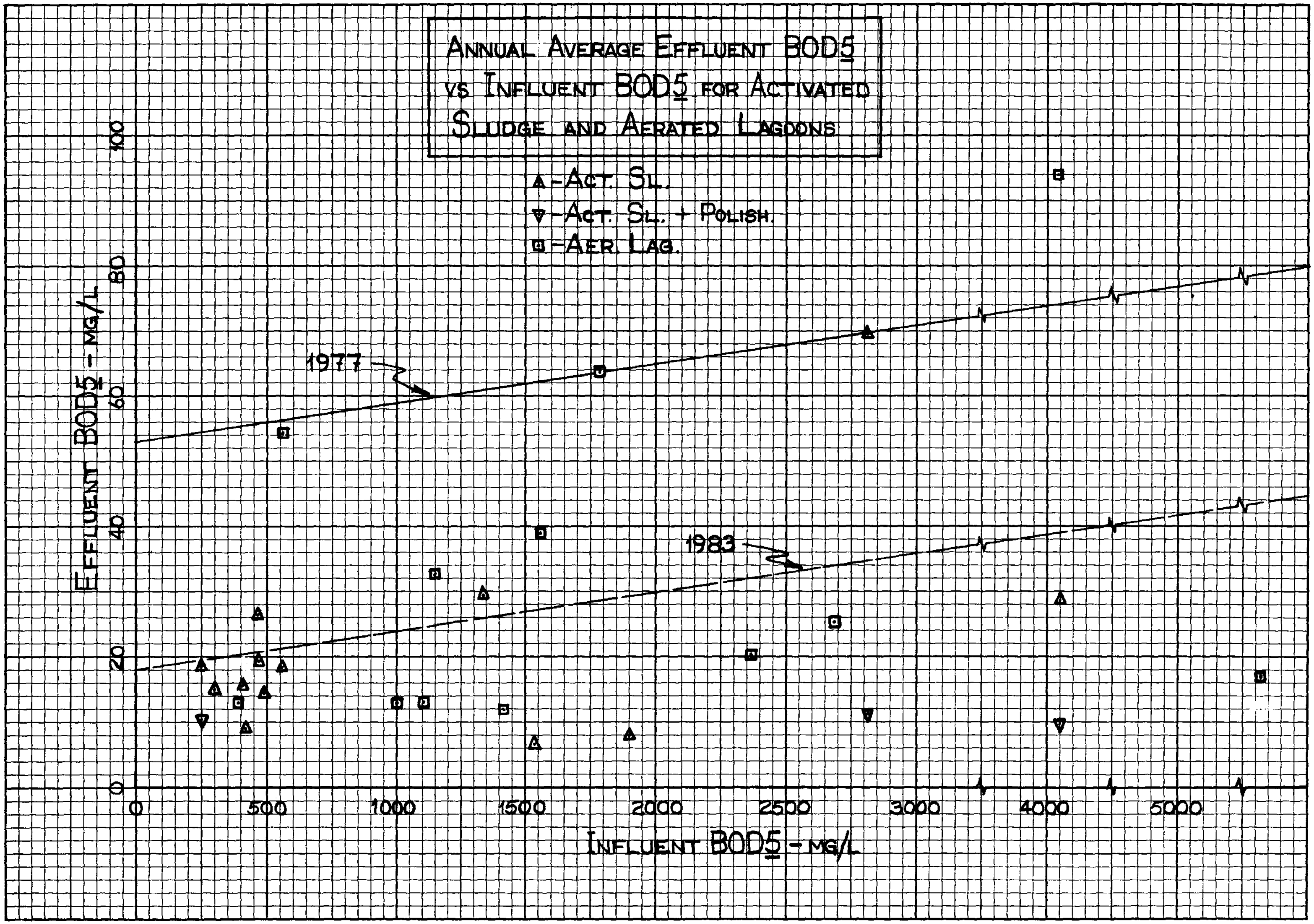
The next step in the data analysis was to plot for each treatment system the influent raw waste BOD5 concentration versus the treated effluent annual average, maximum month and maximum day BOD5 and TSS concentrations. These characteristics have been plotted and appear as Figures 68-73. Regression analyses were performed on these data sets to determine the mathematical correlation between the influent BOD5 and the six effluent characteristics. The following equations represent the results of these analyses.

The annual average effluent BOD5 and TSS concentrations were expressed by the following relationship with the influent BOD5 concentration:

$$\text{Effluent BOD5} = 18 + .006\ (\text{Influent BOD5})$$
$$\text{Effluent TSS} = 41 + .009\ (\text{Influent BOD5})$$

The maximum thirty day effluent BOD5 and TSS concentrations were expressed as follows:

FIGURE 68



ANNUAL AVERAGE EFFLUENT BOD5 VS INFLUENT BOD5 FOR ACTIVATED SLUDGE AND AERATED LAGOONS
▲-ACT. SL.
▼-ACT. SL. + POLISH.
▣-AER. LAG.
1977
1983
EFFLUENT BOD5 - MG/L
0
20
40
60
80
100
0
500
1000
1500
2000
2500
3000
4000
5000
INFLUENT BOD5 - MG/L

FIGURE 69

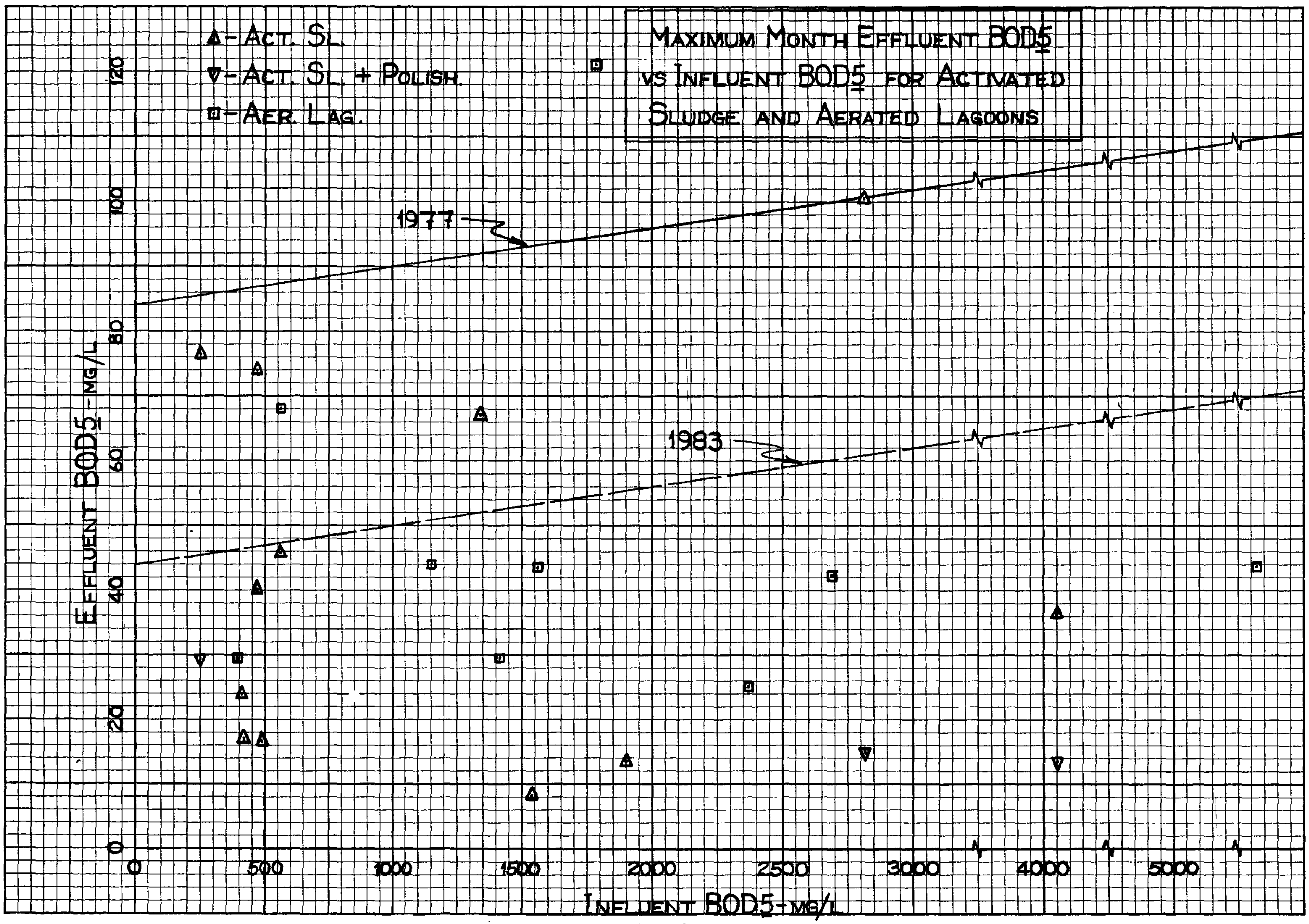
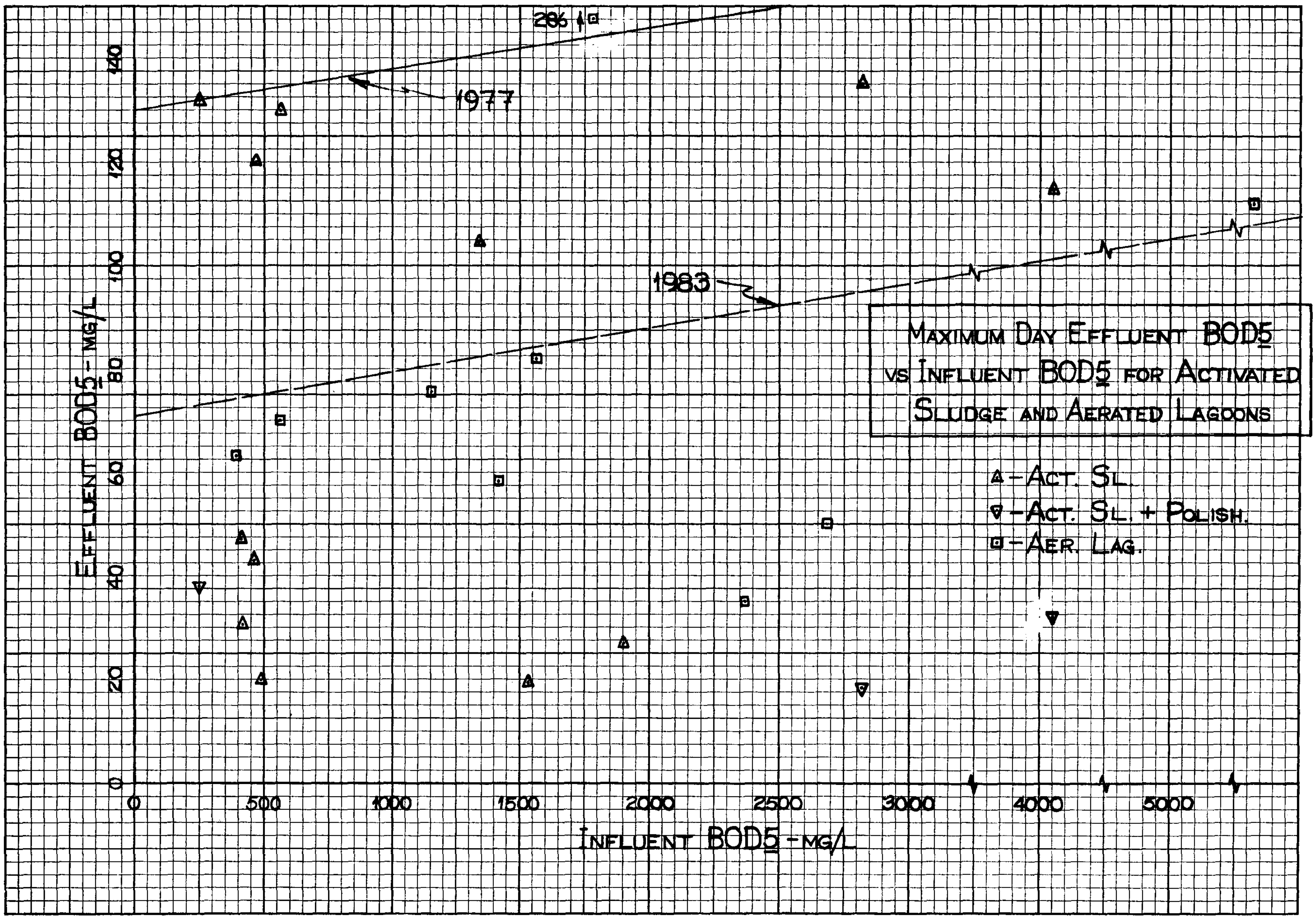
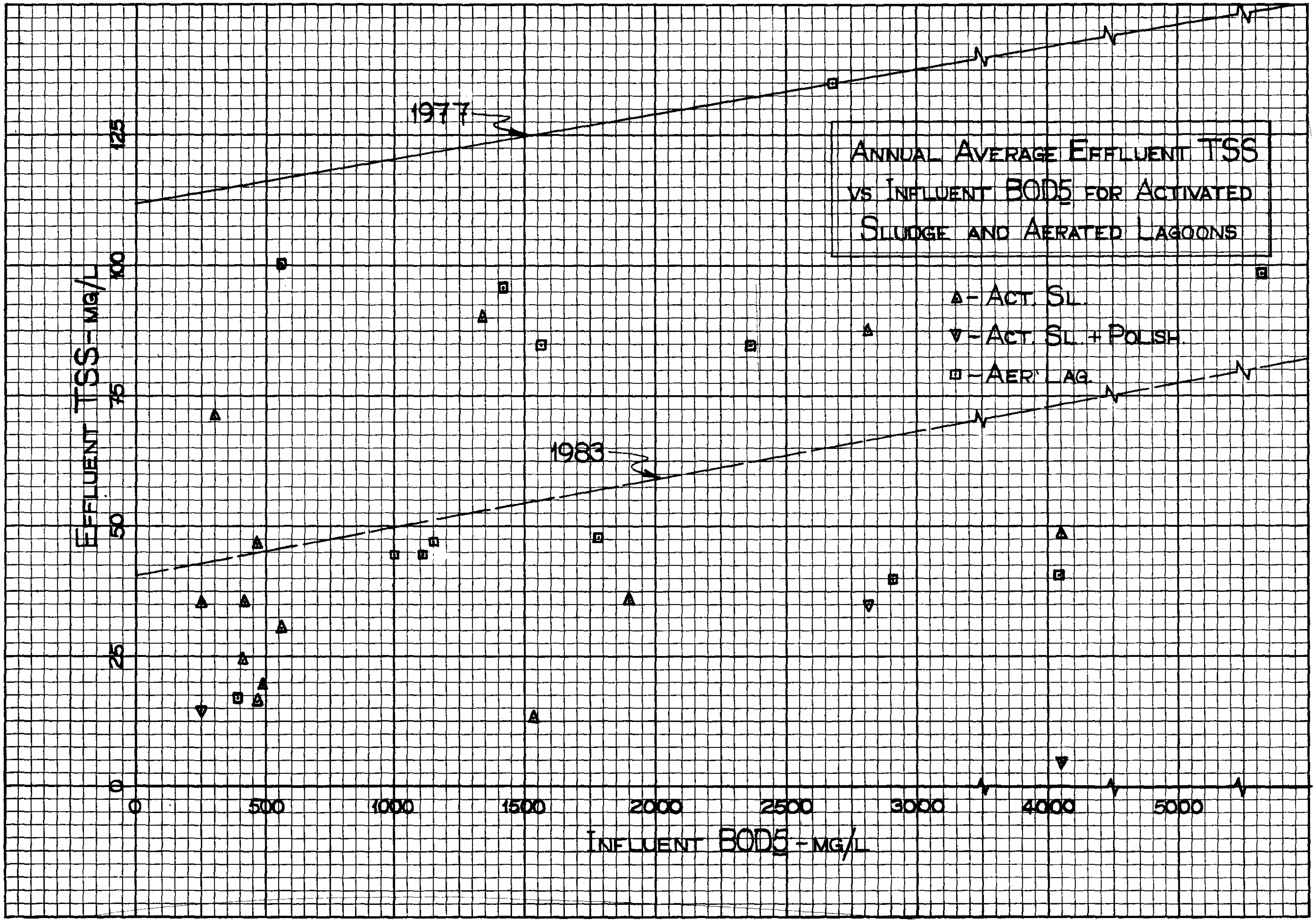

