Part 1 of 3

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Water Use Efficiency Report for California League of Food Processors

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Table of Contents

List of Tables

List of Figures

List of Appendices

Section 1: Background and Introduction

1.1 Introduction

This report prepared on behalf of the California League of Food Processors (CLFP) documents the California food processing industry's progress towards improving its overall water footprint. This document compiles industry information from multiple sources with a goal to identify water use efficiency over time. Appropriate water use metrics are identified and baseline years are referenced. Additionally, this document identifies possible measures for individual food processing facilities to consider for implementation so that there is continued improvement in water use efficiency.

This Water Use Efficiency Study also responds to SBX7-7 and the recent release of the Commercial, Industrial, and Institutional Task Force Water Use Best Management Practices Report to Legislature (CII Task Force Report, October 2013).

1.2 Objectives

This study's primary goal is to document the California food processing industry's water efficiency over time by identifying appropriate metrics and baseline values. This study also provides an evaluation of water use in food processing facilities and an assessment of whether usage has become more efficient over time and what has possibly led to the increase in efficiency. Conservation measures, practices and technologies are compiled and presented for consideration. In addition, the study also provides an assessment of whether past changes in water policies or laws may have had an impact on total industry water use.

1.3 California League of Food Processors

Established in 1905, the CLFP represents the business interests of California's food processing industry. CLFP member companies are primarily canners, freezers, dryers, and dehydrators of fruits and vegetables. Additional processor members include snack foods, juice bottlers, and specialty processors of a variety of food products. Members operate over 150 processing plants located throughout the State of California. In addition to the active company membership, over 250 affiliate members - industry suppliers - are participants in CLFP.

CLFP furthers the interests of the food processing industry before the State Legislature and regulatory agencies, and is also a major representative for the California industry at the Federal level. CLFP's purpose is to foster a favorable environment for the growth and strength of the industry within the state. In doing so, California processors can continue to provide consumers with safe and wholesome food produced in an environmentally sound and responsible manner.

Section 2: Research Scope and Design

A literature survey and a survey of CLFP member companies were conducted. This section describes how information and data collected from these surveys were compiled and evaluated in order to identify and propose selection of the appropriate water use metrics for food processors. The surveys were also used to identify and compile best management practices (BMPs) for water use efficiency.

2.1 Literature Survey

A literature survey was conducted to identify publications that address water use and BMPs by food processors. In all, 60 documents spanning six decades were reviewed with the goal of compiling information on food processors' water use, metrics, and baseline water use as well as BMPs. Appendix A provides a bibliography of the references reviewed. The results of the literature survey are described below.

2.1.1 Metrics and Water Use Data

Food processors' water use information has been collected and published since the mid-twentieth century. Publications from the 1960s to the early 1980s contain significant metric and water use data that were collected by government agencies through extensive surveys of food processors. In these decades, manufacturers shared their water use data with the US Environmental Protection Agency (EPA) and the CA Department of Water Resources (DWR).

By the 1980s, this type of public agency-led research appears to have tapered off and industry sponsored surveys became more prevalent in the 1990s. Because information collected by industry typically remains privately-held, more recent publications seem to continue to rely on early work. For example, the 2007 version of the Water Encyclopedia continued to rely on water use data from Kollar's work (AWWA, 1980). Today, industry associations continue to take the lead, such as this study, in collecting water use information from food processors.

Publications by conservation specialists (e.g., Pacific Institute, CII Task Force, etc.) seem to rely on more recent data. It appears looking any earlier than the previous five years for information was not relevant for this work. As an example, the references in Section 5 (Water Use Metrics and Data Collection) of the CII task force document, the section on providing an approach to establish metrics for evaluating water use efficiency, are dated 2007 to 2011. The use of more recent reference material in the CII document may also be because the authors were more focused on Best Management Practices (BMPs) than on water usage statistics.

The literature review showed a progression from an abundance of publically available data in the 1960s to much less available data in the twenty-first century. As a result, only ten out of 60 of the resources reviewed proved relevant to this study. These ten references are listed in Appendix B. The relevant data table from these publications are re-printed in Appendix C.

Although these ten documents had some useful information, it remains difficult to compare data across publications and year. For example, the DWR Bulletin 124 focuses on the supply water into facilities while the EPA publications concentrate on process wastewater, with limited information on water supply. The difference in focus is attributed to EPA needing to establish wastewater discharge limits (the Clean Water Act was promulgated in 1972) and the DWR managing California's water supply resources.

Another issue that makes comparisons between publications difficult is that researchers normalized the water use data differently. Some publications have metrics that normalize water use (or wastewater flow) to units of raw product processed (EPA 1977, EPA 1983, and FEIC 1996); some to units of finished production (Kollar 1980, Water Encyclopedia 1983, Kreith 1993); while DWR Bulletin 124 compares water use to square-foot of water using area and to average-employee-day.

Of the publications listed in Appendix B, the following were selected to evaluate the water use efficiency of food processors over time: EPA (1977), DWR (1979), Kollar (1980), EPA (1983), Water Encyclopedia (1983). These sources are supplemented by data collected through 2011 and 2014 surveys of CLFP member companies as discussed below in Section 2.2.

2.1.2 Best Practices in Water Efficiency

The literature was also reviewed to identify best practices for water use within food processing facilities. As with the metrics data, when reviewing 50 years of documents, historical trends become apparent.

Water conservation activities in the pre-1990 publications focused almost exclusively on water reuse and recirculation. Many publications distinguished between "high efficiency" plants and conventional plants. In the 1990s, literature was addressing other forms of water efficiency in manufacturing plants such low flow nozzles, clean-up procedures, and improved controls. Also, in the 1990s, there were a number of pilot tests evaluating the effectiveness of membrane applications to increase the ability to reuse water between processes. Since the 1990s, advances in membrane technologies, including reverse osmosis and nanofiltration, have allowed these technologies to play a larger role in water use efficiency.

In the first decade of the twenty-first century, there was a significant change in approach. BMPs were incorporated into, and considered part of, a process of self-improvement. Examples include Queensland Eco-Efficiency Toolkit (2004) and EBMUD's Water Smart Guidebook (2008), Comprehensive Guide to Sustainable Management of Winery Water (2008).

BMPs continue to evolve. The Commercial, Industrial, and Institutional Task Force Water Use Best Management Practices Report to Legislature (CII Task Force Report, October 2013) has a few pages dedicated to the specific best practices for food processing. This section of the CII Report has only one reference. However, other sections of the CII Report have extensive references.

Researches such as Gour Choudury, PhD are developing technologies to replace and improve existing water using processes. For example, Dr. Choudury and his team has developed, piloted, and patented a new lye-peeling system that significantly reduces water use in fruit processing. The new system employs a fluid mixture of liquid and gas to remove skin from the fruit. However, the high cost of converting a facility over to the new system is a challenge. Dr. Choudury continues to test concepts that reduce water use in other phases of fruit processing. This includes improved cleaning and sanitation processes that reduce water use and reduce salts in the process wastewater streams.

This historical perspective of Water Conservation BMPs within the food processing industry is summarized in Table 1.

Table 1 - Historical Overview of Best Management Practices

Timeframe	Best Management Practice
1960s - 1980s	• BMPs focused on opportunities to reuse water within specific processes.[(a)]
1990s	• BMPs started to include tools and practices like nozzles, clean-up procedures, and improved controls. • Pilot studies in the 1990s focused on testing membrane technology in process water streams to be able to increase water reuse, to reduce effluent, and to conserve water.[(b)]
2000 - 2010	• BMPs are incorporated into, and considered part of, a process of self-improvement.
2014	• The CII Task Force Report provides a compendium of BMPs. • Gour Choudhury's recent work that pushes beyond typical tools.

Notes:

(a) *Recycling* typically refers to reusing water within the same process.
(b) *Reusing* water typically indicates capturing water from one process for reuse in another process.

2.2 CLFP Member Survey

CLFP member companies participated in two water use surveys. The fist was distributed in April of 2011 and the second in May of 2014. These surveys are discussed below and Appendix D contains copies of both.

2.2.1 2011 CLFP survey

2.2.1.1 2011 Survey Design and Methodology

CLFP distributed a Water Use Survey to its member companies in 2011 in response to Senate Bill X7-7 (SBX7-7). SBX7-7 was enacted in 2009 and requires a statewide 20% reduction in water use by 2020. As part of the legislation, a task force was formed to develop BMPs for the CII sector and to determine the potential water savings from those BMPs. Through the 2011 survey CLFP was hoping to gather information on member companies' water usage and conservation effort. Table 2 shows the rate of response among the member companies.

Table 2 - Number of Respondents to 2011 and 2014 CLFP Surveys

	2011	2014
Tomato Processors	13	11
Dairy Processors	2	1
Dehydrators	3	10
Olive Processors	2	2
Fruit Processors	4	4
Vegetable Processors	4	0
Soup Processors	1	0
Nut Processors	0	1
Total Respondents	29	29
Number of respondents who participated in both surveys = 16		

2.2.1.2 2011 Survey Results

Overall, the 2011 responses from CLFP members mirrored information gleaned from the literature – there is a high rate of water reuse among the respondents, water conservation is important to most, and the majority of the facilities had implemented low flow nozzles, written clean-up procedures, and improved controls since 2006. As in the literature review (Table 1, above), the survey responses shows that recycling (i.e., reusing water within the same process) and reuse (i.e., capturing water for reuse in another process) have been important factors in overall water use efficiency for decades. The CLFP surveys do not distinguish between recycling and reuse. Rather, the surveys try to determine if respondents use water more than once within their facilities.

Most of the respondents use water on-site at least twice. Question number 23 on the 2011 survey asks “what percentage of your total process water did you reuse on-site for processing activities.” A summary of the responses to this question is as follows:

- Fifteen respondents identified the percentage of water reuse at their facility.
- Eleven respondents indicated that there was some reuse at their plant, but because it was unmetered, they could not provide an estimate.
- Only three of the 29 respondents indicated no reuse within the plant.
- All the tomato processors responding to the survey indicated some reuse within the plant.
- Many reuse the water for irrigation of crops.

A key point raised in the 2011 survey is that many of the dairy and tomato processors extract a portion of their water supply from the raw product. The general public is likely unaware of this opportunity to recover water from processing of tomatoes and milk. With the appropriate treatment, this water can be extracted and put to use within the plant. However, the water treatment can have high capital and operating costs depending upon the ultimate use.

Most (90%) respondents indicated their facility had water conservation programs and within the previous five years many had taken some steps to improve water use efficiency: 76% had replaced high volume hoses with high pressure; half had improved clean-up procedures, a third had installed low-volume cleaning systems, and almost a third converted cleaning and sanitizing systems to ozone.

Just over half of respondents rated water conservation as a high priority and had set water efficiency improvement goals ranging from 5% to 20%. However, only a quarter of the facilities conducted a comprehensive facility water usage assessment.

2.2.2 2014 CLFP Survey

A follow-up survey was developed and distributed to CLFP member companies in 2014. A copy of the survey is provided in Appendix D and Table 2 (above) shows the rate of responses. Combined, the two surveys provide water use and facility data for the period spanning 2006 to 2013.

2.2.2.1 2014 Survey Design and Methodology

The 2011 Survey was used as a base to develop the 2014 survey questionnaire. Some questions were slightly altered, some new questions were added, and other questions remain unchanged. Based on the insights gained in the literature survey and from the 2011 CLFP survey, it was apparent that the new survey should continue to request information on water reuse within the facility, water sourced from raw materials and other water efficiency practices. Thus, the 2014 Survey was developed to collect the following information:

- Facility general information
- Water use, products processed, discharge for 2009 - 2013
- Water supply, metering, costs
- Water use breakdown by area
- BMPs, recycling
- Future conservation
- Plans, factors, needs

The survey included direct questions, data entry tables, check boxes, and relative rankings.

2.2.2.2 2014 Survey Results

The 2014 survey responses confirm and augment findings from the literature survey and the 2011 CLFP survey. Responses indicated a high rate of water reuse and a desire to increase the water reuse opportunities within the plant (i.e., using water more than once via recycling, recirculation or reuse). Additionally, most had not only identified water conservation as a priority, but also identified several “next steps” for increasing water use efficiency.

As with the 2011 survey, the 2014 survey responses indicated widespread in-plant recycling and reuse to minimize fresh water intake. Examples include:

- Cooling water for sanitation, cleaning spray, flume make-up
- Flumes to other flumes
- Cooling tower to flumes, condensers, vacuum pumps
- Steam condensate to boilers
- Cooler to cooling tower

- Retort to cooling tower
- Facility to irrigation

In all, 18 respondents identified some form of in-plant recycling, including all eleven tomato processors. The lower rate of reuse among the 2014 survey respondents compared to the 2011 survey (62% of respondents versus 90%) is due to fewer tomato processors, fruit processors, and vegetable processors participating in the 2014 survey and the increased participation by dehydrators. See Table 2, above, for participants by category.

The 2014 survey also confirmed that tomato processors are using water extracted from raw products. Tomato-sourced water is used by the respondents for the following processes:

- Process condensate to flume
- Evaporate condensate to rotary screen cleaning sprays
- Condensate to boilers

Question 12 of the 2014 survey asked companies to estimate the percentage of process water consumed for nine different water using activities. Based on the responses shown in Table 3, the percentage used for each activity varies significantly from facility to facility. The variation is due: (a) to different rates of reuse/re-circulation among facilities; and (b) differing abilities to extract water from the raw product for use. Also, the eleven tomato processors responding to the survey produce different finished products – some make pastes while other are canning. It is also suspected that, without submeters, many respondents were estimating the percentage allocation among processes.

Table 3 - Percent Water Consumption by Internal Process

Water Using Process	Tomato Processors	Dehydrators
	(% range of process water used)	
1. Flume	8-30%	0%
2. Wash raw product	2-40%	50-94%
3. Boiler feed water	1-32%	0-5%
4. Boiler make up water	1-18%	0-3%
5. Plant Sanitation	3-30%	5-50%
6. One pass Cooling	0-25%	0%
7. Recirculation Cooling Make-up	2-22%	0%
8. Product Cooling and Heating	2-15%	0%
9. Other Ancillary Utility Use	1-20%	0-1%
10. Other Uses	1-10%	0%

Question 11 in the 2014 survey asked if facilities had implemented specific water conservation improvements in the last ten years. These water conservation BMPs, are *in addition* to the reuse opportunities discussed above. Figure 1 shows the number of facilities that have implemented the specified improvements.

Figure 1 - Water Conservation Improvements in Place

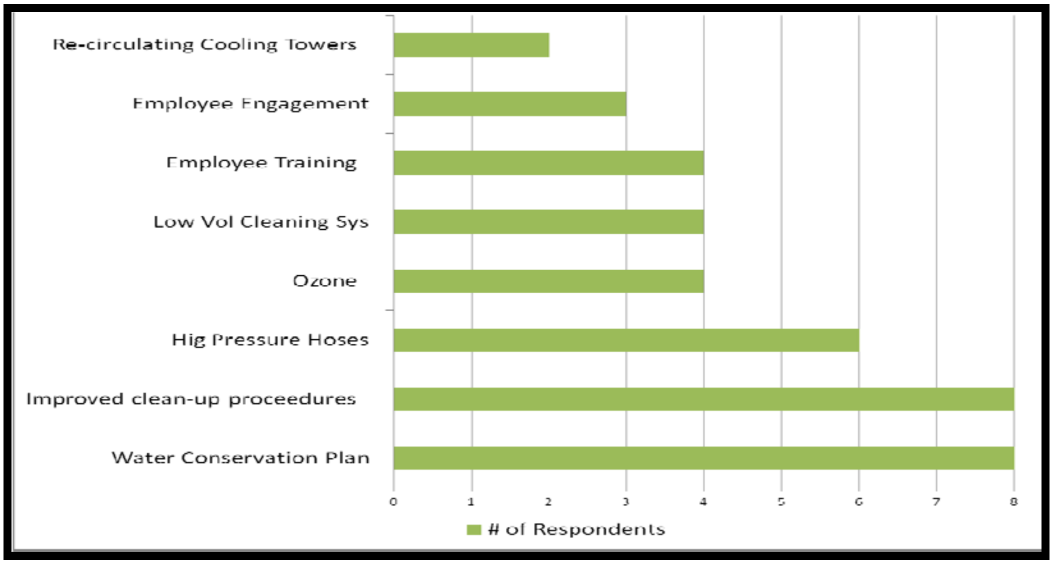
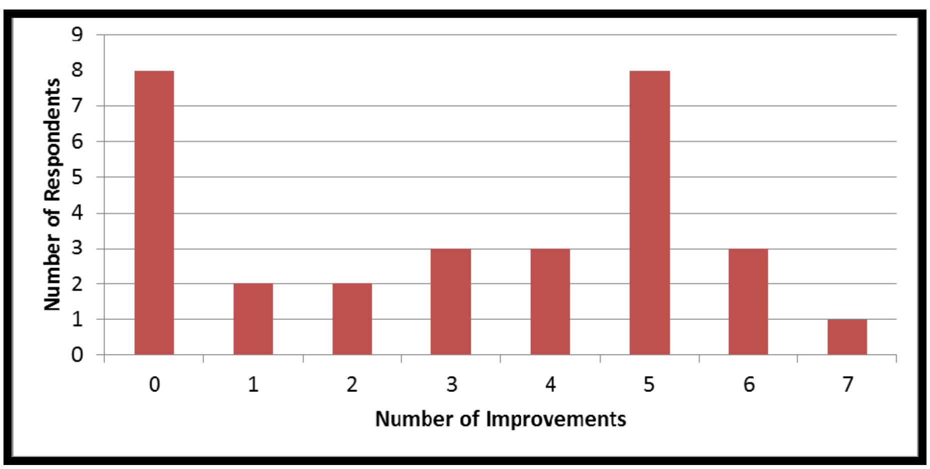


Figure 2 looks at the responses slightly differently and show that the majority of the respondents have implemented at least three water conservation improvements. However, eight of the respondents have not implemented any of the specified water conservation BMPs. Of these eight, most were dehydrators (prunes) and these specified improvements may not apply. As shown above in Table 3, half the dehydrators' water use is attributed to washing raw product and the other half to sanitation.

Figure 2 - Number of Conservation Improvements Implemented



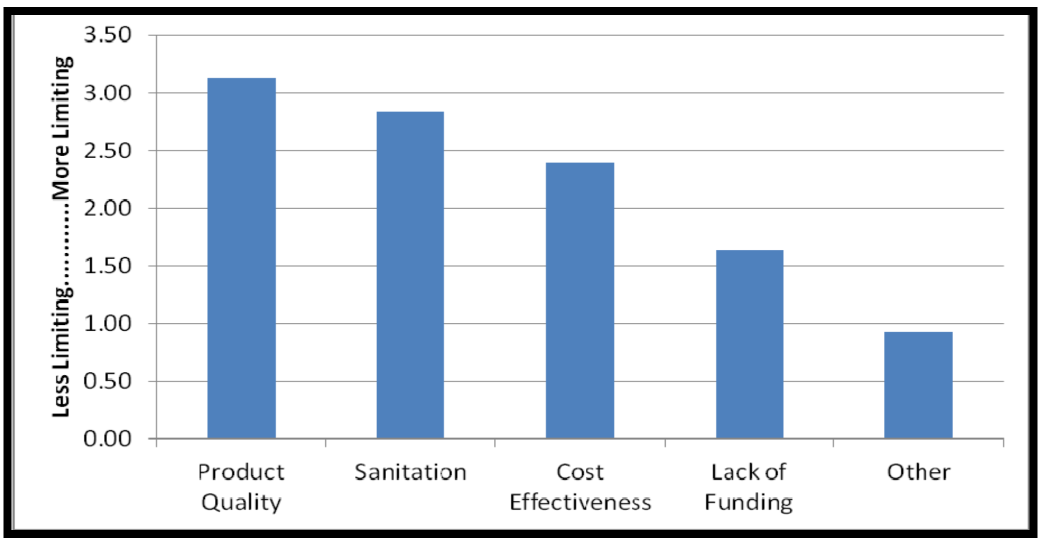
There are a few contradictions in the facilities' responses about water conservation targets and conservation plans:

- 17 respondents identified a water conservation target.
- 13 facilities had conducted a "water usage assessment".
- 8 facilities have a water conservation plan in place.
- Only 4 facilities train their employees in water conservation.
- Only 3 facilities have some form of employee engagement.

A water usage assessment typically informs a facility as to the level of conservation possible and where to best focus resources. The water usage assessment collects information that is used to develop a conservation target and to develop an action plan. Further, conservation plans usually include employees in the process. It appears that several of the facilities would benefit by using the plan–do–check–act of self-improvement described in the Queensland Eco-Efficiency Toolkit (2004), EBMUD's Water Smart Guidebook (2008), and Comprehensive Guide to Sustainable Management of Winery Water (2008).

The survey also asked respondents what prevented further conservation efforts. As shown in Figure 3, the facilities feel constrained most by product quality and sanitation issues, followed by the costs to undertake additional water conservation activities. There is pressure on processors to improve food safety and water is critical for plant sanitation. Often, regulations and stringent safety standards drive a facility's decisions for process improvements and equipment upgrades. Potable water, cooling water, steam and ice must be safe and it must be available in sufficient quantities, at suitable pressures and temperatures, to meet operational requirements.

Figure 3 - Limiting Factors for Additional Conservation



Finally, the respondents listed future water savings measures that they are considering for implementation. These are included in Section 4 (Best Management Practices), below.

2.2.3 Facility Interviews

Following the distribution of the 2014 CLFP survey, on-site interviews were conducted with four CLFP members. The purpose of these interviews was to confirm survey results and gather additional information on BMPs. Details on site-specific BMPs that were in place or under consideration were collected .The site visits included different BMPs as well as discussion around what facilities considered when identifying and implementing water efficiency projects. In deference to CLFP member's request for confidentiality, information from these interviews is interwoven throughout this report.

Section 3: Quantitative Findings

3.1 Summary

Based on the most useful and consistent metrics applied to producer category, the average CLFP survey respondent's water usage is substantially below historical values given in references. This study also evaluates the trends in absolute and unit water usage by individual facilities to demonstrate water conservation progress. The trend of total water usage has been down for CLFP survey respondents over the 2006 to 2013 period. The trend has also been slightly down for unit water use per ton of product produced over the 2006 to 2013 period.

3.2 Metric Selection

Metrics provide a quantity of water use during a period of time as well as a normalizing factor that may be an indicator of efficiency or productivity of water. Baseline values are the first year metrics, to which all future years are compared.

The metrics selected for this study are shown in Table 4 along with their description. Water use tends to be a function of the individual food processing facility and the tonnage of product processed. Therefore *intake process water per ton of raw product processed* was selected as the primary metric for this study. The other metrics selected were useful indicators of measures taken to increase overall water use efficiency that were available in the literature and 2011 CLFP survey. The 2014 CLFP survey was designed to augment information that was collected during the literature survey and the 2011 CLFP survey.

Table 4 - Description of Selected Metrics

Metric	Description	Purpose
Intake process water per ton of product	Volume of fresh water used to process each ton of raw product.	• To show if volume of fresh water used to process a unit of product is improving.
Internal recycling/reuse percentage	Percent of fresh water used more than once within a facility	• To determine if the fresh water is used efficiently overtime. The higher the percentage of recycling, the higher the efficiency. • This metric should increase as the intake process water metric decreases
Discharge % of intake	Percent of freshwater leaving the facility as process wastewater	• This ratio can capture those processors that extract process water from raw materials.
External reuse % of discharge	Percent of process wastewater that is put to beneficial use for irrigation	• This is also water being used in lieu of freshwater for irrigation.

3.3 Baseline Values

A goal of this project was to develop a baseline year as early as possible. Initially, it was anticipated that historical reference metric values from the literature survey would be used as baselines for comparisons with the 2014 CLFP survey results. As discussed in Section 2.1, 60 publications dating back to the 1960s were reviewed and only ten of these (Appendix B) contain relevant information. Of these ten documents, five publications were selected to evaluate water use efficiency: EPA (1977), DWR (1979), Kollar (1980), EPA (1983), Water Encyclopedia (1983) over time.

Table 5 shows the difficulties in comparing data across publications and year for the historical references reviewed and in providing baseline values for water intake per unit of raw product processed. This was also addressed in Section 2.1.