▲ - ACT. SL.
▼ - ACT. SL. + POLISH.
□ - AER. LAG.
MAXIMUM MONTH EFFLUENT BOD5 VS INFLUENT BOD5 FOR ACTIVATED SLUDGE AND AERATED LAGOONS
1977
1983
EFFLUENT BOD5 - MG/L
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
4000
5000
INFLUENT BOD5 - MG/L

FIGURE 70



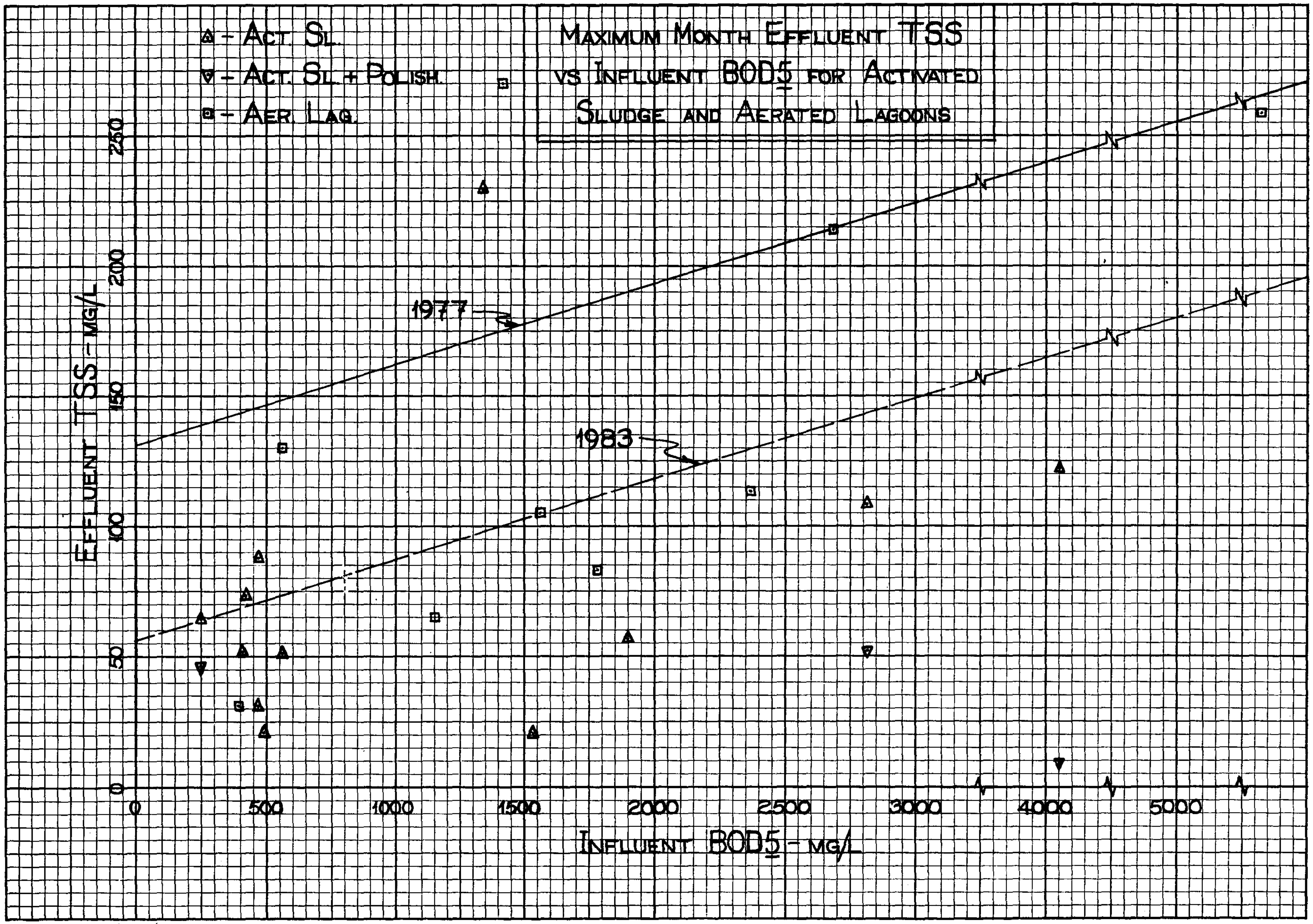
MAXIMUM DAY EFFLUENT BOD5 VS INFLUENT BOD5 FOR ACTIVATED SLUDGE AND AERATED LAGOONS
△ - ACT. SL.
▽ - ACT. SL. + POLISH.
⊡ - AER. LAG.
1977
1983
286
EFFLUENT BOD5 - MG/L
0
20
40
60
80
100
120
140
INFLUENT BOD5 - MG/L
0
500
1000
1500
2000
2500
3000
4000
5000

FIGURE 71



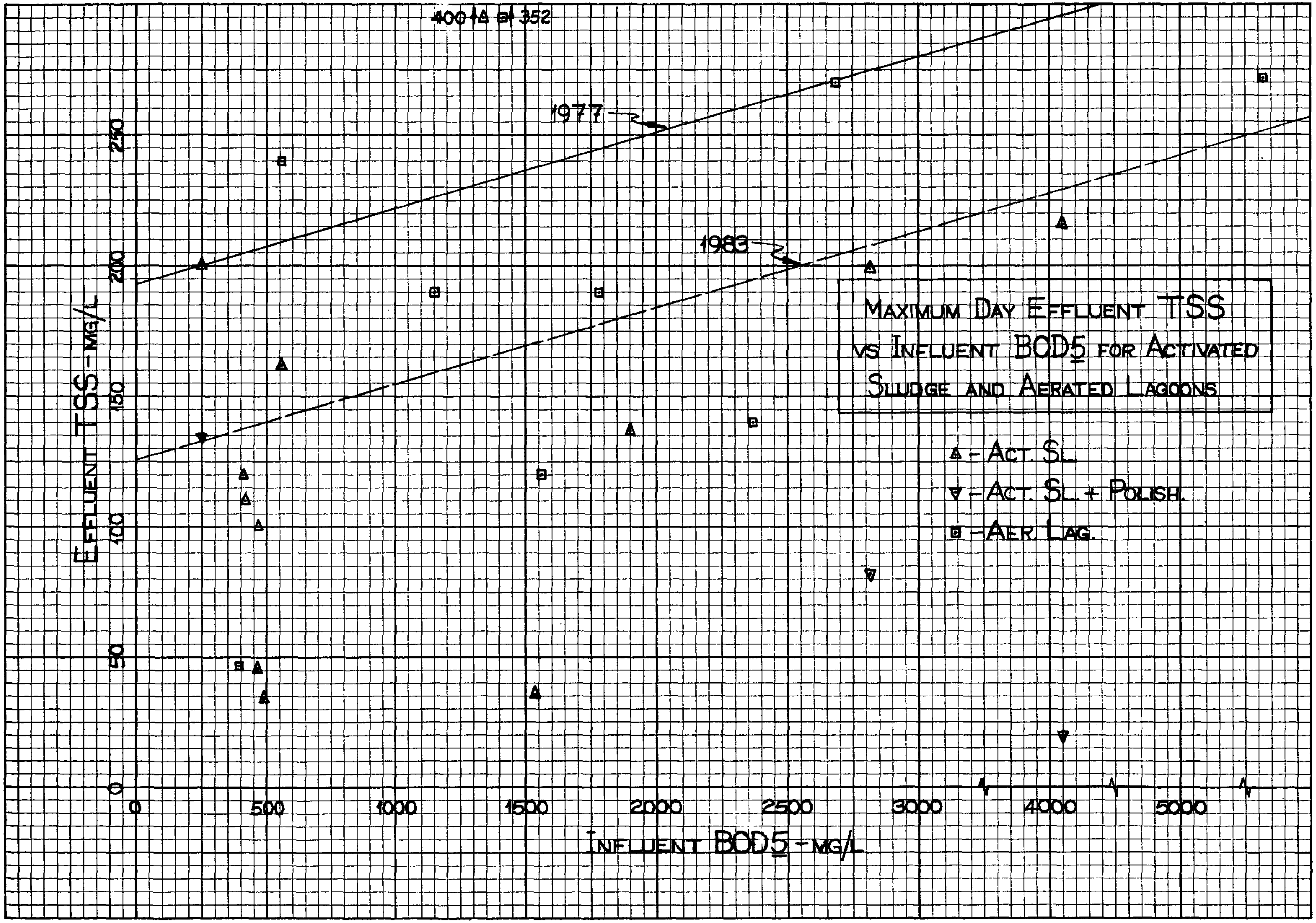
ANNUAL AVERAGE EFFLUENT TSS
VS INFLUENT BOD5 FOR ACTIVATED
SLUDGE AND AERATED LAGOONS
▲ - ACT. SL.
▼ - ACT. SL. + POLISH.
▫ - AER. LAG.
1977
1983
EFFLUENT TSS - MG/L
0
25
50
75
100
125
0
500
1000
1500
2000
2500
3000
4000
5000
INFLUENT BOD5 - MG/L