Table 5 - Intake Process Water per Ton of Raw Product (gal per ton)

Product Category	EPA[(a)] (1977)	Kollar (1980; Produced Product)	EPA WW Dev. Doc. (1983; Calc.)	FEIC (1993)	CLFP Survey (2014)
Tomato Paste				920	351
Canned Fruit	3,000	9,400	2,763	4,174	1,538
Canned Tomato	1,700	9,400	1,036	920	773
Canned Olives			6,276		4,475
Dehydrated Onions			3,410	1,000	1,035
Dehydrated Fruit			829[(b)]		80
Frozen Fruit & Vegetables		14,100	1,097[(c)]		2,490

Notes:

(a) EPA values were for wastewater generation. These were converted to equivalent intake water values using average ratios of wastewater to intake water from the CLFP 2014 survey.
(b) Plums
(c) Peaches

Alternative approaches to establishing baseline values were therefore considered, including using values from the 2011 CLFP survey (whether 2006 values or averages of several years). Unfortunately, there were a number of facilities that participated in the 2014 survey that were not part of the 2011 survey. In some cases, the new participants had unit water use rates that were substantially different than the water use rate values of respondents to both surveys. Thus, using data from the 2011 survey for establishing baseline values would make comparisons with 2014 survey data potentially misleading.

Due to the difficulties in using the historical data, general comparisons of survey metric values with historical reference values were determined to provide the most useful conclusions along with evaluating trends within the data from the two CLFP surveys. Averages from the 2014 CLFP survey can be used to provide baseline values for future comparisons.

3.4 Metrics - Survey Results

This section discusses the results of the four selected metrics described in Table 4, above.

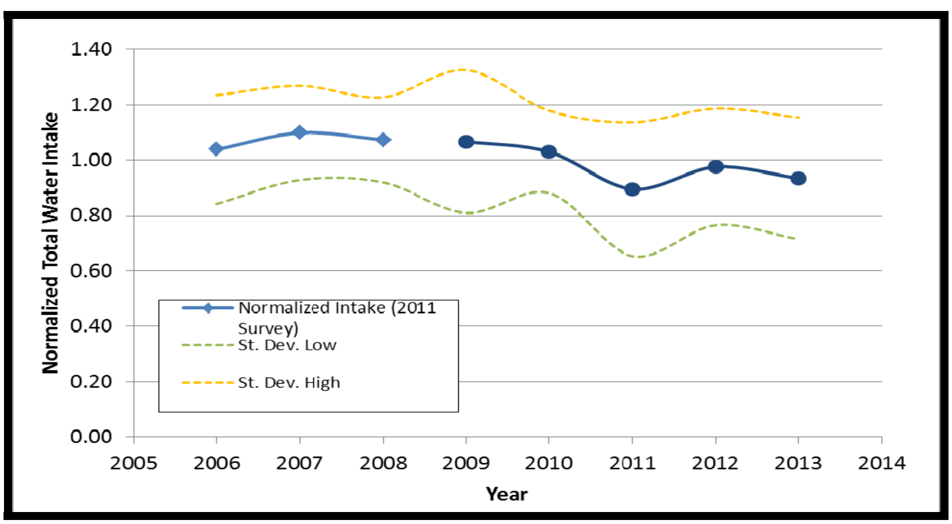
3.4.1 Intake Water per Unit of Raw Product

Values from historical references are shown in Table 5. For those historical reference documents that specified wastewater volume instead of water intake, the wastewater volumes were multiplied by the average ratios of intake process water over wastewater volume from the 2014 CLFP survey for each product category to give equivalent values in intake process water per ton of product shown in the table. Overall, the 2014 CLFP survey results compare very favorably with the water usage given in the historical references.

Comparisons of water use trends for product category averages between the 2011 and 2014 survey results were difficult because some of the new respondents in the 2014 survey had very different unit water use rates than the prior respondents, and would skew a straightforward trend comparison. Therefore, total water intake and unit water intake over time were normalized for each survey respondent (i.e., each year's value was divided by the average value for all years for that facility).

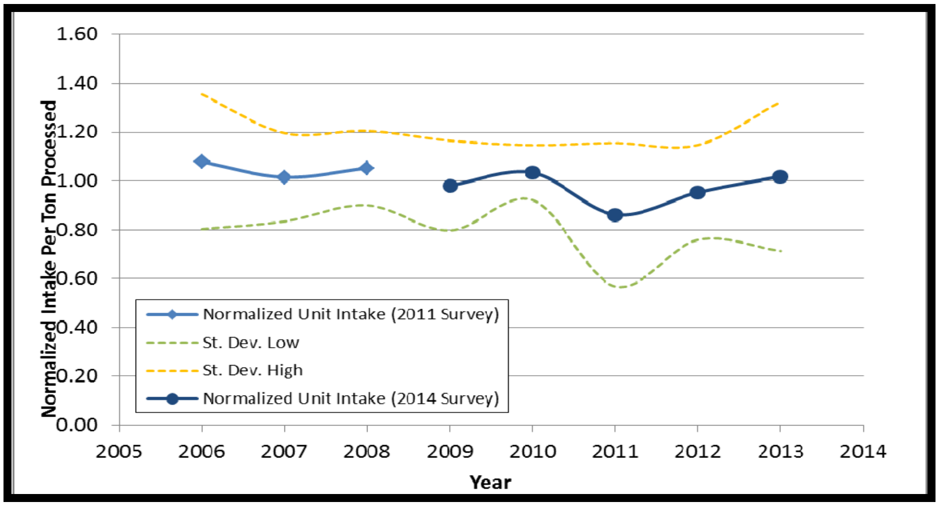
The average *normalized total water intake over time* for all facilities is shown in Figure 4. This shows that, on average, normalized total water intake over time was in a downtrend over the 2006 to 2013 period.

Figure 4 - Normalized Total Water Intake by Facility (Average of All Respondents)



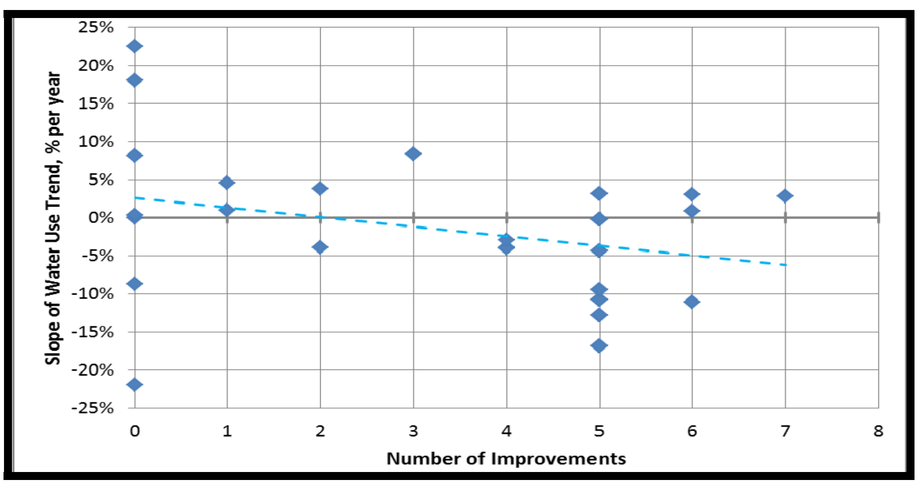
The average *normalized unit water intake over time* for all facilities is shown in Figure 5. The trend for unit water intake (i.e. water use per ton of raw product) is slightly downward over the period, but less so than the trend for total water intake.

Figure 5 - Normalized Unit Water Intake Over Time - Average of All Respondents



Another interesting comparison for water usage is to compare intake unit water usage with the number of conservation improvements implemented (shown previously in Figure 3). As can be seen in Figure 6, although there is a large amount of variability, there is a general downward trend in water usage per ton of product processed as the number of conservation measures implemented increased for the respondents to the survey.

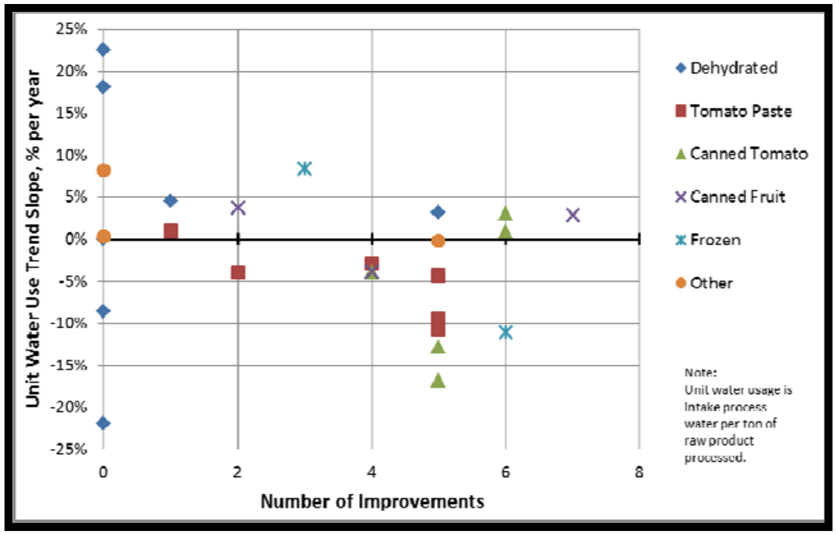
Figure 6 - Unit Water Usage Trend vs. Conservation Improvements Implemented



Note: Water use trend is for normalized intake gallons per ton processed per year.

The water usage trends versus number of conservation improvements implemented is further broken down by processor category in Figure 7. As can be seen in the figure, the strongest correlation between numbers of improvements and water use improvement trend was for the tomato paste processors.

Figure 7 - Water Usage Trends vs. Number of Conservation Improvements Implemented



3.4.2 Recycling/Reuse Percentage

As stated in Section 2.1.2, recycling and reuse have historically been considered to be important factors in overall water use efficiency. *Percentage of intake water recycled/reused* was selected as a good indicator of the main indicator of water conservation progress for facilities. The values from historical references and the 2014 CLFP survey are shown below in Table 6.

Table 6 - Internal Recycling/Reuse as a Percentage of Fresh Intake Water

	Internal Recycling/Reuse as a % of Fresh Intake Water			
Product Category	DWR (1979)	Kollar (1980)	Water Encyclopedia (1983)	CLFP Survey (2014)[(a)]
Tomato Paste				10.8%
Canned Fruit	138%	110%	166%	11.0%
Canned Tomato Products				26.6%
Dehydrated Onions				45.0%
Dehydrated Fruit				0.0%
Nuts				0.8%
Frozen Fruit and Vegetables		60%	76%	na
Dairy	95%	64%	50%	11.5%

Note:

(a) The survey asks if water is used more than once within a facility and does not distinguish between recycling (i.e., reusing water within the same process) and reuse (i.e., capturing water for reuse in another process).

Recycling/reuse in the CLFP survey results was very low compared to the historical references. This was surprising given that *unit intake water usage per mass of product produced* was generally much lower in the CLFP survey than in the historical reference literature. Most of the historical reference studies had obtained values for gross water use by all processes in a facility, then derived values for recycling based on the difference between gross water use and fresh intake water. The CLFP surveys asked directly for the amount of intake water recycled within or between processes.

One possible explanation between the CLFP surveys and the historical references is that the CLFP survey respondents may have inadvertently underestimated their recycling/reuse amounts. More detailed measurements or estimates of gross water use for each process could provide a better basis for calculation of recycling amounts in any future surveys.

3.4.3 Discharge Percentage and Total External Reuse

Some facilities recover and use the water within raw products in lieu of fresh water. *Discharge as a percentage of intake* is a metric that gives an indication of how much product water is utilized and can be calculated from some of the historical references as well as from the 2014 CLFP survey data. The values by category are shown in Table 7 below.

Table 7 - Discharge Percentage of Intake

Product Category	Discharge % of Intake[a] DWR (1979)	Kollar (1980)	Water Encyclopedia (1983)	CLFP Survey (2014)	CLFP Survey – Irrigation % of Discharge[b]
Tomato Paste				126.7%	76.9%
Canned Fruit	89.7%	91.0%	86.0%	90.0%	95.0%
Canned Tomato Products	89.7%		86.0%	106.2%	99.3%
Dehydrated Onions				96.8%	
Dehydrated Fruit				123.3%	
Nuts				92.5%	
Frozen Fruit & Vegetables		98.0%	97.0%	90.5%	
Dairy	112.0%	93.0%	91.0%	66.5%	

Notes:

(a) Higher percentages indicate higher amount of water being recovered from raw products.
(b) Percentage of discharged water put to beneficial use outside the facility.

The *discharge as a percentage of intake* is notably higher for the tomato processors in the CLFP survey compared to the historical references and is also greater than 100%. This indicates that tomato processors are likely recovering more of the product water than had typically been recovered during the times of the historical reference surveys.

Total external reuse provides a measure of how much discharged water is put to beneficial use outside the facility. Often this is in the form of irrigation reuse. The far right column of Table 7 (above) shows the irrigation percentage of discharge. Most of the major respondents reuse their discharge water for irrigation, offsetting what otherwise would have been localized fresh irrigation water demand in the area.

3.5 Conclusions

The survey results indicate a much better *average water use efficiency per ton of product processed* compared to historical literature reference values. The survey results also show slightly decreasing trends for unit water use over the 2006 to 2014 period. There was a substantial amount of variability between some of the respondents in each category, indicating the potential for improved water use efficiency in some facilities.

Reported *water recycling and reuse as a percentage of intake* was low for the 2014 survey respondents compared to the historical reference values, but some of that discrepancy may be due to survey and reporting methodology. The *discharge as a percentage of unit intake water* was generally similar for the 2014 survey respondents and historical reference values. The exception was for tomato processors, who seem to be recovering more water contained in the raw product than the industry has historically. Much of the discharge water is further reused for irrigation.

Section 4: Best Management Practices

A historical overview of best management practices in the food processing industry is provided in Section 2 (above) and summarized in Table1. This historical perspective shows that food processing facilities have reused and recirculated water within their processes since the 1950s. Alternative BMPs, beyond recycling and reuse, have evolved over the past 25 years to include tools (i.e., low flow nozzles) and improved procedures. And, within the last ten years, guidebooks have emerged that encourage facilities to incorporated BMPs into a process of plan–do–check–act. Implied in this process is that every facility or process is unique and that appropriate BMPs will be site specific.

4.1 Recycle/Reuse

The practice of reuse and recycling continues to the present day with food processors looking for cost effective measures to expand in-plant water reuse. An increased piloting of membrane technology began in the 1990s (Table 1). These pilot studies looked to increase water reuse between processes to reduce process water discharges and to conserve water. Since the 1990s, advances in membrane technologies, including reverse osmosis and nanofiltration, have allowed these technologies to play a larger role in water use efficiency at better pricing.

Several respondents to the 2014 CLFP identified plans for future reuse/recycling projects. In addition, four on-site interviews were conducted to identify BMPs that were in place or under consideration. Recycling/reuse BMPs identified by facilities include:

- Improved recycling/re-circulation to reduce fresh water uses.
- Reuse cooling tower overflow for grounds sanitation.
- Reuse cooling water.
- Reuse process condensate in place of fresh water in areas of production.
- Re-circulate seal water.
- Eliminate one pass cooling.
- Reuse process water for irrigation.
- Because cooling towers are grouped, could recirculate water from the last (third cell) back to the first cooling tower resulting in several hundred thousand gallons per day of water savings.
- Lye concentrators recover and reuse caustic. Less lye in process water so savings in chemicals.
- Directed cooling tower return water to flumes.

- Fruit washing – first with ‘recycled’ water and then with freshwater. Capture the last rinse water for to become the first (‘recycled’) rinse water.
- Defrost water reused for irrigation.
- Also reusing defrost water for nightly cleaning and sanitation of the belts.
- Increased ability to source water from raw materials (i.e., incoming tomato or milk) by adding treatment.
- Reject water from RO units is collected and reused.
- Looking at ways to prevent water from touching the ground so they can increase recycle or reuse opportunities.

4.2 Alternative BMPs

The CLFP surveys queried member companies if specific BMPs, beyond recycling/reuse, that are currently in place. Respondents also wrote-in future conservation improvements that are in the planning stages. During the facility interviews additional proposed or planned BMPs were identified: BMPs identified by facilities include:

- Employee engagement
- Employee training
- Water conservation plan
- Low volume high pressure cleaning systems
- High pressure hoses
- Nozzles – over time have gone from unrestricted hoses, to restricted flow hoses, to hoses with shut-offs
- Nozzles on every hose
- Reduction in high flow hoses
- Improved clean-up procedures
- Improve cleaning, sanitation, and conveying procedures
- Spill control in flumes
- Processing techniques to reduce water and dilute chemicals
- Lower the pressure of high pressure pumps
- Ozone system or improve ozone system

- Use of ozone on belt sprays to reduce potable water sprays and cleaning chemical use.
- Eliminate ozone water overspray by retrofitting belts with a roller system.
- Water saving sprays
- Reduce product spillage to reduce sanitation water
- Rent meters and monitor points of interest
- Install submeters
- Leak control
- Install meter/ball valve to regulate blowdown at cookers
- Peeling – selectively using both steam and caustic (potassium hydroxide). Mostly caustic since steam is pricey and caustic does a good job. Steam used for "organics."
- Peeling – High pressure air following sodium hydroxide (2.5%) application for peeling. Potential to minimize or eliminate recycle rinse and freshwater rinse. Trial.
- Eliminate troughs that take defective fruit out of the system. By expanding the conveyer and widening the pulley, conserve water.
- Appoint/hire "water manager" who looks for trends and blips and ways to improve efficiency.
- Challenge chemical supplier on reducing water/chemicals needed for cleaning and sanitation. Rely less on third party chemical supplier and rely on internal process and "validation study."
- Evaluate: CIP processes chemicals, timing, water use; the need to rinse to neutral; and added staff, including a sanitizer coordinator, in each production area.
- Reduce chemical use via substitution and increased efficiency.
- Employees – success breeds success. As employees see that conservation is possible, they are now behind it.

4.3 Compendium, Guidebooks, and Plan–Do–Check–Act

Appendix E provides a compendium of BMPs collected during the literature survey. This includes those in the CII Task Force Report as well as publications from the United Kingdom, New Zealand, Australia, and throughout the United States. The CII Task Force Report recognizes that "…every facility is unique and what may work at one vegetable processing plant may not be applicable at another." Thus, it is up to the CII entity to determine which alternative BMPs are the most appropriate for their situation.

Thus, Appendix E presents possible BMP options. However, the identification, screening, and implementations of BMPs at a particular facility should be part of a larger, integrated process. The BMPs in Appendix E are sorted into the following categories:

- Food and Beverage specific
- Cleaning Activities
- Pipes and Equipment
- Thermodynamic Processes
- Reuse Opportunities
- Water Treatment Systems
- Alternate Water Sources.

Although few BMPs specific to food processors were identified in the literature, there are several operations that are common across industrial entities. This includes boilers, cooling towers, and source water treatment. Note that, the literature contains a great deal of information on water efficiency measures for restrooms, kitchens, landscaping, and other ancillary facilities. However, Appendix E and this document focus on water uses directly involved in food processing.

Section 5: Recommendations and Next Steps

One of the objectives of this study is to assess whether past changes in water policies or laws have had an impact on total industry water use. It appears that there has been an effort among food processors for over a half a century to be water efficient without the influence of water conservation policy or legislation. As examples:

- It is assumed that plants implemented water reuse strategies, not in response to public policy, but to be cost effective and to potentially reduce stress on local public works.

- Many of the facilities responding to the CLFP survey and who participated in facility interviews mentioned corporate initiatives for water conservation. These internal programs have had varying levels of success but were implemented without the influence of public policy.

- The legislation that has had the largest impact on water use in the food industry is the Clean Water Act and those associated with food safety. Many facilities have site-specific discharge limits that require greater water efficiency or reducing the volume of water used at the facility. For those who discharge to publically owned treatment works (POTWs), there are benefits to reducing wastewater volumes including reducing costs and time associated with wastewater treatment and handling

Another objective of this study is to assess whether water usage by the food processing industry has become more efficient over time and what has led to the increase in efficiency. As described throughout this report, consistent water usage data was not available. But, based on the information in Section 3, it appears that the industry has become more efficient. To ensure consistent data are available in the future, the following are recommended:

- *Document in-plant recycling, recirculation and reuse* – Ensure the general public is aware that water recycling and reuse have been common practice within the industry for over half a century.

- *Document water sourced from raw materials* – Remind the public and legislature that food processors extract plant processing water from raw materials and reuse as a means to address both water supply and process wastewater generation.

- *Expand industry adoption of sub-metering* – Although most facilities have a generally good idea of which activities required the most water, there is some uncertainty. And, the survey results discussed in Section 3 indicate a need to better understand the volume of water currently being reused with some facilities. Sub metering is a relatively inexpensive way to gather more precise information to ensure that facilities focus limited resources wisely. For example, sub metering will help confirm if new water conservation improvements were successful. Additionally, sub metering data will help quantify the volume of water recycled or reused within the plant, and within the industry. The State, through the water and energy utilities, could do more to provide financial incentives to help firms change equipment or provide training similar to what is done with energy conservation and efficiency programs.

- *Regular reporting to CLFP* – Continue to solicit water use data every 3 to 5 years from CLFP member companies. Continue to review and develop metrics (gallons/year; gallons/ton of product, gallon/tax dollar generated; gallon/product moved; etc.).

Identifying possible BMPs for food processors was also an objective of this study (see Section 4). However, it appeared that some facilities are implementing water conservation programs without having performed an audit, without involving employees, and without follow up to determine the success of the BMPs. Further, every facility is unique and BMPs should be site specific. Thus, it is recommended that facilities undertake a process of plan–do–check–act to identify, implement, and monitor appropriate BMPs. Suggested avenues for CLFP to continue to assist with an industry wide program include:

- *Facility Audits* – Assist selected facilities in self-auditing. During this process, CLFP can continue to collect data that will bolster and confirm the data in this study. In addition, these representative facilities can become case studies on how to self-audit, identify water efficiency measures, develop benchmarks, and apply metrics.

- *Hotspot Identification* – Determine those processes that account for largest percentage of water consumption (becomes focus area) and what measures are being used to address.

- *Self-Audit Framework* – Based on pilot site water audits, develop a procedure for facilities to self-audit. This framework will focus on those processes that represent the majority of water consumption. Facilities can then identify BMPs that address the large water using activities.

- *Guidebook* – Develop a practical manual and tool for CLFP members to benchmark water use at their faculties, document their efficiencies, set water conservation targets, and develop action plans to further goals. By doing so, facilities will be participating in a process of plan–do–check–act.

- *Employee engagement* – employees can make a significant difference in water conservation.

- *Expand Industry Adoption of sub-metering* – as discussed above.

Section 4 and Appendix E includes possible of BMPs collected during the literature and CLFP member company surveys. But, most are not specific to the food processing industry. Thus, another recommendation includes:

- *Develop Best Practices and Innovative Technologies* – Using the practical knowledge gained from work at the pilot sites and hotspot identification; develop practices and technologies that address hotspots specific to food processors. These practices and technologies may not currently be in use and will need to be formulated.

- *Alternative Water Supplies* – Appendix E identifies potential opportunities to substitute alternative water supplies such as recycled water, rainwater, stormwater, air conditioner condensate, filter and membrane reject water, foundation drain water, etc. These should be further explored to determine their applicability for various uses at food processing facilities.

- *Non Process Water BMPs* – Develop reference list or material for non-process water (restrooms, kitchens, landscaping, HVAC, visitor centers, administration, etc.) including volumes, metrics, and best practices.

Final recommendations that will be necessary as facilities become more water efficient include:

- *Process Wastewater Quality* – As water use efficiency increases, the concentration of constituents in process wastewater will also increase. Thus, analyzing the unintended consequences of water conservation may include evaluating the use of loading rates for land application treatment (lbs/acre) versus concentrations (mg/l) in regulating process wastewater treatment and land application practices and protection of groundwater and surface water supplies.

- *Synergies* – Analyze and support associated savings associated with increased water efficiencies. This may include energy, cost savings, wastewater treatment and disposal, chemical use, etc.

Appendix A

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Appendix A: References

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Appendix B

Most Useful References for Metric Data

Appendix B: Most Useful References for Metric Data

Reference (in order of relevance)	PROs	CONs
1. Kollar, K.L. and MacAuley, P., Water Requirements for Industrial Development, J. Am. Water Works Assoc., vol. 72, no. 1. Copyright AWWA, Reprinted with permission. 1980. (Kollar, 1980)	• Gives metrics: water use by various units of production for: Meatpacking, Poultry dressing, Dairy, Canned fruits and vegetables, frozen fruit and vegetables, Malt beverage. • Breaks out water use into percentage noncontact cooling, process related, and sanitary. • Breaks water use down into gross water use, intake by unit of production, consumption, and discharge. • Comparison of high recycling plants to 1973 industry average by gallon of water per unit of production.	• Not California specific.
2. The Water Encyclopedia, Second Edition. van der Leeden, Frits. Troise, Fred L. Todd, David Keith. Lewis Publishers. 1983 (Water Encyclopedia 1983)	• Gives metrics: water use versus industrial units of production for the following: Meatpacking, Poultry dressing, Dairy products, Canned fruits & vegetables, Frozen fruits & vegetables, Wet corn milling, Cane sugar, Beet sugar, Malt beverage (from Kollar, 1980). • Comparison of average plants to high recycling plants using 1973 industry average using gallon per unit of production. • Total United States industrial water broken down by: Percent noncontact cooling; Percent process and related; Percent sanitary and misc.	• Not California specific.
3. US EPA, Technology Transfer Seminar Publication Pollution Abatement in the Fruit and Vegetable Industry. Volume 2: In Plant Control of Process Wastewater. July 1977. (EPA 1977)	• Metrics: water use (gallon per ton) for various processes. • Provides average gallons of wastewater per ton of product for different commodities • Gives water use and process wastewater flows for several different food processing categories. • Discusses water conservation and identifies where water can be recovered and reused.	• Not California specific.