FIGURE 72



MAXIMUM MONTH EFFLUENT TSS
VS INFLUENT BOD5 FOR ACTIVATED
SLUDGE AND AERATED LAGOONS
- ACT. SL.
- ACT. SL. + POLISH.
- AER. LAG.
1977
1983
EFFLUENT TSS - MG/L
INFLUENT BOD5 - MG/L
0
50
100
150
200
250
500
1000
1500
2000
2500
3000
4000
5000

FIGURE 73



400 352
1977
1983
MAXIMUM DAY EFFLUENT TSS VS INFLUENT BOD5 FOR ACTIVATED SLUDGE AND AERATED LAGOONS
- ACT. SL.
- ACT. SL. + POLISH.
- AER. LAG.
EFFLUENT TSS - MG/L
0
50
100
150
200
250
INFLUENT BOD5 - MG/L
0
500
1000
1500
2000
2500
3000
4000
5000

$$\text{Effluent BOD5} = 44 + .006\ (\text{Influent BOD5})$$
$$\text{Effluent TSS} = 56 + .031\ (\text{Influent BOD5})$$

The maximum day effluent BOD5 and TSS concentrations were expressed as follows:

$$\text{Effluent BOD5} = 71 + .008\ (\text{Influent BOD5})$$
$$\text{Effluent TSS} = 126 + .029\ (\text{Influent BOD5})$$

The preceding analysis resulted in effluent concentrations which were the average of the best twenty-seven treatment plants in the industry. However, this approach was modified to a more conservative approach to further allow for differences in raw material quality, periods of multiple commodity changeover, plant upsets, vacation and peak periods and seasonality. The conservative "enveloping" approach was to establish a minimum BOD5 removal rate of 85 percent and base all other treatment performance levels on the highest effluent values, rather than the average values, so that all or nearly all of the twenty-seven treatment plants would achieve the annual average, the maximum thirty day, and the maximum day effluent concentrations. This was accomplished by increasing the intercept of the regression expressions to a level where all or nearly all plants would achieve the required effluent levels. The following equations represent the results of this conservative approach.

The modified annual average effluent BOD5 and TSS concentrations were determined by the following relationships with the influent BOD5 concentration:

$$\text{Effluent BOD5} = 53 + .006\ (\text{Influent BOD5})$$
$$\text{Effluent TSS} = 112 + .009\ (\text{Influent BOD5})$$

The maximum thirty day effluent BOD5 and TSS concentrations were determined as follows:

$$\text{Effluent BOD5} = 84 + .006\ (\text{Influent BOD5})$$
$$\text{Effluent TSS} = 131 + .031\ (\text{Influent BOD5})$$

The maximum day effluent BOD5 and TSS concentrations were determined as follows:

$$\text{Effluent BOD5} = 130 + .008\ (\text{Influent BOD5})$$
$$\text{Effluent TSS} = 193 + .029\ (\text{Influent BOD5})$$

The relationships above are met by all or nearly all of the twenty-seven treatment plants. The annual average BOD5 and TSS effluent concentrations are met by all plants except one aerated lagoon (ST40) for BOD5. The maximum thirty day effluent concentrations are achieved by all plants, except one aerated lagoon (GR33) for BOD5, and one aerated lagoon and one activated sludge plant (PE78 and TO96) for TSS. The maximum day effluent concentrations are achieved by all plants, except one aerated lagoon (GR33) for BOD5, and two aerated lagoons and one activated sludge plant (PN26, PE78 and TO96) for TSS. In summary, the three BOD5 limitations are achieved by eleven aerated lagoons and all fourteen activated sludge plants and the three TSS limitations are achieved by eleven aerated lagoons and thirteen activated sludge plants. All the limitations are met by twenty-two treatment plants, nine aerated lagoons (ON26, CO78, MU50, BT 52, BN28, TO51, TO52, PK60 and CH59) and thirteen activated sludge plants (CO59, *C54, GR32, BN43, GN90, PO60, CT91, BN26, PR51, PN25, CS99, SL01 and TO99).

Some of the characteristics of the twenty-seven treatment plants are that nine have influent BOD5 concentrations less than 500 PPM, eleven have influent BOD5 concentrations between 500 and 2000 PPM, and seven have influent BOD5 concentration greater than 2000 PPM. Plant sizes range from less than 1 million kilograms (2.2 million pounds) per year to over 50 million kilograms (1,100 million pounds) per year. Eight plants belong to single-plant companies, eight plants belong to companies owning between two and ten plants, and eleven plants belong to companies owning more than ten plants.

The twenty-seven plants process the following commodities: caneberries; cherries; dried fruit; grapes; peaches; pears; pickles; plums; strawberries; tomatoes; asparagus; beets; broccoli; brussels sprouts; carrots; cauliflower; corn; dehydrated vegetables; dry beans; lima beans; mushrooms; onions; peas; sauerkraut; snap beans; spinach; squash, sweet potatoes; white potatoes; jams and jellies; and soups. From this list of fruits, vegetables and specialties, it is important to note that all major commodities are processed at one or more of the twenty-seven treatment plants. Those commodities not appearing in this table are relatively minor when compared with other commodities on a total production basis. In addition, most if not all of the plants processing these other commodities discharge to municipal treatment systems and are not affected by these limitations. Nevertheless, the fact the process wastewater from these other commodities is treated in conventional biological treatment systems similar to the twenty-seven treatment plants upon which the limitations have been established, demonstrates the achievability and practicability of these limitations for all industry commodities and subcategories.

A final consideration which should be discussed is the annual average of all plant discharge data. This limitation is necessary for all industry dischargers because of the seasonal and multi-product nature of this industry which often imparts significant variability in daily, monthly and seasonal waste loads to treatment systems as noted above and in Sections IV and V. Plants within each industry segment are characterized by processing seasons varying from less than a month to six months or a year, during which one to several commodities, styles and/or products are processed concurrently and/or consecutively. Achievement of high quality effluent discharges have nonetheless been demonstrated throughout the processing year by existing treatment systems within the industry. As detailed below in the subsection titled "Limitations for Multi-Commodity Plants," the maximum day and maximum thirty day limitations are based on peaks and thus limit pollutant discharges during peak production periods and thus during peak discharge periods. The annual average limitations are dependent on neither the production schedule nor the length of the discharge period. The annual average, therefore, limits pollutant discharges during periods of less than peak production and thus periods of less than peak discharge. In summary, the annual average limitation has been adopted along with the maximum day and maximum thirty day limitations for plants which continuously or intermittently discharge process waste water during the processing season to simplify compliance monitoring and to assure that fruit, vegetable and specialty processors provided the necessary conservative design and diligent operation to achieve and maintain a year round treatment system performance approaching that exemplified by the twenty-seven plants used to develop the limitations.

The annual average has also been employed to handle the large number of industry plants which store process waste water in large stabilization lagoons. This treatment is necessitated in many areas of the midwest and parts of the east and west where processing plants discharge either to low flow or intermittent streams which are limited in their ability to assimilate any wastewater. With stabilization lagoons, processors have the ability to contain most or all of an entire processing season's raw waste load. Discharge is normally allowed for controlled periods during fall or spring months when stream flow is at prescribed levels. The amount of discharge is controlled by the states and determined by the actual stream flow rate and the treated effluent BOD5 (primarily). This method of discharge does not lend itself to normal compliance monitoring techniques and limitations, since state approved discharge periods and allowable effluent concentrations vary significantly. Therefore, for those plants which store all or a portion of the process waste water for the entire processing season, the only meaningful limitations are the annual averages of BOD5 and TSS, which permit a maximum of total pollutant mass which can be discharged over the period of controlled release based upon the total amount of processing for the processing season.

Processes Employed

All plants within each subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not significantly alter the characteristics of the wastewater generated. Application of the best technology currently available does not require major changes in existing industrial processes for the subcategories studied. Water conservation practices, improved housekeeping and product handling practices, and improved maintenance programs are currently available and are being used in the industry, and can be incorporated at all plants within a given subcategory.

The technology to achieve these effluent limitations is practiced within the subcategories under study. The concepts are proven, available for implementation, and applicable to the wastes in question. The waste treatment techniques are also broadly applied within many other industries. The technology required may necessitate improved monitoring of waste discharges and of waste treatment components on the part of some plants, and may require more extensive training of personnel in the operation and maintenance of waste treatment facilities. However, these procedures are currently practiced in some plants and are common practice in many other industries.

Total Cost of Application

Based on information contained in Section VIII of this report, the total investment cost to achieve the best practicable effluent limitations with aerated lagoons is estimated to be about $33.5 million. The associated annual cost would be approximately $9.7 million. These estimations assume no in-place treatment facilities. When existing facilities are considered along with the exclusion from limitations of plants less than 1,816 kkg (2,000 tons) per year, the total industry investment cost is estimated to be $24.5 million and the annual cost is estimated to be $7.6 million.

Costs per individual plant for meeting the 1977 limitations with aerated lagoons varied from $40,000 for small plants to as much as $565,000 for a large plant. The corresponding annual costs ranged from $9,000 to $156,000. Activated sludge costs were higher, ranging from $162,000 to $1,809,000 with the corresponding annual costs from $36,000 to $364,000. The investment costs for spray irrigation ranged from $46,000 to $880,000.

Non-Water Quality Environmental Impact

Energy requirements for this industrial category to comply with the effluent limitations are approximately 0.3 million KWH/day. This is a very small portion of the total energy consumed by this industry for production.

Solid waste disposal is usually accomplished by landfill or spreading on agricultural land. An increasing portion of the solid waste by-products of production are being used primarily for animal feed, while research into other methods of reuse is increasing. The disposal of solids generated by treatment systems should increase slighly but not create significant new disposal problems in terms of fill or land availability.

There are no known radioactive substances used in this industry. Noise levels associated with treatment systems are not significant. No significant air pollution problems have been identified for either processing or waste treatment or land disposal. Well designed and operated land disposal and biological treatment systems do not produce strong, offensive odors. No hazardous chemicals are required as part of this treatment technology.

Factors To Be Considered in Applying BPCTCA Limitations

1. Land treatment by spray irrigation, or equivalent methods providing minimal discharge should be encouraged.

2. The nature of biological treatment plants is such that on the order of four days may be required to reach the daily maximum limitation after initial start-up at the beginning of the processing season.