Reference (in order of relevance)	PROs	CONs
4. US EPA, Office of Water and Hazardous Materials. Development Document for Interim Final and Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Fruits, Vegetable and Specialties Segment of the Canned and Preserved Fruits and Vegetables Point Source Categories. October 1975 (EPA 1975)	• Metrics: raw waste flows (gallon per ton) in 1977 and 1983 for several dozen commodities. • Discusses BACT for effluent reduction • Over 500 sources of info relating to raw waste load characteristics of fruit and vegetable processing were obtained. 50,000 data points. Used computer modeling to aggregate, correlate, and predict gallons per ton. • Discusses challenges associated with estimation of baseline values.	• Not California specific. • Mostly process wastewater data. • Another EPA Development Document provided water use (gallons per tons) in granularity as well as process flow diagrams for the Apple, Citrus, and Potato processors.
5. a. CA DWR. Bulletin No. 124-3 "Water use by Manufacturing Industries in California 1979." 1982. (DWR 1982) 5. b. CA DWR, Bulletin No. 124-2 Water Use by Manufacturing Industries in California 1970). March 1977. (DWR 1977) 5. c. CA DWR, Bulletin No. 124. Water Use by Manufacturing Industries in California 1957-1959). April 1964. (EPA 1964)	• California specific. • Tables 4 and 5. • Based on hundreds of survey responses • Total water intake for cooling, processing, boiler feed, and sanitation; • Total annual water use, water recirculated; water required without recirculation; water treated prior to use; water treat.	• Calculates cubic feet-of-water/SF and cubic feet-of-water/average-employee-day. These are then broken into the use categories (cooling, processing, boiler, etc.)
6. Mannapperuma, Jatal D., Yates, E. D., and Singh, R. Paul. "Survey of Water Use in the California Food Processing Industry." Food Industry Environmental Conference. 1996. (FEIC 1993)	• California specific. • 71 respondents to the survey. • Consumption rates were significantly lower than rates reported in earlier surveys. • Some metrics as follows: o Tomatoes ranged from 144 to 1870 gal per ton of tomatoes. o Wine ranged from 625 to 2800 gal per ton of grapes o Peach 1800 to 3900 gal per ton o Olives 3000 to 10,400 gallons per ton o apple sauce, apricots, artichokes, asparagus, Brussels sprout, cheese, cherry, frozen fruit, garlic, meat, mushrooms, onions, pears, pumpkins, raisins, seafood, specialty, vegetable oils, yams, zucchini.	• Uses raw material (i.e., grapes vs. wine) to normalize the data.
7. Kreith, Marcia. Water Inputs in California Food Production, Sacramento, Calif.: Water Education Foundation. September 27, 1991. (WEF 1991)	• California specific. • Gallon per pound of purchased food.	• The normalization to pound of retail food in the summary charts may be an issue.

Reference (in order of relevance)	PROs	CONs
8. Katie Bromley-Challenor, Mark Kowalski, Richard Barnard, Stephen Lynn. Technical report. "Water use in the UK food and drink industry. A review of water use in the food and drink industry in 2007 and 2010, by sub-sector and UK nations." For WRAP. July 2013 (WRAP 2013)	• Total water use by sub categories (2007 and 2010) as well as number of employees and meals.	• Not related to California products.

Appendix C

Data Tables from Literature Survey

1. Kollar, K.L. and MacAuley, P., Water Requirements for Industrial Development, J. Am. Water Works Assoc., vol. 72, no. 1. Copyright AWWA, Reprinted with permission. 1980. (Kollar, 1980)

TABLE 2

Percentage of Gross Industrial Water Use by Purpose

Industry	Parameters of Water Use	Gross Water Use by Unit of Production	Percentage Noncontact Cooling*	Percentage Process and Related*	Percentage Sanitary and Miscellaneous*
Meatpacking	gal/lb carcass weight	3.6 gal/lb	42	46	12
Poultry dressing	gal/bird poultry slaughter	11.6 gal/bird	12	77	12
Dairy products	gal/lb milk processed	0.85 gal/lb	53	27	19
Canned fruits and vegetables	gal/case 24-303 cans eq	225 gal/case	19	67	13
Frozen fruits and vegetables	gal/lb frozen product	11.2 gal/lb	19	72	8
Wet corn milling	gal/bu corn grind	416 gal/bu	36	63	1
Cane sugar	gal/ton cane sugar	28 100 gal/ton	30	69	1
Beet sugar	gal/ton beet sugar	33 100 gal/ton	31	67	2
Malt beverages	gal/barrel malt beverage	1500 gal/bbl	72	13	15
Textile mills	gal/lb fiber consumption	34 gal/lb	57	37	6
Sawmills	gal/bd ft lumber	5.4 gal/bd ft	58	36	6
Pulp and paper mills	gal/ton pulp and paper	130 000 gal/ton	18	80	1
Paper converting	gal/ton paper converted	6600 gal/ton	18	77	5
Alkalis and chlorine	gal/ton chlorine	29 800 gal/ton	85	14	1
Industrial gases	gal/1000 cu ft industrial gases	636 gal/mcf	86	13	1
Inorganic pigments	gal/ton inorganic pigments	97 800 gal/ton	41	58	1
Industrial inorganic chemicals	gal/ton chemicals 100 percent basic	14 500 gal/ton	83	16	1
Plastic materials and resins	gal/lb plastic	24 gal/lb	93	7	
Synthetic rubber	gal/lb synthetic rubber	55 gal/lb	83	17	Z
Cellulosic man-made fibers	gal/lb fibers	231 gal/lb	69	30	1
Organic fibers, noncellulosic	gal/lb fibers	101 gal/lb	94	6	1
Paints and pigments	gal/gal paint	13 gal/gal	79	17	4
Industrial organic chemicals	gal/ton chemical building blocks	125 000 gal/ton	91	9	1
Nitrogenous fertilizers	gal/ton fertilizer	28 508 gal/ton	92	8	Z
Phosphatic fertilizers	gal/ton fertilizer	35 602 gal/ton	71	28	1
Carbon black	gal/lb carbon black	4.6 gal/lb	57	38	6
Petroleum refining	gal/barrel crude oil input	1851 gal/bbl	95	5	Z
Tires and inner tubes	gal/tire car and truck tires	518 gal/tire	81	16	3
Hydraulic cement	gal/ton cement	1360 gal/ton	82	17	1
Steel	gal/ton steel net production	62 600 gal/ton	56	43	1
Iron and steel foundries	gal/ton ferrous castings	12 400 gal/ton	34	58	8
Primary copper	gal/lb copper	53 gal/lb	52	46	2
Primary aluminum	gal/lb aluminum	49 gal/lb	72	26	2
Automobiles	gal/car domestic automobiles	36 500 gal/car	28	69	3

*Z = less than 0.5 percent of gross water use; percentages may not add evenly due to rounding

to desalinate saltwater at a high cost in dollars and energy. New water intensive industries are not likely to locate in these islands, unless they can satisfy much of their water requirements with saline water.

Geographic Distribution of Water Intensive Manufacturing Industries

Table 1 shows the geographic distribution of water intensive manufacturing industries.

The paper industry is located in almost every section of the nation, but especially in the south Atlantic Gulf and Columbia-North Pacific regions. The chief determinant in locating paper mills is access to adequate supplies of softwoods for paper fiber. However, about 20 percent of the paper mills recycle waste fiber, and thus are usually located near cities or other sources of wastepaper. Those plants that buy paper and convert it into paper products are usually located near their industrial or retail customers.

The chemical industries produce a wide variety of products, of which petrochemicals and fertilizer are the most water intensive. Since access to petroleum and natural gas feedstocks are of primary importance, the chemical industry is heavily concentrated in the Texas Gulf and lower Mississippi regions. Other important concentrations of chemical plants are in such industrial centers as the Great Lakes, Ohio, and Atlantic regions.

The petroleum refining industry is found largely in oil-producing regions and in coastal regions where oil is imported. Three of the largest water-using areas are the Texas Gulf, lower Mississippi, and California regions, which are both oil importers and oil producers. Since the Arkansas-White-Red region is a major oil-producing district, it supports a large number of refineries despite the relative scarcity of water. The Middle Atlantic region refines large amounts of imported oil.

TABLE 3

Water Use Per Employee

Industry Group	Gross Water Use Per Employee		Intake Per Employee	
	L/day	*gpd*	*L/day*	*gpd*
Food and kindred products	15 540	4200	10 360	2800
Tobacco manufacturers	22 570	6100	1480	400
Textile mill products	6660	1800	2960	800
Apparel and related products	370	100	370	100
Lumber and wood products	5920	1600	3700	1000
Furniture and fixtures	440	120	370	100
Paper and allied products	43 930	38 900	42 920	11 600
Printing and publishing	370	100	370	100
Chemicals and allied products	149 110	40 300	56 240	15 200
Petroleum and coal products	603 100	163 000	94 350	25 500
Rubber and plastic products	10 730	2900	3700	1000
Leather and leather products	740	200	703	190
Stone, clay, and glass products	11 470	3100	5550	1500
Primary metal industries	78 440	21 200	44 030	11 900
Fabricated metal products	2960	800	1110	300
Machinery, except electrical	3700	1000	1480	400
Electrical machinery	9250	2500	1110	300
Transportation equipment	17 020	4600	2220	600
Instruments and related products	4440	1200	1110	300
Miscellaneous manufacturing	1110	300	2960	200

More than two thirds of the water use in primary metals manufacture occurs in the Great Lakes and Ohio regions, the heartland of the American steel industry. The steel industry has been concentrated in this area since the industrial revolution, reflecting the abundance of iron ore, coking coal, limestone, and water. Virtually all major steel mills are located alongside