3. Thought was given to imposing a limitation upon TDS and chlorides, since these constituents are found in heavy concentrations in wastes from the subcategories which brine or pickle their product. These subcategories include sauerkraut, pickles, and olives. It is known that treatment technology exists to remove these constituents from the raw waste, but it is very costly. (Ref. 45,46,47) The potential harm to the environment from these constituents is entirely a function of their disposal location; e.g., chlorides and TDS cause no harm to ocean waters which already contain over three percent dissolved solids. It was decided, therefore, that the mandatory imposition of an expensive tertiary treatment system would not be reasonable. The individual permit writer, however, is alerted to the presence of high TDS and chlorides in wastes from these subcategories which must be evaluated with regard to their potential effect on the environment.

4. The major commodities comprising the canned and preserved fruits and vegetables industry have been described individually, and effluent limitations guidelines and standards have been recommended. Minor commodities such as artichokes, okra, and rhubarb, are typically processed in multi-product plants where their contribution to the annual raw tonnage or wastewater character is insignificant. It is estimated that minor commodities represent less than two percent of the canned and preserved fruits and vegetables.

   In order to develop effluent limitations guidelines and standards for the processing of minor commodities, review the process unit operations and wastewater characteristics for commodities described in this report. Select those major commodities which resemble the minor commodity in processing unit operations. Next select from this list of major commodities, the commodity which most closely resembles the minor commodity in wastewater volume and characteristics. This commodity and the minor commodity are similar. Thus, the effluent limitations guidelines should be similar in processing and waste volume and characteristics.

Limitations for Multi-Commodity Plants

The guidelines and standards for BPCTCA set forth earlier in Section IX apply to single-product plants. Limitations for any multi-product plant can be derived from these tabulations on the basis of a weighted average, i.e., the sum of the production for each single product or commodity processed in the plant multiplied by the guideline value for each corresponding product or commodity.

In the example below (See Table 191), the guidelines are applied to a multi-product fruit and vegetable plant. The production information obtained from the plant includes the average daily raw material production of each commodity for each month and the total seasonal or annual production of each commodity. The initial step is to calculate the thirty day limitations for each month so that the maximum thirty day limitations can be determined. In this example, the maximum thirty day BOD_5 limitation for BPCTCA is 2,150 lb per day, which is the sum of the production for each commodity processed during the peak month multiplied by the guideline value for each corresponding commodity (566 tons per day of canned peaches multiplied by 2.36 pounds per ton for BPCTCA, plus 213 tons per day of pears mutliplied by 2.24 pounds per ton for BPCTCA plus 544 tons per day of tomato products multiplied by 0.62 pounds per ton for BPCTCA). The TSS limitation is calculated similarly. The second step is to calculate the maximum day limitations using the production for the same time period as used to calculate the maximum thirty day limitations. In this example, the maximum day BOD_5 limitation for BPCTCA is 3,300 pounds per day. The third step in the development of limitations for this multi-product plant is to calculate the annual average limitations. In this example, 65,862 pounds per year is the annual average BOD_5 limitation and it is the sum of the total production for the processing season for each commodity processed multiplied by the appropriate BOD_5 guideline value. The annual average TSS limitation is calculated similarly.

As noted above, those plants which discharge continuously or intermittently during the processing season, must comply with the maximum day, maximum thirty day, and annual average effluent limitations. Those plants which employ long term waste stabilization, where all or a portion of the process wastewater discharge is stored for the entire processing season and released at a controlled rate with state approval, must comply with only

TABLE 191 DEVELOPMENT OF LIMITATIONS FOR A MULTI-PRODUCT MODEL PLANT

COMMODITY	AVERAGE DAILY PRODUCTION (TON/DAY)							TOTAL SEASONAL PRODUCTION
	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	
Spinach Canned	163	199						2,844
Apricots			273					3,822
Peaches, Canned			316	307	566			19,884
Pears				171	213	206	-	9,800
Tomatoes, Products				490	544			9,252

LIMITATIONS	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	TOTAL SEASONAL PRODUCTION
THIRTY DAY LIMITATIONS (lb)/(DAY)								
BOD5	636	776	1,805	1,411	2,150	461		
TSS	994	1,214	3,188	2,546	3,898	911		
MAXIMUM DAY LIMITATIONS (lb)/(DAY)								
BOD5					3,300			
TSS					5,325			
ANNUAL AVERAGE LIMITATIONS (lb)/(YEAR)								
BOD5								65,862
TSS								135,273

the annual average effluent limitations. More specifically, the total pounds of BOD_5 and TSS discharged during the state authorized period(s) of controlled release are determined from the total production for the related, preceding processing season.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY AVAILABLE

INTRODUCTION

The effluent limitations which must be achieved no later than July 1, 1983, are not based on an average of the best performance within an industrial subcategory, but are determined by identifying the very best control and treatment technology employed by a specific point source within this industrial category or subcategory, or by one industry where it is readily transferable to another. A specific finding must be made as to the availability of control measures and practices to eliminate the discharge of pollutants, taking into account the cost of such elimination.

Consideration must also be given to:

- The age of the equipment and facilities involved.
- The process employed.
- The engineering aspects of the application of various types of control techniques.
- Process changes.
- The cost of achieving the effluent reduction resulting from application of the technology.
- Non-water quality environmental impact (including energy requirements).

Also, Best Available Technology Economically Achievable (BATEA) emphasizes in-process controls as well as control or additional treatment techniques employed at the end of the production process.

This level of technology considers those plant processes and control technologies which, at the pilot plant, semi-works, or other level, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities. It is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants. Although economic factors are considered in this development, the costs for this level of control are intended to be the top-of-the-line of current technology, subject to limitations imposed by economic and engineering feasibility. However, there may be some technical risk with respect to performance and with respect to certainty of costs. Therefore, some industrially sponsored development work may be needed prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The wastewater effluent limitations guidelines for the 58-subcategories of the canned and preserved fruits and vegetables industry are based on the information contained in Sections III through VIII of this report. Based on this information, a determination has been made that the quality of effluent attainable for each identified pollutant through the application of the BATEA is as listed in the tables below.

Suggested BATEA includes the BPCTCA and advanced technology (filtration for large plants) which has been satisfactorily demonstrated in the fruits and vegetables industry. In addition, significant reductions in the volume of wastewater generated have been included as an integral part of BATEA. These water usage reductions have been demonstrated in all subcategories throughout the fruits and vegetables industry. The water use reductions will result in more effective treatment on the part of end-of-pipe biological treatment facilities already established to implement BPCTCA.

As pointed out in Section IX, land treatment is a highly effective technology for treating wastewaters from the fruits and vegetables industry. The considerations of land treatment made in Section IX for 1977 apply here for 1983 alternatives. Where suitable land is available, irrigation is an option that not only is recommended from the discharge viewpoint, but may be more economical than the other systems.

The BATEA effluent limitations guidelines tabulated below are proposed for both medium size plants and large plant. Small plants are excluded and therefore not required to meet these limitations as a result of potential economic impacts identified by a separate study which is discussed in Section IV of this document. Definitions of small, medium, and large size plants also appear in Section IV.

BOD5 Effluent Limitations

Commodity (Fruits)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of raw material) English units (lb/1000 lb of raw material)			
Apricots			
MEDIUM	0.977	0.619	0.300
LARGE	0.977	0.619	0.300
Caneberries			
MEDIUM	0.217	0.137	0.063
LARGE	0.217	0.137	0.063
Cherries			
Sweet			
MEDIUM	0.370	0.237	0.121
LARGE	0.370	0.237	0.121
Sour			
MEDIUM	0.857	0.542	0.261
LARGE	0.857	0.542	0.261
Brined			
MEDIUM	0.571	0.376	0.229
LARGE	0.571	0.376	0.229
Cranberries			
MEDIUM	0.517	0.330	0.165
LARGE	0.517	0.330	0.165
Dried Fruit			
MEDIUM	0.539	0.346	0.203
LARGE	0.539	0.346	0.203
Grape Juice			
Canning			
MEDIUM	0.469	0.301	0.140
LARGE	0.469	0.301	0.140
Pressing			
MEDIUM	0.089	0.056	0.027
LARGE	0.089	0.056	0.027
Olives			
MEDIUM	1.826	1.154	0.549
LARGE	1.826	1.154	0.549
Peaches			
Canned			
MEDIUM	0.806	0.510	0.244
LARGE	0.806	0.510	0.244
Frozen			
MEDIUM	0.277	0.257	0.141
LARGE	0.277	0.257	0.141

Pears			
MEDIUM	0.581	0.373	0.195
LARGE	0.581	0.373	0.195
Pickles			
Fresh Pack			
MEDIUM	0.580	0.362	0.159
LARGE	0.580	0.362	0.159
Process Pack			
MEDIUM	0.508	0.323	0.163
LARGE	0.508	0.323	0.163
Salt Station			
MEDIUM		No Discharge	
LARGE		No Discharge	
Pineapples			
MEDIUM	0.880	0.554	0.257
LARGE	0.880	0.554	0.257
Plums			
MEDIUM	0.233	0.146	0.066
LARGE	0.233	0.146	0.066
Raisins			
MEDIUM	0.165	0.109	0.066
LARGE	0.165	0.109	0.066
Strawberries			
MEDIUM	0.526	0.330	0.150
LARGE	0.526	0.330	0.150
Tomatoes			
Peeled			
MEDIUM	0.375	0.236	0.108
LARGE	0.375	0.236	0.108
Products			
MEDIUM	0.281	0.175	0.075
LARGE	0.281	0.175	0.075

TSS Effluent Limitations

Commodity (Fruits)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of raw material) English units (lb/1000 lb of raw material)			
Apricots			
MEDIUM	1.928	1.094	0.622
LARGE	0.977	0.619	0.300
Caneberries			
MEDIUM	0.415	0.221	0.134
LARGE	0.217	0.137	0.063
Cherries			
Sweet			
MEDIUM	0.758	0.460	0.244
LARGE	0.370	0.237	0.121
Sour			
MEDIUM	1.686	0.952	0.544
LARGE	0.857	0.542	0.261
Brined			
MEDIUM	1.328	0.974	0.423
LARGE	0.571	0.376	0.229
Cranberries			
MEDIUM	1.044	0.618	0.336
LARGE	0.517	0.330	0.165
Dried Fruit			
MEDIUM	1.122	0.701	0.360
LARGE	0.539	0.346	0.203
Grape Juice			
Canning			
MEDIUM	0.918	0.496	0.297
LARGE	0.469	0.301	0.140
Pressing			
MEDIUM	0.175	0.099	0.056
LARGE	0.089	0.056	0.027
Olives			
MEDIUM	3.564	1.980	1.149
LARGE	1.826	1.154	0.549
Peaches			
Canned			
MEDIUM	1.577	0.880	0.509
LARGE	0.806	0.510	0.244
Frozen			
MEDIUM	0.563	0.313	0.274
LARGE	0.277	0.257	0.141

Pears			
MEDIUM	1.209	0.755	0.388
LARGE	0.581	0.373	0.195
Pickles			
Fresh Pack			
MEDIUM	1.072	0.530	0.348
LARGE	0.580	0.362	0.159
Process Pack			
MEDIUM	1.028	0.613	0.331
LARGE	0.508	0.323	0.163
Salt Station			
MEDIUM		No Discharge	
LARGE		No Discharge	
Pineapples			
MEDIUM	1.690	0.907	0.546
LARGE	0.880	0.554	0.257
Plums			
MEDIUM	0.437	0.224	0.142
LARGE	0.233	0.146	0.066
Raisins			
MEDIUM	0.383	0.281	0.122
LARGE	0.165	0.109	0.066
Strawberries			
MEDIUM	0.996	0.519	0.322
LARGE	0.526	0.330	0.150
Tomatoes			
Peeled			
MEDIUM	0.712	0.373	0.230
LARGE	0.375	0.236	0.108
Products			
MEDIUM	0.514	0.247	0.167
LARGE	0.281	0.175	0.075