TABLE 4

Water Use Versus Industrial Units of Production

Industry	Parameters of Water Use	Gross Water Used by Unit of Production	Intake by Unit of Production	Consumption by Unit of Production	Discharge by Unit of Production
Meatpacking	gal/lb carcass weight	3.6 gal/lb	2.2 gal/lb	0.1 gal/lb	2.1 gal/lb
Poultry dressing	gal/bird poultry slaughter	11.6 gal/bird	10.3 gal/bird	0.5 gal/bird	9.8 gal/bird
Dairy products	gal/lb milk processed	0.85 gal/lb	0.52 gal/lb	0.03 gal/lb	0.48 gal/lb
Canned fruits and vegetables	gal/case 24–303 cans eq	225 gal/case	107 gal/case	10 gal/case	98 gal/case
Frozen fruits and vegetables	gal/lb frozen product	11.2 gal/lb	7.1 gal/lb	0.2 gal/lb	6.9 gal/lb
Wet corn milling	gal/bu corn grind	416 gal/bu	223 gal/bu	18 gal/bu	205 gal/bu
Cane sugar	gal/ton cane sugar	28 100 gal/ton	18 250 gal/ton	950 gal/ton	17 300 gal/ton
Beet sugar	gal/ton beet sugar	33 100 gal/ton	11 100 gal/ton	390 gal/ton	10 700 gal/ton
Malt beverages	gal/barrel malt beverage	1500 gal/bbl	420 gal/bbl	90 gal/bbl	330 gal/bbl
Textile mills	gal/lb fiber consumption	34 gal/lb	14 gal/lb	1.4 gal/lb	12.8 gal/lb
Sawmills	gal/bd. ft lumber	5.4 gal/bd ft	3.3 gal/bd ft	0.6 gal/bd ft	2.7 gal/bd ft
Pulp and paper mills	gal/ton pulp and paper	130 000 gal/ton	38 000 gal/ton	1800 gal/ton	36 200 gal/ton
Paper converting	gal/ton paper converted	8600 gal/ton	3900 gal/ton	270 gal/ton	3600 gal/ton
Alkalis and chlorine	gal/ton chlorine	29 800 gal/ton	22 200 gal/ton	700 gal/ton	21 600 gal/ton
Industrial gases	gal/1000 cu ft industrial gases	636 gal/mcf	226 gal/mcf	31 gal/mcf	193 gal/mcf
Inorganic pigments	gal/ton inorganic pigments	97 800 gal/ton	49 400 gal/ton	1600 gal/ton	47 800 gal/ton
Industrial inorganic chemicals	gal/ton chemicals 100 percent basis	14 500 gal/ton	4750 gal/ton	470 gal/ton	4300 gal/ton
Plastic materials and resins	gal/lb plastic	24 gal/lb	6.7 gal/lb	0.6 gal/lb	6.1 gal/lb
Synthetic rubber	gal/lb synthetic rubber	55 gal/lb	6.5 gal/lb	1.4 gal/lb	5.1 gal/lb
Cellulosic man-made fibers	gal/lb fibers	231 gal/lb	68 gal/lb	4.6 gal/lb	63 gal/lb
Organic fibers, noncellulosic	gal/lb fibers	101 gal/lb	38 gal/lb	1.1 gal/lb	37 gal/lb
Paints and pigments	gal/gal paint	13 gal/gal	7.8 gal/gal	0.4 gal/gal	7.4 gal/gal
Industrial organic chemicals	gal/ton chemical building blocks	125 000 gal/ton	54 500 gal/ton	2800 gal/ton	51 700 gal/ton
Nitrogenous fertilizers	gal/ton fertilizer	28 506 gal/ton	4001 gal/ton	701 gal/ton	3299 gal/ton
Phosphatic fertilizers	gal/ton fertilizer	35 602 gal/ton	8461 gal/ton	1277 gal/ton	7184 gal/ton
Carbon black	gal/lb carbon black	4.6 gal/lb	3.9 gal/lb	0.9 gal/lb	3.1 gal/lb
Petroleum refining	gal/barrel crude oil input	1851 gal/bbl	289 gal/bbl	28 gal/bbl	261 gal/bbl
Tires and inner tubes	gal/tire car and truck tires	518 gal/tire	153 gal/tire	14 gal/tire	139 gal/tire
Hydraulic cement	gal/ton cement	1360 gal/ton	830 gal/ton	150 gal/ton	680 gal/ton
Steel	gal/ton steel net production	62 600 gal/ton	38 200 gal/ton	1400 gal/ton	36 800 gal/ton
Iron and steel foundries	gal/ton ferrous castings	12 400 gal/ton	3030 gal/ton	260 gal/ton	2760 gal/ton
Primary copper	gal/lb copper	53 gal/lb	17 gal/lb	4.1 gal/lb	13 gal/lb
Primary aluminum	gal/lb aluminum	49 gal/lb	12 gal/lb	0.2 gal/lb	11.8 gal/lb
Automobiles	gal/car domestic automobiles	36 500 gal/car	11 464 gal/car	649 gal/car	10 814 gal/car

navigable waterways, because of the competitive cost of barge transportation and the large volumes of water needed in steelmaking.

Applications of Water by Industry

Table 2 shows the different industrial uses of water. The table deals with the three broadest and most commonly used classifications: noncontact cooling, process and related uses, and sanitary and miscellaneous uses.

Noncontact cooling is the largest water use for the manufacturing sector as a whole. In this application water is separated from the material being cooled by heat exchanger surfaces. The most common noncontact cooling uses are equipment cooling, process temperature control, steam electric power condensing, and air conditioning.

Process uses include a variety of applications where water comes in contact with process materials or waste products, or is incorporated in the product. The most common process applications are inclusion in food and beverages, slurrying, paper forming, bleaching, dissolving, rinsing, scalding, fume scrubbing, spray cooling, and barometric condensing. Included in this category is boiler feedwater, which is used to generate steam for process purposes or steam electric power generation.

The third category covers sanitary and miscellaneous uses, chiefly sanitary service water for the personal use of employees. It also includes water for plant cleanup, groundskeeping, firefighting, and dust control.

The relative importance of the different water uses varies considerably among industries. Cooling water is the dominant use in the petroleum refining and chemical industries, while process uses are more important in the paper and food processing industries. The paper industry is by far the largest user of process water, accounting for more than half of its total on a gross use basis. Sanitary uses of water are relatively minor except in the food processing industries, which have special sanitary requirements and are generally labor intensive.

Most "dry" industries use water chiefly for air conditioning and sanitary service. Sanitary service requirements rarely exceed 1 kL/day (300 gpd) per employee, and average about 340 L/day (90 gpd) for all manufacturing. Air conditioning is the largest water use in such dry industries as tobacco, instruments, and machinery. Water in evaporative air conditioning systems is usually very easy to recycle, and most such systems are designed to recycle the water twenty to 50 times. In situations where water is especially short, industries have the option of using dry heat exchangers or vapor compression air conditioners, both of which are more costly and energy intensive for commercial-sized applications.

The "wet" industries are for the most part those that convert raw materials into intermediate industrial goods. They are often termed heavy industries or smokestack industries. Most of these industries are capital intensive and energy intensive, rather than labor intensive.

While these plants are not especially labor intensive in themselves, they provide an important industrial base for the community. They function both as markets

TABLE 5

Water Use Versus Standardized Units of Production

Industry	Parameters of Water Use	Gross Water Used by Unit of Production	Intake by Unit of Production	Consumption by Unit of Production	Discharge by Unit of Production
Meatpacking	gal/ton carcass weight	7194 gal/ton	4331 gal/ton	78 gal/ton	4253 gal/ton
Poultry dressing	gal/ton ready-to-cook weight	7369 gal/ton	6542 gal/ton	296 gal/ton	6246 gal/ton
Dairy products	gal/ton milk processed	1692 gal/ton	1036 gal/ton	63 gal/ton	964 gal/ton
Canned fruits and vegetables	gal/ton vegetables canned	19 700 gal/ton	9400 gal/ton	850 gal/ton	8550 gal/ton
Frozen fruits and vegetables	gal/ton vegetables frozen	22 500 gal/ton	14 100 gal/ton	300 gal/ton	13 800 gal/ton
Wet corn milling	gal/ton corn ground	14 869 gal/ton	7988 gal/ton	643 gal/ton	7345 gal/ton
Cane sugar	gal/ton cane sugar	28 102 gal/ton	18 256 gal/ton	944 gal/ton	17 312 gal/ton
Beet sugar	gal/ton beet sugar	33 145 gal/ton	11 118 gal/ton	386 gal/ton	10 731 gal/ton
Malt beverages	gal/gal beer and malt liquor	49 gal/gal	14 gal/gal	3 gal/gal	11 gal/gal
Textile mills	gal/ton textile fiber input	69 808 gal/ton	30 016 gal/ton	3008 gal/ton	27 008 gal/ton
Sawmills	gal/bd ft lumber	5.4 gal/bd ft	3.3 gal/bd ft	0.63 gal/bd ft	2.7 gal/bd ft
Pulp and paper mills	gal/ton paper	130 047 gal/ton	37 971 gal/ton	1178 gal/ton	36 193 gal/ton
Paper converting	gal/ton paper converted	6584 gal/ton	3861 gal/ton	273 gal/ton	3588 gal/ton
Alkalis and chlorine	gal/ton chlorine	29 840 gal/ton	22 302 gal/ton	676 gal/ton	21 626 gal/ton
Industrial gases	gal/ton weight of gas	18 080 gal/ton	5700 gal/ton	780 gal/ton	4900 gal/ton
Inorganic pigments	gal/ton pigments	97 800 gal/ton	49 400 gal/ton	1600 gal/ton	47 800 gal/ton
Industrial inorganic chemicals	gal/ton chemical products	14 500 gal/ton	4700 gal/ton	470 gal/ton	4300 gal/ton
Plastic materials and resins	gal/ton plastics	47 061 gal/ton	13 338 gal/ton	1078 gal/ton	12 276 gal/ton
Synthetic rubber	gal/ton synthetic rubber	110 600 gal/ton	13 200 gal/ton	2800 gal/ton	10 873 gal/ton
Cellulosic man-made fibers	gal/ton fibers	462 230 gal/ton	135 100 gal/ton	9200 gal/ton	125 846 gal/ton
Organic fibers, noncellulosic	gal/ton fibers	202 123 gal/ton	76 523 gal/ton	2153 gal/ton	74 369 gal/ton
Paints and pigments	gal/gal paint	13.2 gal/gal	7.8 gal/gal	0.4 gal/gal	7.4 gal/gal
Industrial organic chemicals	gal/ton chemical building blocks	124 700 gal/ton	54 500 gal/ton	2800 gal/ton	51 700 gal/ton
Nitrogenous fertilizers	gal/ton fertilizer	28 506 gal/ton	4001 gal/ton	701 gal/ton	3299 gal/ton
Phosphatic fertilizers	gal/ton fertilizer	35 602 gal/ton	8461 gal/ton	1277 gal/ton	7184 gal/ton
Carbon black	gal/ton carbon black	9200 gal/ton	7885 gal/ton	1771 gal/ton	6114 gal/ton
Petroleum refining	gal/gal crude petroleum input	44 gal/gal	6.9 gal/gal	0.7 gal/gal	6.2 gal/gal
Tires and inner tubes	gal/tire car and truck tires	518 gal/tire	153 gal/tire	14 gal/tire	139 gal/tire
Hydraulic cement	gal/ton cement	1355 gal/ton	831 gal/ton	146 gal/ton	685 gal/ton
Steel	gal/ton steel net tons	62 601 gal/ton	38 200 gal/ton	1400 gal/ton	36 800 gal/ton
Iron and steel foundries	gal/ton ferrous castings	12 407 gal/ton	3024 gal/ton	260 gal/ton	2764 gal/ton
Primary copper	gal/ton copper	106 000 gal/ton	34 000 gal/ton	8200 gal/ton	26 000 gal/ton
Primary aluminum	gal/ton aluminum	98 300 gal/ton	23 900 gal/ton	381 gal/ton	23 500 gal/ton
Automobiles	gal/car automobiles	36 500 gal/car	11 464 gal/car	649 gal/car	10 814 gal/car

and suppliers for many other businesses. Since access to markets and suppliers is among the chief determinants of new plant location, these heavy industries serve to support a number of light industries and services.

Many environmentalists still harbor a lingering aversion to certain water intensive industries (such as steel mills, refineries, and paper mills). Because of pollution control laws and major efforts by industries to improve their image, these plants are becoming much more harmonious with their surroundings. Water quality improvements are dramatic as industries upgrade discharge treatment and recycle more wastewater. New "greenfield" plants are becoming especially attractive as advanced pollution control technology is combined with careful landscaping and handsome architecture.

TABLE 6

*Typical Water Uses in Paper Mills**

Purpose	Gross Water Use		Intake Requirement (Low Reuse)		Intake Requirement (High Reuse)	
	ML/day	mgd	*ML/day*	mgd	*ML/day*	mgd
Kraft pulping (process use)	118	32	51	14	22	6
Kraft pulping (cooling system)	44	12	44	12	1.5	0.4
Bleaching	140	38	70	19	18	5
Paper forming (process system)	129	35	44	12	22	6
Paper forming (cooling system)	14	4	14	4	0.7	0.2
Electric power cooling†	51	14	51	14	1.8	0.5
Net totals‡	499	135	225	61	44	12.1

*1000 ton per day integrated bleached kraft paper mill

†Condenser cooling requirements for a steam electric plant producing half of the total electric power needs

‡Intake net totals are less than the sum of the individual components because much of the wastewater from high quality uses is cascaded to lower quality uses.

Water Use Per Employee

Table 3 shows some of the variations by industry in average water use per employee. These are overall averages for each industry group and are shown only for purposes of comparison. Two different parameters of water use are intake and gross water use. Intake is the volume of water taken into the plant, either purchased from water utilities or self-supplied. Gross water use is the sum of the intake water plus the reused water, and is a measure of the total volume of intake that would have been required if water were used on a once-through basis.

It is readily apparent from Table 3 that some industry groups tend to require much more water per employee than others. For example, the apparel and furniture industries average about 380 L/day (100 gpd) per employee, while paper and petroleum refining require thousands of L/day per employee. For the most part the wet industries use water chiefly for industrial cooling and process applications, while the dry industries use water for air conditioning and sanitary service.