BOD5 Effluent Limitations

Commodity (Vegetables)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units	(kg/kkg of raw material)		
English units	(lb/100 lb of raw material)		
Asparagus			
MEDIUM	0.280	0.163	0.070
LARGE	0.280	0.163	0.070
Beets			
MEDIUM	0.375	0.250	0.103
LARGE	0.375	0.250	0.103
Broccoli			
MEDIUM	1.639	1.020	0.431
LARGE	1.639	1.020	0.431
Brussels Sprouts			
MEDIUM	1.657	1.027	0.420
LARGE	1.657	1.027	0.420
Carrots			
MEDIUM	0.810	0.518	0.266
LARGE	0.810	0.518	0.266
Cauliflower			
MEDIUM	2.356	1.460	0.597
LARGE	2.356	1.460	0.597
Corn			
Canned			
MEDIUM	0.179	0.118	0.072
LARGE	0.179	0.118	0.072
Frozen			
MEDIUM	0.893	0.563	0.262
LARGE	0.893	0.563	0.262
Dehydrated Onion/Garlic			
MEDIUM	0.947	0.592	0.261
LARGE	0.947	0.592	0.261
Dehydrated Vegetables			
MEDIUM	1.465	0.915	0.400
LARGE	1.465	0.915	0.400
Dry Beans			
MEDIUM	1.193	0.747	0.332
LARGE	1.193	0.747	0.332
Lima Beans			
MEDIUM	1.457	0.909	0.395
LARGE	1.457	0.909	0.395

Mushrooms			
MEDIUM	1.000	0.627	0.280
LARGE	1.000	0.627	0.280
Onions (Canned)			
MEDIUM	1.397	0.891	0.449
LARGE	1.397	0.891	0.449
Peas			
Canned			
MEDIUM	1.022	0.654	0.339
LARGE	1.022	0.654	0.339
Frozen			
MEDIUM	0.857	0.542	0.257
LARGE	0.857	0.542	0.257
Pimentos			
MEDIUM	2.004	1.251	0.586
LARGE	2.004	1.251	0.586
Sauerkraut			
Canning			
MEDIUM	0.225	0.143	0.071
LARGE	0.225	0.143	0.071
Cutting			
MEDIUM	0.027	0.017	0.009
LARGE	0.027	0.017	0.009
Snap Beans			
Canned			
MEDIUM	0.791	0.492	0.206
LARGE	0.791	0.492	0.206
Frozen			
MEDIUM	1.066	0.667	0.294
LARGE	1.066	0.667	0.294
Spinach			
Canned			
MEDIUM	0.852	0.532	0.231
LARGE	0.852	0.532	0.231
Frozen			
MEDIUM	1.037	0.645	0.272
LARGE	1.037	0.645	0.272
Squash			
MEDIUM	0.251	0.160	0.079
LARGE	0.251	0.160	0.079
Sweet Potato			
MEDIUM	0.384	0.261	0.186
LARGE	0.384	0.261	0.186
White Potato (Canned)			
MEDIUM	0.385	0.260	0.177
LARGE	0.385	0.260	0.177

TSS Effluent Limitations

Commodity (Vegetables)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of raw material)			
English units (lb/1000 lb of raw material)			
Asparagus			
MEDIUM	0.502	0.210	0.163
LARGE	0.280	0.163	0.070
Beets			
MEDIUM	0.919	0.719	0.291
LARGE	0.375	0.250	0.103
Broccoli			
MEDIUM	2.965	1.387	0.963
LARGE	1.639	1.020	0.431
Brussels Sprouts			
MEDIUM	2.943	1.309	0.958
LARGE	1.657	1.027	0.420
Carrots			
MEDIUM	1.665	1.018	0.535
LARGE	0.810	0.518	0.266
Cauliflower			
MEDIUM	4.174	1.852	1.357
LARGE	2.356	1.460	0.597
Corn			
Canned			
MEDIUM	0.415	0.205	0.132
LARGE	0.179	0.118	0.072
Frozen			
MEDIUM	1.719	0.928	0.555
LARGE	0.893	0.563	0.262
Dehydrated Onion/Garlic			
MEDIUM	1.756	0.874	0.570
LARGE	0.947	0.592	0.261
Dehydrated Vegetables			
MEDIUM	2.705	1.331	0.877
LARGE	1.465	0.915	0.400
Dry Beans			
MEDIUM	2.228	1.126	0.722
LARGE	1.193	0.747	0.332
Lima Beans			
MEDIUM	2.681	1.308	0.869
LARGE	1.457	0.909	0.395

Mushrooms			
MEDIUM	1.872	0.950	0.606
LARGE	1.000	0.627	0.280
Onions (Canned)			
MEDIUM	2.833	1.692	0.911
LARGE	1.397	0.891	0.449
Peas			
Canned			
MEDIUM	2.111	1.303	0.678
LARGE	1.022	0.654	0.339
Frozen			
MEDIUM	1.670	0.925	0.539
LARGE	0.857	0.542	0.257
Pimentos			
MEDIUM	3.836	2.094	1.239
LARGE	2.004	1.251	0.586
Sauerkraut			
Canning			
MEDIUM	0.450	0.263	0.145
LARGE	0.225	0.143	0.071
Cutting			
MEDIUM	0.057	0.037	0.018
LARGE	0.027	0.017	0.009
Snap Beans			
Canned			
MEDIUM	1.425	0.660	0.463
LARGE	0.791	0.492	0.206
Frozen			
MEDIUM	1.980	0.989	0.642
LARGE	1.066	0.667	0.294
Spinach			
Canned			
MEDIUM	1.567	0.760	0.508
LARGE	0.852	0.532	0.231
Frozen			
MEDIUM	1.876	0.877	0.609
LARGE	1.037	0.645	0.272
Squash			
MEDIUM	0.505	0.297	0.162
LARGE	0.251	0.160	0.079
Sweet Potato			
MEDIUM	1.013	0.856	0.320
LARGE	0.384	0.261	0.186
White Potato (Canned)			
MEDIUM	0.981	0.799	0.310
LARGE	0.385	0.260	0.177

BOD5 Effluent Limitations

Commodity (Specialties)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Annual Average of daily values for entire discharge period shall not exceed
Metric units	(kg/kkg of final product)		
English units	(lb/1000 lb of final product)		
Added Ingredients			
MEDIUM	0.652	0.400	0.164
LARGE	0.652	0.400	0.164
Baby Food			
MEDIUM	0.424	0.267	0.125
LARGE	0.424	0.267	0.125
Chips			
Potato			
MEDIUM	1.404	0.892	0.436
LARGE	1.404	0.892	0.436
Corn			
MEDIUM	1.031	0.662	0.350
LARGE	1.031	0.662	0.350
Tortilla			
MEDIUM	1.598	1.010	0.481
LARGE	1.598	1.010	0.481
Ethnic Foods			
MEDIUM	0.697	0.438	0.200
LARGE	0.697	0.438	0.200
Jams/Jellies			
MEDIUM	0.186	0.120	0.067
LARGE	0.186	0.120	0.067
Mayonnaise and Dressings			
MEDIUM	0.201	0.130	0.071
LARGE	0.201	0.130	0.071
Soups			
MEDIUM	2.292	1.436	0.640
LARGE	2.292	1.436	0.640
Tomato-Starch-Cheese Canned Specialities			
MEDIUM	0.728	0.454	0.197
LARGE	0.728	0.454	0.197

TSS Effluent Limitations

Commodity (Specialties)	Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed	Average of daily values for entire discharge period shall not exceed
Metric units (kg/kkg of final product)			
English units (lb/1000 lb of final product)			
Added Ingredients			
MEDIUM	0.000	0.000	0.000
LARGE	0.000	0.000	0.000
Baby Food			
MEDIUM	0.818	0.444	0.264
LARGE	0.424	0.267	0.125
Chips			
Potato			
MEDIUM	2.784	1.596	0.896
LARGE	1.404	0.892	0.436
Corn			
MEDIUM	2.519	1.362	0.693
LARGE	0.031	0.662	0.350
Tortilla			
MEDIUM	3.119	1.733	1.007
LARGE	1.598	1.010	0.481
Ethnic Foods			
MEDIUM	1.326	0.698	0.428
LARGE	0.697	0.438	0.200
Jams/Jellies			
MEDIUM	0.404	0.270	0.129
LARGE	0.186	0.120	0.067
Mayonnaise and Dressings			
MEDIUM	0.432	0.284	0.138
LARGE	0.201	0.130	0.071
Soups			
MEDIUM	4.288	2.175	1.389
LARGE	2.292	1.436	0.640
Tomato-Starch-Cheese Canned Specialties			
MEDIUM	1.339	0.654	0.434
LARGE	0.728	0.454	0.197

For medium and large plants in all fruit, vegetable and specialty subcategories, pH shall at all times remain within the range of 6.0 to 9.5, and fecal coliform MPN shall remain less than 400 counts per 100 ml. For medium and large plants in the specialty product subcategories, oil and grease concentrations shall not exceed 20 mg/l. Within the vegetables segment, limitations for the cauliflower subcategory are in terms of kilograms (kg) of pollutants per 1000 kilograms (kkg) of final product. Within the specialties segment, the limitations for the soups subcategory are in terms of kilograms (kg) of pollutants per 1000 kilograms (kkg) of raw ingredients.

Any medium or large fruit, vegetable, or specialty product processing plant which continuously or intermittently discharges process wastewater during the processing season shall meet the annual average, maximum thirty day average, and maximum day effluent limitations for BOD_5 and TSS. Processing plants employing long term waste stabilization, where all or a portion of the process wastewater discharge is stored for the entire processing season and released at a controlled rate with state approval, shall meet only the annual average effluent limitations for BOD_5 and TSS.

IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Suggested BATEA for the 58 subcategories of the canned and preserved fruits and vegetables industry includes biological treatment, either aerated or aerobic lagoons or activated sludge, listed under the best practicable control technology currently available. It also may include the primary settling, air flotation, roughing filter, or nutrient addition for the appropriate industry subcategories under BPCTCA. See the individual treatment cost tables in Appendix C to determine the auxiliary components of each treatment chain. BATEA technologies, in addition to those included as part of BPCTCA, combine in-plant waste load reductions with improved end-of-pipe treatment. The only additional external treatment facility which may be needed is a multi-media filter to reduce effluent suspended solids for large plants. Disinfection is also included in BATEA.

The BATEA internal controls do not require major changes in existing processes for any subcategory. However, the controls require very strict management control programs over housekeeping and water use practices. Management must establish and encourage the adoption of water conservation practices, installation of waste monitoring equipment, improvement of plant maintenance, improvement of production scheduling practices, quality control improvement, finding alternate uses for products currently wasted, and improvement in housekeeping and product handling practices.

The following paragraphs describe several in-plant controls and modifications that may also be utilized to provide alternatives and trade-offs between controls and additional end-of-pipe effluent treatment.

- Recycle of raw material wash water. Solids removal and chlorination may be required. This step is presently being practiced at many plants.

- Utilization of low water usage peel removal equipment. Some of this equipment is being used, such as the rubber abrading system used for the removal of peels of several subcategories (dry caustic method).

- Utilization of low water use blanching methods. Several such methods are in the research and demonstration stage. (Ref. 48,49)

- Removal of solids from transport and slicing waters. Hydroclones or liquid cyclones can recover starch particles from potato chip wash water and particles from fruit slicing waters.

- Improved mechanical cleaning of belts to replace belt wash water.

- Recirculation of all cooling water through cooling towers or spray ponds. Cooling waters include barometric condensor water, can cooling water, freezer water, etc.

- Practice of extensive dry cleanup to replace washing and, where possible, use of continuous dry cleanup and materials recovery procedures. Push to-open valves need to be used wherever possible. Spray nozzles can be redesigned for lower water flow. Automatic valves that close when the water is not in use should be installed.

- Reuse of pickle fermentation and storage brine to eliminate the discharge of wastewater from salting stations. Presently under study in the industry.