The relative importance of water can be circumvented by some industries in water-short areas by water recirculation. As shown in Table 3 the petroleum refining industry averages 0.6 ML/day (163 000 gpd) per employee of gross water use, yet withdraws only 0.1 ML/day (25 500 gpd) per employee. This works out to an industry-wide recycling rate of 6.4. Some petroleum refineries on the Great Plains and in California operate at recycling rates as high as 40. Since water in petroleum refining is used overwhelmingly for noncontact

TABLE 7

Water Intake Requirements: Average Plants Versus High Recycling Plants

Industry	Parameters of Water Use	Intake		Recycling Rate*	
		1973 Industry Average	BAT† With Maximum Feasible Recycling	1973 Industry Average	BAT† With Maximum Feasible Recycling
Meatpacking	gal/lb carcass weight	2.2 gal/lb	0.5 gal/lb	1.66	6.67
Poultry dressing	gal/bird poultry slaughter	10.3 gal/bird	1.7 gal/bird	1.13	6.71
Dairy products	gal/lb milk processed	0.52 gal/lb	0.13 gal/lb	1.64	6.67
Canned fruits and vegetables	gal/case 24–303 cans eq	107 gal/case	29 gal/case	2.10	7.75
Frozen fruits and vegetables	gal/lb frozen product	7.1 gal/lb	1.6 gal/lb	1.60	7.25
Wet corn milling	gal/bu corn grind	223 gal/bu	46 gal/bu	1.86	9.09
Cane sugar	gal/ton cane sugar	18 250 gal/ton	5300 gal/ton	1.54	5.26
Beet sugar	gal/ton beet sugar	11 100 gal/ton	6200 gal/ton	2.98	5.38
Malt beverages	gal/barrel malt beverage	420 gal/bbl	105 gal/bbl	3.50	14.3
Textile mills	gal/lb fiber consumption	14 gal/lb	1.8 gal/lb	2.23	18.2
Sawmills	gal/bd ft lumber	3.3 gal/ft	0.8 gal/ft	1.64	6.85
Pulp and paper mills	gal/ton pulp and paper	38 000 gal/ton	10 700 gal/ton	3.42	12.2
Paper converting	gal/ton paper converted	3900 gal/ton	750 gal/ton	1.70	8.93
Alkalis and chlorine	gal/ton chlorine	22 200 gal/ton	860 gal/ton	1.34	34.5
Industrial gases	gal/1000 cu ft industrial gases	226 gal/mcf	18 gal/mcf	2.82	34.5
Inorganic pigments	gal/ton inorganic pigments	49 400 gal/ton	6100 gal/ton	1.98	16.1
Industrial inorganic chemicals	gal/ton chemicals 100 percent basis	4750 gal/ton	470 gal/ton	3.08	31.2
Plastic materials and resins	gal/lb plastic	6.7 gal/lb	0.7 gal/lb	3.53	33.3
Synthetic rubber	gal/lb synthetic rubber	6.5 gal/lb	1.6 gal/lb	8.38	33.3
Cellulosic man-made fibers	gal/lb fibers	68 gal/lb	8.4 gal/lb	3.42	27.8
Organic fibers, noncellulosic	gal/lb fibers	38 gal/lb	5.0 gal/lb	2.64	20.0
Paints and pigments	gal/gal paint	7.8 gal/gal	0.8 gal/gal	1.69	16.1
Industrial organic chemicals	gal/ton chemical building blocks	54 500 gal/ton	4000 gal/ton	2.29	31.2
Nitrogenous fertilizers	gal/ton fertilizer	4000 gal/ton	900 gal/ton	7.12	31.2
Phosphatic fertilizers	gal/ton fertilizer	8500 gal/ton	2400 gal/ton	4.21	14.7
Carbon black	gal/lb carbon black	3.9 gal/lb	0.3 gal/lb	1.17	16.1
Petroleum refining	gal/barrel crude oil input	289 gal/bbl	55 gal/bbl	6.38	33.9
Tires and inner tubes	gal/tire car and truck tires	153 gal/tire	18 gal/tire	3.39	29.4
Hydraulic cement	gal/ton cement	830 gal/ton	180 gal/ton	1.83	7.41
Steel	gal/ton steel net production	38 200 gal/ton	5300 gal/ton	1.64	11.9
Iron and steel foundries	gal/ton ferrous castings	3030 gal/ton	1080 gal/ton	4.10	11.5
Primary copper	gal/lb copper	17 gal/lb	4.5 gal/lb	3.12	11.9
Primary aluminum	gal/lb aluminum	12 gal/lb	2.9 gal/lb	4.11	16.9
Automobiles	gal/car domestic automobiles	11 500 gal/car	2200 gal/car	3.18	16.3

*The recycling rate is obtained by dividing gross water use by intake.
†Best available technology economically achievable as defined by Water Pollution Control Act amendments of 1972

cooling and condensing, it is relatively cost effective to recirculate the wastewater after it has been cooled.

Industrial Production Versus Water Usage

Table 4 relates water use to uniform production units for 34 water intensive manufacturing categories. These 34 industries account for 88 percent of all manufacturing water requirements. Good judgment should be exercised in interpreting these ratios, since they represent overall averages for these industries.

The physical production units shown in Table 4 are a diverse set of inputs and outputs peculiar to each industry. In some cases the production parameter is a unit of input, such as barrels of crude oil refined or number of chickens processed. In other cases a particular measure of output was used, such as automobiles assembled or pounds of meat packed. This approach was required to reflect industry practice.

For water resource planners it is interesting to compare water requirements by standarized production parameters. Table 5 shows the data presented in Table 4 in similar format, except that the water use ratios are expressed in a more uniform standardized form. All physical production units have been recalculated into either tons or gallons, except in cases where this would be totally inappropriate.

The descriptions of the industries in Tables 4 and 5 require proper interpretation. In addition to interindustry variations in water use, there are also many intra-industry variations. Even plants in the same industry can utilize a wide range of industrial processes

TABLE 8

Water Recycling in the Twenty Plants with the Highest Rates in 34 Major Water-Using Industries, 1970

Industry	Gross Water Use*	Intake*	Mean Recycling Rate†	Highest Recycling Rate†	Tenth Highest Recycling Rate†	Twentieth Highest Recycling Rate†
Meat packing plants	49.732	20.335	2.45	7.06	2.41	1.85
Poultry dressing	3.473	1.990	1.75	4.28	1.30	1.14
Fluid milk	8.118	0.859	9.45	71.71	7.92	3.96
Canned fruit and vegetables	10.673	3.419	3.12	18.24	2.50	1.76
Frozen fruit and vegetables	17.353	9.259	1.87	7.13	1.97	1.39
Wet corn milling	53.986	32.109	1.68	11.91	2.31	1.11
Beet sugar	58.949	16.829	3.50	22.24	2.97	1.84
Malt liquors	64.350	12.675	5.08	10.00	2.85	1.11
Shortening and cooking oils	48.106	5.425	8.87	113.53	8.23	1.30
Cigarettes	60.765	2.292	26.51	33.39	15.31	1.11
Weaving mills, cotton	74.289	1.186	62.64	285.31	64.25	27.99
Weaving mills, synthetics	88.114	0.717	122.89	558.25	111.27	48.53
Weaving and finishing, wool	19.163	2.637	7.27	93.44	24.19	1.18
Pulp mills	713.440	208.179	3.43	7.57	3.84	1.41
Papermills, except building paper	723.008	71.057	10.18	76.54	8.96	6.06
Paperboard mills	272.670	14.515	18.79	50.00	14.68	8.22
Alkalies and chlorine	198.798	87.167	2.28	25.11	1.79	1.12
Industrial gases	141.450	1.490	94.93	157.80	84.83	46.23
Cyclic intermediate and crudes	327.354	55.446	5.90	160.00	13.45	2.24
Inorganic pigments	120.387	50.222	2.40	15.22	1.53	1.11
Industrial organic chemicals	962.830	35.142	27.40	48.18	23.20	15.80
Industrial inorganic chemicals	505.919	16.670	30.35	70.95	30.10	23.81
Plastic materials and resins	704.229	5.131	137.25	613.60	27.37	13.81
Cellulosic man-made fibers	209.801	48.088	4.36	20.83	4.30	1.37
Organic fibers, noncellulosic	392.335	151.969	2.58	28.06	2.82	1.16
Pharmaceutical preparations	70.621	15.385	4.59	104.73	7.36	1.11
Fertilizers	282.251	23.373	12.08	90.60	9.72	2.45
Petroleum refining	2026.521	30.221	67.06	251.05	44.08	34.36
Cement, hydraulic	20.868	4.320	4.83	97.35	2.58	1.77
Blast furnaces and steel mills	394.549	29.050	13.58	95.13	18.86	6.76
Electrometallurgical products	22.732	1.827	12.44	65.81	25.84	5.07
Gray iron foundaries	35.396	10.254	3.45	15.23	2.86	1.82
Primary copper	78.473	33.218	2.36	9.85	2.23	1.18
Primary aluminum	65.519	15.723	4.17	10.10	3.50	1.66

*Billions of gallons per year; 1 bil gal = 3.7 GL
†The recycling rate is obtained by dividing gross water use by intake.

2. The Water Encyclopedia, Second Edition. van der Leeden, Frits. Troise, Fred L. Todd, David Keith. Lewis Publishers. 1983 (Water Encyclopedia 1983).

Table 7G.78 Water Use Versus Industrial Units of Production in the United States

Industry	Parameters of Water Use	Gross Water Used by Unit of Production	Intake by Unit of Production	Consumption by Unit of Production	Discharge by Unit of Production
Meatpacking	gal/lb carcass weight	3.6 gal/lb	2.2 gal/lb	0.1 gal/lb	2.1 gal/lb
Poultry dressing	gal/bird poultry slaughter	11.6 gal/bird	10.3 gal/bird	0.5 gal/bird	9.8 gal/bird
Dairy products	gal/lb milk processed	0.85 gal/lb	0.52 gal/lb	0.03 gal/lb	0.48 gal/lb
Canned fruits and vegetables	gal/case 24–303 cans eq	225 gal/case	107 gal/case	10 gal/case	98 cal/case
Frozen fruits and vegetables	gal/lb frozen product	11.2 gal/lb	7.1 gal/lb	0.2 gal/lb	6.9/gal/lb
Wet corn milling	gal/lb corn grind	416 gal/bu	223 gal/bu	18 gal/bu	205 gal/bu
Cane sugar	gal/ton cane sugar	28,100 gal/ton	18,250 gal/ton	950 gal/ton	17,300 gal/ton
Beet sugar	gal/ton beet sugar	33,100 gal/ton	11,100 gal/ton	390 gal/ton	10,700 gal/ton
Malt beverages	gal/barrel malt beverage	1,500 gal/bbl	420 gal/bbl	90 gal/bbl	330 gal/bbl
Textile mills	gal/lb fiber consumption	34 gal/lb	14 gal/lb	1.4 gal/lb	12.8 gal/lb
Sawmills	gal/bd ft lumber	5.4 gal/bd ft	3.3 gal/bd ft	0.6 gal/bd ft	2.7 gal/bd ft
Pulp and paper mills	gal/ton pulp and paper	130,000 gal/ton	38,000 gal/ton	1,800 gal/ton	36,200 gal/ton
Paper converting	gal/ton paper converted	6,600 gal/ton	3,900 gal/ton	270 gal/ton	3,600 gal/ton
Alkalis and chlorine	gal/ton chlorine	29,800 gal/ton	22,200 gal/ton	700 gal/ton	21,600 gal/ton
Industrial gases	gal/1,000 cu ft industrial gases	636 gal/mcf	226 gal/mcf	31 gal/mcf	193 gal/mcf
Inorganic pigments	gal/ton inorganic pigments	97,800 gal/ton	49,400 gal/ton	1,600 gal/ton	47,800 gal/ton
Industrial inorganic chemicals	gal/ton chemicals 100 percent basic	14,500 gal/ton	4,750 gal/ton	470 gal/ton	4,300 gal/ton
Plastic materials and resins	gal/lb plastic	24 gal/lb	6.7 gal/lb	0.6 gal/lb	6.1 gal/lb
Synthetic rubber	gal/lb synthetic rubber	55 gal/lb	6.5 gal/lb	1.4 gal/lb	5.1 gal/lb
Cellulosic man-made fibers	gal/lb fibers	231 gal/lb	68 gal/lb	4.6 gal/lb	63 gal/lb
Organic fibers, noncellulosic	gal/lb fibers	101 gal/lb	38 gal/lb	1.1 gal/lb	37 gal/lb
Paints and pigments	gal/gal paint	13 gal/gal	7.8 gal/gal	0.4 gal/gal	7.4 gal/gal
Industrial organic chemicals	gal/ton chemical building blocks	125,000 gal/ton	54,500 gal/ton	2,800 gal/ton	51,700 gal/ton
Nitrogenous fertilizers	gal/ton fertilizer	28,506 gal/ton	4,001 gal/ton	701 gal/ton	3,299 gal/ton
Phosphatic fertilizers	gal/ton fertilizer	35,602 gal/ton	8,461 gal/ton	1,277 gal/ton	7,184 gal/ton
Carbon black	gal/lb carbon black	4.6 gal/lb	3.9 gal/lb	0.9 gal/lb	3.1 gal/lb
Petroleum refining	gal/barrel crude oil input	1,851 gal/bbl	289 gal/bbl	28 gal/bbl	261 gal/bbl
Tires and inner tubes	gal/tire car and truck tires	518 gal/tire	153 gal/tire	14 gal/tire	139 gal/tire
Hydraulic cement	gal/ton cement	1,360 gal/ton	830 gal/ton	150 gal/ton	680 gal/ton
Steel	gal/ton steel net production	62,600 gal/ton	38,200 gal/ton	1,400 gal/ton	36,800 gal/ton
Iron and steel foundries	gal/ton ferrous castings	12,400 gal/ton	3,030 gal/ton	260 gal/ton	2,760 gal/ton
Primary copper	gal/lb copper	53 gal/lb	17 gal/lb	4.1 gal/lb	13 gal/lb
Primary aluminum	gal/lb aluminum	49 gal/lb	12 gal/lb	0.2 gal/lb	11.8 gal/lb
Automobiles	gal/car domestic automobiles	36,500 gal/car	11,464 gal/car	649 gal/car	10,814 gal/car