Water usage and pollutant reductions resulting from BATEA internal controls were discussed in Section V. It must be emphasized that the BATEA water usage and pollutant levels are being achieved by many plants throughout the subcategories and by at least one plant in every subcategory. In fact, over 25 percent of the plants investigated in Section V have water usage data below the BATEA water usage.

It should be emphasized that the BATEA limitations are based on BPCTCA with internal management improvements and improved external treatment facilities. As mentioned previously, land treatment can also be utilized to achieve the limitations in instances where suitable land is economically available to the processor.

BATEA alternatives have been listed although none of these technologies nor other specific external facilities or internal controls are of themselves required. Due to economic, space, or other factors, many plants may choose to use any set of alternative internal and/or external technologies. Conversely, some plants may choose technologies and/or controls in addition to BATEA. A specific processing plant may select biological treatment, land treatment, or any other end-of-pipe or in-plant technology as the most effective method of meeting the limitations.

ENGINEERING ASPECTS OF CONTROL TECHNIQUE APPLICATIONS

The specified levels of effluent reduction are achievable because many plants throughout the industry subcategories are achieving the reduced water usage and because at least eleven treatment plants are currently operating at or below the specified effluent levels. The treatment systems include aerated or aerobic lagoons and activated sludge. Limitations including filtration as a part of BATEA are currently achieved by six industry plants. BATEA effluent levels are a result of three technologies: internal controls for reduced raw waste loads; improved operation of BPCTCA biological treatment; and multi-media filtration.

The rationale used for reducing water usage to help meet the BATEA guidelines is focused around the significant number of fruit and vegetable processing plants that currently achieve water usages less than the expected 1983 water use displayed in Section V. Over 25 percent of the plants investigated report water usages below the usages anticipated by BATEA. The 1983 water use figures and the minimum (1983) water usage figures on the subcategory raw waste summaries represent the mean log normal water usage minus one standard deviation. The ratios of minimum water use to average water use varied from subcategory to subcategory over a range of 0.22 to 0.88 with an average of about 0.55. Thus, it was concluded that a significant reduction in raw waste volume has already been achieved by many plants and can be achieved by other plants prior to 1983.

Based upon developments in in-plant controls and demonstrated raw wasteloads at some existing plants, it was concluded that flow reduction would be accompanied by a reduction in effluent BOD_5. There is less contact between product and water within the plant and there is increase effectiveness on the part of end-of pipe treatment facilities since they would handle lower volumes with the same size facilities.

From the discussion in Section V of subcategory raw waste load characterization, the actual flow, BOD_5 and TSS ratios selected for use in BATEA effluent limitation calculation were based upon analysis of the log mean raw waste loads of individual processing plants, rather than equally weighing each of the data samples for each plant in each subcategory. This approach was taken to insure that in every subcategory at least one processor would have a raw waste load presently equal to or less than the raw waste load determined to be achieved by other processors in that subcategory by 1983. These reduced raw waste load figures represent an average water usage reduction and an accompanying reduction in effluent limitations of about thirty percent of BPCTCA.

The rationale used for improving the performance of existing BPCTCA biological treatment systems to help meet the BATEA guidelines is based upon the Act and its legislative history. These documents call for the average performance of the best plants to serve as the basis for 1977 effluent limitations and the performance of the best plants to serve as the basis for 1983 effluent limitations. In Section IX, the 1977 limitations were developed utilizing a conservative approach so that twenty-two of twenty-seven industry plants would meet all of the 1977 effluent levels. The 1983 effluent levels were established based upon regression analyses performed for each treatment system on the influent raw waste BOD5 concentration versus the treated effluent annual average, maximum month and maximum day BOD5 and TSS concentrations. See Figures 18 to 23. The following equations represent the results of these analysis.

The annual average effluent BOD5 and TSS concentrations were expressed by the following relationship with the influent BOD5 concentration:

$$\text{Effluent BOD5} = 18 + .006 \text{ (Influent BOD5)}$$
$$\text{Effluent TSS} = 41 + .009 \text{ (Influent BOD5)}$$

The maximum thirty day effluent BOD5 and TSS concentrations were expressed as follows:

$$\text{Effluent BOD5} = 44 + .006 \text{ (Influent BOD5)}$$
$$\text{Effluent TSS} = 56 + .031 \text{ (Influent BOD5)}$$

The maximum day effluent BOD5 and TSS concentrations were expressed as follows:

$$\text{Effluent BOD5} = 71 + .008 \text{ (Influent BOD5)}$$
$$\text{Effluent TSS} = 126 + .029 \text{ (Influent BOD5)}$$

The regression analysis resulted in effluent concentrations which were the average of the twenty-seven treatment plants in the industry. All of the effluent levels for BOD5 and TSS are met by eleven of the twenty-seven plants and thus represent a reasonable and attainable improvement in BPCTCA biological treatment performances.

The annual average, maximum thirty day, and maximum day BOD5 effluent levels are met by seventeen biological treatment systems, including seven aerated lagoons (PE78, CO78, MU50, BN28, TO51, TO52 and PK60) and ten activated sludge plants (*C54, BN43, GN90, PO60, CT91, BN26, PR51, PN25, CS99 and TO99). The TSS effluent levels are met by twelve biological treatment systems, including five aerated lagoons (ST40, MU50, T051, TO52 and CH59) and seven activated sludge plants (*C54, BN43, PO60, CT91, BN26, PR51 and CS99). The eleven biological treatment systems, meeting all the BOD5 and TSS limitations include three aerated lagoons (MU50, TO51 and TO52) and eight activated sludge systems (*C54, BN43, PO60, CT91, BN26, PR51, CS99 and TO99).

As detailed above, the BATEA effluent levels result from internal controls and improved biological treatment performance plus multi-media filtration. Tertiary filtration has been successfully demonstrated at GR32 and has been installed in at least two other fruit and vegetable plants. The performance of plant GR32 is detailed in Table 92. The BOD5 and TSS concentrations prior to filtration are variable and are similar to the effluent levels observed from either aerated or aerobic lagoons or activated sludge. Thus, the filtered effluent levels should be achieved with either aerated or aerobic lagoons or activated sludge biological treatment. However, the 1983 effluent levels after multi-media filtration have been developed based on the regression analysis discussed above. It has been determined that the filter will add additional control over the biological system with the reduction of the TSS effluent concentrations to the same level as the BOD5 concentrations. The following equations represent the results of these determinations.

The annual average effluent BOD5 and TSS cocentrations were expressed by the following relationships with the influent BOD5 concentration:

Effluent BOD5 = 18 + .006 (Influent BOD5)
Effluent TSS = 18 + .006 (Influent BOD5)

The maximum thirty day effluent BOD5 and TSS concentrations were expressed as follows:

Effluent BOD5 = 44 + .006 (Influent BOD5)
Effluent TSS = 44 + .006 (Influent BOD5)

The maximum day effluent BOD5 and TSS concentrations were expressed as follows:

Effluent BOD5 = 71 + .008 (Influent BOD5)
Effluent TSS = 71 + .008 (Influent BOD5)

The results of this analysis resulted in effluent concentrations which are met by six treatment systems: MU50 is an aerated lagoon system without filtration; PR51 and CT91 are activated sludge plants without any polishing lagoons; *C54 and PO60 are activated sludge with polishing lagoons; and GR32 is activated sludge plus multi-media filtration.

The discussion in Section IV of this document dealt in part with potential economic impacts for various plant sizes. As a result of potential impacts on medium size plants, filtration has been eliminated. Therefore, only large plants will be required to comply with the limitations derived from the application of filtration to the effluent from biological treatment systems.

Processes Employed

All plants within each subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not alter the characteristics of the waste water generated. Application of the BATEA includes internal controls but does not require major changes in existing industrial processes for the subcategories studied. Several in-plant controls and modifications have been discussed. Strict water conservation and product handling practices, and good housekeeping and maintenance programs are currently available. The technology to achieve the 1983 raw waste loads is currently practiced by at least one plant within each subcategory studied. The concepts are reasonably proven, available and applicable to the wastes from the fruits, vegetables and specialties industry.

Total Cost of Application

Based on information contained in Section VIII of this report, the total investment cost to achieve the best available effluent limitations is estimated to be about $40 million. The associated annual cost would be approximately $10 million. These estimates assume no treatment currently in-place and include filtration only for plants greater than 9,080 kkg (10,000 tons) per year.

The total capital industry cost to meet both the BPCTCA and BATEA limitations with aerated lagoons is estimated to be about $64.5 million. The associated annual cost is estimated to be $17.6 million.

Non-Water Quality Environmental Impact

Total energy requirements for this industrial category to comply with the proposed BATEA regulations are approximately 0.45 million KWH/day. This is a very small portion of the total energy consumed by this industry for production.

Solid waste disposal is usually accomplished by landfill or spreading on agricultural land. An increasing portion of the solid waste by-products of production are being used primarily for animal feed, while reasearch into other methods of reuse is increasing. The disposal of solids generated by treatment systems should increase slighly but not create significant new disposal problems in terms of fill or land availability.

There are no known radioactive substances used in this industry. Noise levels associated with treatment systems are not significant. No significant air pollution problems have been identified for either processing or waste treatment or land disposal. Well designed and operated land disposal and biological treatment systems do not produce strong, offensive odors. No hazardous chemical are required as part of this treatment technology.

Factors To Be Considered In Applying BATEA Limitations

1. Land treatment by spray irrigation or equivalent methods providing minimal discharge should be encouraged.

2. The nature of biological treatment plant is such that on the order of four days may be required to reach the daily maximum limitation after initial start-up at the beginning of the processing season.

3. Thought was given to imposing a limitation upon TDS and chlorides, since these constituents are found in heavy concentrations in wastes from the subcategories which brine or pickle their product. These subcategories include sauerkraut, pickles, and olives. It is known that treatment technology exists to remove these constituents from the raw waste, but it is very costly. (Ref. 45,46,47) The potential harm to the environment from these constituents is entirely a function of their disposal location; e.g., chlorides and TDS cause no harm to ocean waters which already contain over 3 percent dissolved solids. It was decided, therefore, that the mandatory imposition of an expensive tertiary treatment system would not be reasonable. The individual permit writer, however, is alerted to the presence of high TDS and chlorides in wastes from these subcategories which must be evaluated with regard to their potential effect on the environment.

4. The major commodities comprising the canned and preserved fruits and vegetables industry have been described individually, and effluent limitations guidelines and standards have been recommended. Minor commodities such as artichokes, okra, and rhubarb, are typically processed in multi-product plants where their contribution to the annual raw tonnage or wastewater character is insignificant. It is estimated that minor commodities represent less than two percent of the canned and preserved fruits and vegetables. In order to develop effluent limitations guidelines and standards for the processing of minor commodities, review the process unit operations and wastewater characteristics for commodities described in this report. Select those major commodities which resemble the minor commodity in processing unit operation. Next select from this list of major commodities, the commodity which most closely resembles the minor commodity in wastewater volume and characteristics. This commodity and the minor commodity are similar. Thus, the effluent limitations guidelines should be similar in processing and waste volume and characteristics.

<u>Limitations for Multi-Commodity Plants</u>

The methodology outlined in Section IX is also applicable to calculation of BATEA limitations, and is therefore not repeated here.

SECTION XI

NEW SOURCE PERFORMANCE STANDARD

INTRODUCTION

The effluent limitations that must be achieved by new sources are termed performance standards. The New Source Performance Standards apply to any source for which construction starts after the publication of the proposed regulations for the Standards. The Standards are determined by adding to the consideration underlying the identification of the Best Practicable Control Technology Currently Available a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, New Source Performance Standards are based on an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives are considered. However, the end result of the analysis is to identify effluent standards which reflect levels of control achievable through the use of improved production in particular (as well as control technology), rather than prescribing a particular type of process or technology which must be employed. A further determination made is whether a standard permitting no discharge of pollutant is practicable.

EFFLUENT REDUCTION ATTAINABLE FOR NEW SOURCES

The effluent limitations for new sources are the same as those achievable by the best available technology economically achievable (see Section X). This limitation is achievable in newly constructed plants.

The in-plant controls and waste treatment technology identified in Section X are available now and applicable to new plants. Land disposal remains the most desirable disposal method. The land availability requirements for treatment can be considered in site selection for a new plant. Thus, land treatment will probably be the most attractive new source alternative.

The new source technology is the same as that identified in Section X. The conclusion reached in Section X with respect to the Engineering Aspects of Control Technique Application, Process Changes, Non-Water Quality Environmental Impact, Factors to be Considered in Applying BATEA Guidelines, and Limitations for Multi-Commodity Plants also apply to these New Source Performance Standards.

PRETREATMENT REQUIREMENTS

With proper pretreatment, where necessary, all effluents from plants within this industry are compatible with a well designed and operated publically owned activated sludge or trickling filter waste treatment plant. A judgement must be made, based on each individual plants circumstances, as to the type and degree of pretreatment necessary, if any, to protect the operation of the public treatment plant and the quality of its effluent. The industry and the municipalities are encouraged to seek together the most cost-effective solutions to problems on a case-by-case basis, and not rely on arbitrary "them and us" judgements.

The following waste constituents from this industry have the potential to adversely affect public treatment systems:

- Flow Volume - The industry is generally characterized by high volumes of waste discharged seasonally, and often with wide hourly fluctuations in flow volume. The effect of such volumes and fluctuations upon the municipal system depends upon the size of the municipality, type of municipal treatment plant, the presence of other high volume dischargers, and other factors. In troublesome cases, flow equalization, either at the industrial plant or the municipal plant, may be an answer. Installation of cooling towers to reduce high volume cooling water discharges is often done. This document and many literature sources also discuss various methods of in-plant flow volume reduction.

- Organic Strength - The industry generally discharges wastes with relatively high BOD5 concentrations. These soluable organics are amenable to biological treatment and should be entirely compatible with municipal treatment, provided the municipal system is designed with sufficient organic removal capacity to properly handle the imposed BOD5 load. In troublesome cases, pretreatment to remove BOD5 at the industry plant may be necessary, but this is generally not cost-effective because the same waste is being treated twice. An industry financed expansion of the municipal treatment plant may be a better answer. In any case, arbitrary sewer discharge BOD5 limits should generally be avoided unless absolutely necessary. Such limits may create an impossible economic and technical situation for the processing plant which discharges a high strength waste.

- pH - Most municipalities impose pH limits upon industrial dischargers as required to protect the collection system, and maintain pH into the municipal treatment facilities within ranges compatible with good biological treatment. Plants in this industry which lye peel may discharge wastes with high pH. Conversely, some fruits are acidic and their processing produces a low pH waste.

- Oil and grease - A few subcategories of this industry discharge relatively high concentrations of oil and grease. This may be regulated as necessary to protect the collection system against stoppages and occasionally even to protect the treatment system unit processes if grease build-up has become a problem.

TDS and Chlorides - Several subcategories of this industry use a brining process which generates a waste with high concentrations of chlorides and other dissolved inorganic chemicals. These pass through a biological municipal treatment system and may degrade receiving waters, depending upon the nature of the receiving waters, the dilution in the municipal system, and other factors. Whether a municipality should accept high concentrations of TDS should be decided on a case-by-case basis.

SECTION XII

ACKNOWLEDGEMENTS

The Environmental Protection Agency wishes to acknowledge the contributions to this project by Stearns, Conrad, and Schmidt Consulting Engineers, Inc., Long Beach, California. The work at SCS was performed under the direction of Mr. Curtis J. Schmidt, Jr., Project Manager, and assisted primarily by Ken LaConde and Chip Clements. Subcontractors were Environmental Associates, Inc., Corvallis, Oregon, Environmental Science and Engineering, Gainesville, Florida, and Aqua - Tech Laboratories, Inc., Portland, Oregon. Technical guidance was provided by Dr. Wayne Bough, Dr. William Boyle and Mr. Paul Miller.

Various industry organizations also contributed greatly to this study. Of special help were the National Canners Association; American Frozen Foods Institute; Pickle Packers International, Incorporated; The National Kraut Packers Assciation, Inc.; The Potato Chip Institute; The Dried Fruit Association; and the American Dehydrators of Onion and Garlic Association. Special appreciation goes to the more than 300 processing plants nationwide that provided information essential to the study.

Appreciation is expressed to those in the Environmental Protection Agency who assisted in the preparation and completion of of this project: John Riley, George Keeler, Harold Thompson, Acquanetta Delaney, Doris Clark, Barbara Wortman, and Kay Starr. The contributions and assistance of Dr. Raymond D. Loehr, Program Advisor, are gratefully acknowledge. Special thanks are due Ken Dostal for his guidance and Fred Zaiss for his assistance.

SECTION XIII

REFERENCES

1. Bough, W. A. and A. F. Badenhop, "A Comparison of Roasting vs Lye Peeling of Pimentos for Generation of Wastes and Quality of Canned Products," Journal of Food Science (in Press), 1974.

2. Wastewater Treatment and Reuse by Land Application, EPA, Washington, D.C., 1973.

3. Fisk, W. W., "Food Processing Waste Disposal," Water and Sewage Works, III, No. 9, pp. 417-420 (1964).

4. Bouwer, H., "Renovating Secondary Effluent by Groundwater Recharge with Infiltration Basins," Presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland, Pennsylvania State University, University Park, Pa. (August, 1972).

5. Dunlop, S. G., "Survival of Pathogens and Related Disease Hazards," Proceedings of the Symposium on Municipal Sewage Effluent for Irrigation, Louisiana Polytechnic Institute, July 30, 1968.

6. Wastewater Treatment and Reuse by Land Application, loc. cit.

7. Dunlop, loc. cit.

8. Ibid.

9. Reid, S., et. al, Wastewater Management by Disposal on the Land, National Technical Information Service, 1972.

10. O'Leary, P. R., and R. Berner, Study of Fill and Draw Cannery Lagoon Operations in Wisconsin (An Unpublished Interim Report), Dept. of Natural Resources, Madison, Wisc., 1973.

11. Porges, Ralph, "Industrial Waste Stabilization Ponds in the United States," Journal of Water Pollution Control Federation, 35, 1963.

12. Missouri Basin Engineering Health Council, "Waste Treatment Lagoons--State of the Art," EPA Project No. 17090EHX, Cheyenne, Wyo., July, 1971.

13. Parker, C.D., Food Cannery Waste Treatment by Lagoons and Ditches at Shepparton, Victoria, Australia, 21st Industrial Waste Conference, Purdue University, Lafayette, Ind., 1966.

14. Eckenfelder, W. W. Jr., and D. J. O'Connor, "Treatment of Organic Wastes Aerated Lagoons," Journal of Water Pollution Control Federation, 32 (4), p. 365, 1960.

15. Dunlop, loc. cit.

16. Filbert, J. W., "Other Treatment Methods for Potato Wastes," Proceedings of a Symposium on Potato Waste Treatment, FWPCA and University of Idaho, 1968.

17. Graves, L. M., and R. W. Keuneman, "Primary Treatment of Potato Processing Wastes with By-Product Feed Recovery," 41st Annual Conference, Water Pollution Control Federation, Chicago, Ill., Sept., 1968.

18. Wolski, loc. cit.

19. Streebin, Leale E., George W. Reid, and C. H. Hue, Demonstration of a Full-Scale Waste Treatment System for a Cannery, EPA, Water Pollution Control Research Series, 12060 DSB, 1971.

20. National Canners Association, "Waste Reduction in Food Canning Operations," FWPCA, Water Pollution Control Project Series, 1970.

21. Parker, et. al, "Unit Process Performance Modeling and Economics for Canning Waste Treatment," 23rd Industrial Waste Conference, Purdue University, Lafayette, Ind., 1969.

22. U. S. Dept. of the Interior, Summary Report: Advanced Waste Treatment, 1967.

23. Water Pollution Control Federation, "Sludge Dewatering," WPCF Manual of Practice, No. 20, Washington, D.C., 1969.

24. Richter, Glenn A., Aerobic Secondary Treatment of Potato Processing wastes, Proceedings of First National Symposium on Food Processing Wastes, EPA, Portland, Ore., 1970.

25. Los Angeles County, Dept. of County Engineer, "Summary Report: Wastewater Reclamation Project for Antelope Valley Area," Downey, Calif., Oct., 1971.

26. Capital and Operating Costs of Pollution Control Equipment Modules, Vol. I and II, Office of Research and Development, EPA, Washington, D.C., July, 1973.

27. Ibid.

28. Ibid.

29. Development Document for Effluent Limitations Guidelines and Standards of Performance for the Canned and Preserved Fish and Seafood Processing Industry, EPA, Washington, D.C., July, 1973.

30. Ibid.

31. Harnish and Lookup Associates, "Wastewater Facilities Report for Welch Foods, Inc., Brocton, N.Y.," April, 1973.

32. Smith, Robert, "Cost of Conventional and Advanced Treatment of Wastewater," Journal of Water Pollution Control Federation, 40, p. 1546.

33. Eckenfelder, W. W., and C. E. Adams, "Design and Economics of Joint Wastewater Treatment," ASCE, Journal of Sanitary Engineering Division, Feb., 1972.

34. "Electrical Power Consumption for Municipal Wastewater Treatment," NERC Office of Research and Development, EPA, Cincinnati, Ohio, July 1973.

35. Smith, loc. cit.

36. NERC, loc. cit.

37. Ibid.

38. Hittman Associates, Inc., "Electrodialysis Plant Monograph Booklet," U.S. Dept. of the Interior, OSW, August, 1970.

39. Ibid.

40. Ibid.

41. Eckenfelder, W. W. and D. J. O'Connor, Biological Waste Treatment, Pergamon Press, New York, 1961.

42. Ibid.

43. Ibid.

44. Ibid.

45. "Reconditioning of Food Processing Brines," National Canners Association Research Foundation, Western Regional Laboratory, Water Quality Office, EPA, March, 1971.

46. Henne, R. E., and F. R. Geisman, "Recycling Spent Cucumber Pickling Brines," Proceedings of Fourth National Symposium Food Processing Wastes, Syracuse, N.Y., March, 1973.

47. Lowe, E., and E. L. Durkee, "Salt Reclamation from Food Processing Brines," Proceedings of Second National Symposium on Food Processing Wastes, Denver, Colo., March, 1971.

48. Lund, Daryl B., "Impact of the Individual Quick Blanch Process on Cannery Waste Generation," Proceedings of Fourth National Symposium on Food Processing Wastes, Syracuse, N.Y., March, 1973.

49. Ralls, Jack W., *et. al.*, "In-Plant Hot Gas Blanching of Vegetables," Proceedings of Fourth National Symposium on Food Processing Wastes, Syracuse, N.Y., March,1973.

50. Middlebrooks, E.J., *et. al.*, "Upgrading Wastewater Stabilization Ponds to Meet New Discharge Standards," Sumposium Proceedings, Utah State University, Logan, Utah, August 21-23, 1974.

51. Middlebrooks, E.J. *et. al.*, "Evaluation of Techniques for Algae Removal from Wastewater Stabilization Ponds," Utah State Univerity, Logan, Utah, January, 1974.

52. "Direct Filtration of Secondary Effluents," EPA Technology Transfer Design Seminar, Orlando, Florida, May 7-9, 1974

53. Dryden, Frank, and Gerald Stern, "Phosphate Reduction for Limiting Algae Growth in Lakes of Renovated Wastewater", Paper Presented at American Chemical Society Meeting, New York City, September 15, 1966.

54. *Extended Aeration Sewage Treatment in Cold Climates*, Report No. EPA-660/2-74-070, Environmental Protection Agency, Washington, D.C., December, 1974.

55. *International Symposium on Water Pollution Control in Cold Climates*, Report No. 16100 EXH 11/71, Environmental Protection Agency, Washington, D.C., November, 1971.

56. *Biological Waste Treatment in the Far North*, Federal Water Quality Administration, Report No. 1610---06/70, Washington, D.C., June, 1970.

57. *Process Design Manual for Suspended Solids Removal*, Technology Transfer Program, Environmental Protection Agency, Washington, D.C., October, 1971.

58. Johnson, R. D., *et. al.*, "Selected Chemical Characteristics of Soils, Forages, and Drainage Water From the Sewage Farm Serving Melbourne, Australia," U.S. Dept. of the Army, Corps of Engineers, Washington, D.C. January 1974.

NON-INDEXED REFERENCES

Westminster, Md., Edward E. Judge and Sons, Inc., 1973.

Canned Fruits and Vegetables, Census of Manufactures, U.S. Dept. of Commerce, 1972.

Canned Specialties, Census of Manufactures, U.S. Dept. of Commerce, 1972.

Cherries, Statistical Reporting Service, Washington, D.C., 1973.

Frozen Food Pack Statistics, American Frozen Food Institute, Washington, D.C. 1974.

Liquid Wastes from Canning and Freezing Fruits and Vegetables, National Canners Association, 1971.

Methods of the Chemical Analysis of Water and Wastes, Environmental Protection Agency, Washington, D.C., 1971.

Non-Citrus Fruits and Nuts, Statistical Reporting Service, Washington, D.C., 1974.

Pickles, Sauces, and Salad Dressing, U.S. Census of Manufactures, U.S. Department of Commerce, 1972.

Standard Industrial Classification Manual, Executive Office of the President, Office of Management and Budget, 1972.

Standard Methods for the Examination of Water and Wastewater, 13th edition, 1971.

Water Quality Criteria - 1972, Environmental Protection Agency, Washington, D.C., 1973

SECTION XIV

GLOSSARY

Activated Sludge Process - A biological wastewater treatment process in which a mixture of wastewater and biological organisms called activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater by sedimentation and wasted or returned to the process as needed.

Adiabatically - Physically changing without gain or loss of heat.

Aerobic - Living or active in the presence of free oxygen.

Aerobic-Facultative Lagoon - A wastewater treatment pond employing mechanical surface aerators which produces aerobic zones around the aerators and allows solids to settle out in quiescent areas.

Algorithms - A system of mathematical steps which is to be followed in prescribed order for solving a specific type of problem.

Alkalinity - Measure of the ability of the wastewater to produce hydroxyl ions to react with acidic materials and neutralize them. Generally expressed in mg/l as calcium carbonate.

Anaerobic - Living or active in the absence of free oxygen.

Anionic Polymer - Organic compounds characterized by a large moleculr weight and a net negative charge, formed by the union of two or more polymeric compounds. Certain polymers act as coagulants or coagulant aids. Added to wastewater, they enhance settlement of small suspended particles. The large molecules attract the suspended matter to form a large floc.

Anode - The positive pole of an electrode or conducting terminal.

Aquifer - A bed of permeable rock, sand, or other porous substances which contain water in recoverable quantities.

Bacterial Metabolism - The chemical change, constructive and destructive, occurring in bacteria.

Best Available Technology Economically Achievable (BATEA) - Treatment and control required by July 1, 1983, for industrial discharges to surface waters as defined by Section 301(b)(2)(A) of the Act.

Best Practicable Control Technology Currently Available (BPCTCA) - Treatment and control required by July 1, 1977, for industrial discharges to surface waters as defined by Section 301(b)(1)(A) of the Act.

BOD - Biological 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 microorganisms to oxidize the contaminants of water samples under standard laboratory conditions.

BOD5 - A measure of the oxygen consumption of aerobic organisms incubated for five days at 20°C.

Blowdown - A discharge of water from a recirculating system to prevent a buildup of dissolved solids and/or other contaminants.

Brackish Water - A mixture of salt water and fresh water; e.g., with TDS levels from 300 to 30,000 mg/l.

Carbon Adsorption - The separation of small waste particles and molecular species, including color and odor contaminants, by attachment to the surface and open pore structure of carbon granules and powder. The carbon is "activated" or made more adsorbent by treatment and processing.

Cathode - The negative pole of an electrode or conducting terminal.

Cationic Polymer - Same properties and uses as an anionic polymer, except that it carries a net positive charge.

Cell Synthesis - The formation of new cells by bacteria.

Chemical Precipitation - A waste treatment process whereby substances dissolved in wastewater are rendered insoluble and form a solid phase which can be removed by flotation or sedimentation techniques.

Chloramines - Compounds obtained by chlorine disinfection from the action of hypochlorite solutions (weak acidic easily decomposed) on compounds containing NH and NH(2) groups.

Clarification - Process of removing undissolved materials from a liquid. Specifically, removal of solids either by settling or filtration.

Clarifier - A settling basin for separating settleable solids from wastewater.

Coagulation - The mutual attraction and coalescence of oppositely charged colloids to produce a (usually gelatinous) precipitated phase. In water treatment, the addition and subsequent hydration of oxides of aluminum or iron produce positively charged colloids which can be used to remove negatively charged organic colloids.

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.

Coliform - Gram negative, non-spore forming bacilli that ferment lactose with the production of acid and gas and are found primarily in the intestines of man and animals.

Colloidal Particles - Suspended particles in a liquid mixture which have an extremely slow rate of sedimentation.

Cooling Tower - A device for cooling water by spraying in the air and trickling over slats.

Cull - Product which is picked or sorted from the rest because it is poor in quality or defective.

Deaeration - Removal of oxygen from commodities (juices or fruit slices) to prevent adverse effects on properties of the final products by aerobic decomposition.

Desiccate - To dry; to dehydrate as a food.

Denitrification - The process involving the facultative conversion of anaerobic bacteria of nitrates into nitrogen and nitrogen oxides.

Detention Time - The dwell time of wastewater in a treatment unit. Alternately called retention time.

Digestion - The biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization.

Dissolved Air Flotation - A process involving the compression of air and liquid, mixing to super-saturation, and releasing the pressure to generate large numbers of minute air bubbles. As the bubbles rise to the surface of the water, they carry with them small particles that they contact. The process is particularly effective for grease removal.

D.O. - Dissolved Oxygen is a measure of the amount of free oxygen in a water sample.

Effluent - Wastewater or other liquid, partially or completely treated or untreated, flowing out of a process operation, processing plant, reservoir, basin, or treatment plant.

Electrodialysis - A physical separation process which uses membranes and applied voltages to separate ionic species from water.

Eutrophication - Applies to aging of a lake or pond due to the addition of dissolved nutrients.

Evapotranspiration - Water withdrawn from the soil by evaporation and plant transpiration.

Extended Aeration - A form of the activated sludge process which provides for long retention time of wastewaters in the presence of activated sludge and air, usually for greater than 24 hours.

Fecal Coliforms - Coliform bacteria that are derived from the intestinal tract of man and warm blooded animals.

Fescue - Grasses cultivated for meadows or lawns.

Filtration - Removal of solid particles from liquid or particles from air or gas stream by passing the liquid or gas stream through a media with small openings.

Floc - A mass formed by the aggregation of a number of fine suspended particles.

Flocculation - Small coagulated particles become accreted to form larger, more precipitable structures. This process is promoted through the use of chemical coagulants, adjustment of the physical or chemical condition of the system, or biologically through microorganism growth and activity.

Flume - Conduit or chute for conveying water or matter in water.

Ion Exchange - A reversible chemical reaction between a solid and a liquid by means of which ions may be interchanged between the two. It is in common use in water softening and water deionizing.

Influent - A liquid which flows into a containing space or process unit, usually untreated or partially treated wastewater.

IQF - A process for very rapid freezing of fruit or vegetable products.

KWH - Kilowatt-hours, a measure of electrical energy consumption.

Lagoon - A large pond used to hold wastewater for stabilization by natural processes.

Leach - To subject to the action of percolating water or other liquid in order to separate soluble components. To cause water or other liquid to percolate.

Make-up Water - Fresh water added to process water to replace system losses; e.g., blowdown, evaporation, etc.

Mixed Liquor - A mixture of sludge and wastewater in a biological reaction tank undergoing biological degradation in an activated sludge system.

Nitrate, Nitrite - Chemical compounds that include the NO(3) - (nitrate) and NO(2) - (nitrite) ions.

Nitrification - The process of oxidizing ammonia by bacteria into nitrites and nitrates.

Osmosis - Diffusion of a solvent through a semi-permeable membrane into a more concentrated solution, tending to equalize the concentrations on both sides of the membrane.

Orthololidine Residual - A measure of chlorine residual left in treated water after application of chlorine.

Parameter - A derived constant for expressing performance or for use in calculations.

Pathogen - A parasite producing damage in its host; any disease producing microorganism.

Percolation - The movement of water through the soil profile.

pH - A measure of the relative acidity and alkalinity of water. A pH value of 7.0 indicates a neutral condition; less than 7 indicates a predominance of acids, and greater than 7 indicates a predominance of alkalis.

Pneumatic Transport - A system by which loose material is conveyed through tubes by air in motion. May be by positive (forced air) or negative (vacuum) pressure.

Polyelectrolyte - A synthetic or natural polymeric material in which the monomeric unit features an ionized group. Depending on the nature of the latter, a polyelectrolyte may be cationic, anionic, or amphoteric (e.g., proteins). When dispersed, such materials can undergo coagulation with oppositely charged colloids.

Ponding - A waste treatment technique involving the storage of wastewaters in a confined space with evaporation and percolation the primary mechanisms operating to dispose of the water.

Precipitation - The phenomenon that occurs when a substance held in solution in a liquid passes out of solution into solids form.

Primary Waste Treatment - Processes which remove the material in wastewater that floats or will settle. It is accomplished by using screens, tanks for the heavy matter to settle in, and/or dissolved air flotation tanks.

Raw Waste - The wastewater effluent from the fruit or vegetable processing plant prior to treatment.

Receiving Waters - Rivers, lakes, oceans, or other water courses that receive treated or untreated wastewaters.

Retort - Sterilization of food product by cooking, usually with steam under pressure.

Reverse Osmosis - The physical separation of substances from a water stream by reversal of the normal osmotic process; i.e., high pressure, forcing water through a semi-permeable membrane to the pure water side leaving behind a more concentrated waste.

Secondary Treatment - The second step in most waste treatment systems during which bacteria consume the dissolved organic portion of the wastes. It is accomplished by bringing the wastewater and bacteria together under controlled conditions conducive to good bacterial metabolism.

Sedimentation - In wastewater treatment, gravity separation of suspended solids.

Sludge - The solid matter that settles to the bottom of sedimentation tanks.

Slurry - A solids-water mixture with sufficient water content to impart fluid handling characteristics to the mixture.

Spray Irrigation - A method of land application by which wastewater is sprayed from nozzles onto land.

Sump - A chamber into which water can drain and from which it can be pumped periodically.

Suspended Solids - Solids that either float on the surface of or are in suspension in water and which are largely removable by laboratory filtering as in the analytical determination of SS content of wastewater.

Symbiosis - Two organisms living together in a complementary manner to aid the living processes of each.

Tertiary Waste Treatment - Waste treatment systems used to treat secondary treatment effluent and typically using physical-chemical technologies to effect additional waste reduction. Synonymous with advanced waste treatment.

Total Dissolved Solids-TDS - The solids content of wastewater that is soluble and is measured as total solids content minus the suspended solids.

Total Kjeldahl Nitrogen - A measure of the total amount of nitrogen in the ammonia and organic forms in wastewater.

Trickling Filter - A bed of rocks or artificial media over which the wastewater is trickled so the bacteria can break down the organic wastes. The bacteria grow on the media.

Wet Well - A collection chamber from which a pump obtains the water it pumps.

Zero Discharge - The discharge of no pollutants into a receiving body of water. Attainable by treatment to levels beyond analytical detection, or by land treatment (elimination of all direct hydraulic discharge).

Zoogleal Film - A jelly-like mass or aggregate of bacteria formed in trickling filters or other treatment devices.

METRIC UNITS

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F°	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

* Actual conversion, not a multiplier