Source: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

Table 7G.79 Water Use Versus Standardized Units of Production in the United States

Industry	Parameters of Water Use	Gross Water Used by Unit of Production	Intake by Unit of Production	Consumption by Unit of Production	Discharge by Unit of Production
Meatpacking	gal/lb carcass weight	7,194 gal/ton	4,331 gal/ton	78 gal/ton	4,253 gal/ton
Poultry dressing	gal/ton ready-to-cook weight	7,389 gal/ton	6,542 gal/ton	296 gal/ton	6,246 gal/ton
Dairy products	gal/lb milk processed	1,692 gal/ton	1,035 gal/ton	63 gal/ton	964 gal/ton
Canned fruits and vegetables	gal/ton vegetables canned	19,700 gal/ton	9,400 gal/ton	850 gal/ton	8,550 gal/ton
Frozen fruits and vegetables	gal/ton vegetables frozen	22,500 gal/ton	14,100 gal/ton	300 gal/ton	13,800 gal/ton
Wet corn milling	gal/lb corn grind	14,869 gal/ton	7,988 gal/ton	643 gal/ton	7,345 gal/ton
Cane sugar	gal/ton cane sugar	28,102 gal/ton	18,256 gal/ton	944 gal/ton	17,312 gal/ton
Beet sugar	gal/ton beet sugar	33,145 gal/ton	11,118 gal/ton	386 gal/ton	10,731 gal/ton
Malt beverages	gal/beer and malt liquor	49 gal/gal	14 gal/gal	3 gal/gal	11 gal/gal
Textile mills	gal/ton textile fiber input	69,808 gal/ton	30,016 gal/ton	3,008 gal/ton	27,008 gal/ton
Sawmills	gal/bd ft lumber	5.4 gal/bd ft	3.3 gal/bd ft	0.63 gal/bd ft	2.7 gal/bd ft
Pulp and paper mills	gal/ton paper	130,047 gal/ton	37,971 gal/ton	1,178 gal/ton	36,193 gal/ton
Paper converting	gal/ton paper converted	6,584 gal/ton	3,861 gal/ton	273 gal/ton	3,588 gal/ton
Alkalis and chlorine	gal/ton chlorine	29,840 gal/ton	22,302 gal/ton	676 gal/ton	21,626 gal/ton
Industrial gases	gal/ton weight of gas	16,080 gal/ton	5,700 gal/ton	780 gal/ton	4,900 gal/ton
Inorganic pigments	gal/ton pigments	97,800 gal/ton	49,400 gal/ton	1,600 gal/ton	47,800 gal/ton
Industrial inorganic chemicals	gal/ton chemical products	14,500 gal/ton	4,700 gal/ton	470 gal/ton	4,300 gal/ton
Plastic materials and resins	gal/ton plastics	47,061 gal/ton	13,338 gal/ton	1,078 gal/ton	12,278 gal/ton
Synthetic rubber	gal/ton synthetic rubber	110,600 gal/ton	13,200 gal/ton	2,800 gal/ton	10,373 gal/ton
Cellulosic man-made fibers	gal/ton fibers	462,230 gal/ton	135,100 gal/ton	9,200 gal/ton	125,846 gal/ton
Organic fibers, noncellulosic	gal/ton fibers	202,123 gal/ton	76,523 gal/ton	2,153 gal/ton	74,369 gal/ton
Paints and pigments	gal/gal paint	13.2 gal/gal	7.8 gal/gal	0.4 gal/gal	7.4 gal/gal
Industrial organic chemicals	gal/ton chemical building blocks	124,700 gal/ton	54,500 gal/ton	2,800 gal/ton	51,700 gal/ton
Nitrogenous fertilizers	gal/ton fertilizer	28,506 gal/ton	4,001 gal/ton	701 gal/ton	3,299 gal/ton
Phosphatic fertilizers	gal/ton fertilizer	35,602 gal/ton	8,461 gal/ton	1,277 gal/ton	7,184 gal/ton
Carbon black	gal/ton carbon black	9,200 gal/ton	7,885 gal/ton	1,771 gal/ton	6,114 gal/ton
Petroleum refining	gal/gal crude petroleum input	44 gal/gal	6.9 gal/gal	0.7 gal/gal	6.2 gal/gal
Tires and inner tubes	gal/tire car and truck tires	518 gal/tire	153 gal/tire	14 gal/tire	139 gal/tire
Hydraulic cement	gal/ton cement	1,355 gal/ton	831 gal/ton	146 gal/ton	685 gal/ton
Steel	gal/ton steel net tons	62,601 gal/ton	38,200 gal/ton	1,400 gal/ton	36,800 gal/ton
Iron and steel foundries	gal/ton ferrous castings	12,407 gal/ton	3,024 gal/ton	260 gal/ton	2,764 gal/ton
Primary copper	gal/ton copper	106,000 gal/ton	34,000 gal/ton	8,200 gal/ton	26,000 gal/ton
Primary aluminum	gal/ton aluminum	96,300 gal/ton	23,900 gal/ton	381 gal/ton	23,500 gal/ton
Automobiles	gal/car automobiles	36,500 gal/car	11,464 gal/car	649 gal/car	10,814 gal/car

Source: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

Table 7G.81 Water Intake Requirements in the United States — Average Plants Versus High Recycling Plants

		Intake		Recycling Rate[a]	
Industry	Parameters of Water Use	1973 Industry Average	BAT[b] with Maximum Feasible Recycling	1973 Industry Average	BAT[b] with Maximum Feasible Recycling
Meatpacking	gal/lb carcass weight	2.2 gal/lb	0.5 gal/lb	1.66	6.67
Poultry dressing	gal/bird poultry slaughter	10.3 gal/bird	1.7 gal/bird	1.13	6.71
Dairy products	gal/lb milk processed	0.52 gal/lb	0.13 gal/lb	1.64	6.67
Canned fruits and vegetables	gal/case 24–303 cans eq	107 gal/case	29 gal/case	2.10	7.75
Frozen fruits and vegetables	gal/lb frozen product	7.1 gal/lb	1.6 gal/lb	1.60	7.25
Wet corn milling	gal/bu corn grind	223 gal/bu	46 gal/bu	1.86	9.09
Cane sugar	gal/ton cane sugar	18,250 gal/ton	5,300 gal/ton	1.54	5.26
Beet sugar	gal/ton beet sugar	11,100 gal/ton	6,200 gal/ton	2.98	5.38
Malt beverages	gal/barrel malt beverage	420 gal/bbl	105 gal/bbl	3.50	14.3
Textile mills	gal/lb fiber consumption	14 gal/lb	1.8 gal/lb	2.23	18.2
Sawmills	gal/bd ft lumber	3.3 gal/ft	0.8 gal/ft	1.64	6.85
Pulp and paper mills	gal/ton pulp and paper	38,000 gal/ton	10,700 gal/ton	3.42	12.2
Paper converting	gal/ton paper converted	3,900 gal/ton	750 gal/ton	1.70	8.93
Alkalis and chlorine	gal/ton chlorine	22,200 gal/ton	860 gal/ton	1.34	34.5
Industrial gases	gal/1,000 cu ft industrial gases	226 gal/mcf	18 gal/mcf	2.82	34.5
Inorganic pigments	gal/ton inorganic pigments	49,400 gal/ton	6,100 gal/ton	1.98	16.1
Industrial inorganic chemicals	gal/ton chemicals 100 percent basis	4,750 gal/ton	470 gal/ton	3.08	31.2
Plastic materials and resins	gal/lb plastic	6.7 gal/lb	0.7 gal/lb	3.53	33.3
Synthetic rubber	gal/lb synthetic rubber	6.5 gal/lb	1.6 gal/lb	8.38	33.3
Cellulosic man-made fibers	gal/lb fibers	68 gal/lb	8.4 gal/lb	3.42	27.8
Organic fibers, noncellulosic	gal/lb fibers	38 gal/lb	5.0 gal/lb	2.64	20.0
Paints and pigments	gal/gal paint	7.8 gal/gal	0.8 gal/gal	1.69	16.1
Industrial organic chemicals	gal/ton chemical building blocks	54,500 gal/ton	4,000 gal/ton	2.29	31.2
Nitrogenous fertilizers	gal/ton fertilizer	4,000 gal/ton	900 gal/ton	7.12	31.2
Phosphatic fertilizers	gal/ton fertilizer	8,500 gal/ton	2,400 gal/ton	4.21	14.7
Carbon black	gal/lb carbon black	3.9 gal/lb	0.3 gal/lb	1.17	16.1
Petroleum refining	gal/barrel crude oil input	289 gal/bbl	55 gal/bbl	6.38	33.3
Tires and inner tubes	gal/tire car and truck tires	153 gal/tire	18 gal/tire	3.39	29.4
Hydraulic cement	gal/ton cement	830 gal/ton	180 gal/ton	1.63	7.41
Steel	gal/ton steel net production	38,200 gal/ton	5,300 gal/ton	1.64	11.9
Iron and steel foundries	gal/ton ferrous castings	3,030 gal/ton	1,080 gal/ton	4.10	11.5
Primary copper	gal/lb copper	17 gal/lb	4.5 gal/lb	3.12	11.9
Primary aluminum	gal/lb aluminum	12 gal/lb	2.9 gal/lb	4.11	16.9
Automobiles	gal/car domestic automobiles	11,500 gal/car	2,200 gal/car	3.18	16.3

[a] The recycling rate is obtained by dividing gross water use by intake.
[b] Best available technology economically achievable as defined by Water Pollution Control Act amendments of 1972.

Source: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

Table 7G.82 Water Recycling in the 20 Plants with the High…
in the United States, 1970

Industry	Gross Water Use[a]	Intake[a]	Me.			
Meat packing plants	49.732	20.335	2.			
Poultry dressing	3.473	1.990	1.7			
Fluid milk	8.118	0.859	9.45			
Canned fruit and vegetables	10.673	3.419	3.12			
Frozen fruit and vegetables	17.353	9.259	1.87			
Wet corn milling	53.986	32.109	1.68			
Beet sugar	58.949	16.829	3.50			
Malt liquors	64.350	12.675	5.08			
Shortening and cooking oils	48.106	5.425	8.87	[illegible]	8..	
Cigarettes	60.765	2.292	26.51	33.	15.3	[illegible]
Weaving mills, cotton	74.289	1.186	62.64	285.31	64.25	27.99
Weaving mills, synthetics	88.114	0.717	122.89	558.25	111.27	48.53
Weaving and finishing, wool	19.163	2.637	7.27	93.44	24.19	1.18
Pulp mills	713.440	208.179	3.43	7.57	3.84	1.41
Papermills, except building paper	723.008	71.057	10.18	76.54	8.96	6.06
Paperboard mills	272.670	14.515	18.79	50.00	14.68	8.22
Alkalis and chlorine	198.798	87.167	2.28	25.11	1.79	1.12
Industrial gases	141.450	1.490	94.93	157.80	84.83	46.23
Cyclic intermediate and crudes	327.354	55.446	5.90	160.00	13.45	2.24
Inorganic pigments	120.387	50.222	2.40	15.22	1.53	1.11
Industrial organic chemicals	962.830	35.142	27.40	48.18	23.20	15.80
Industrial inorganic chemicals	505.919	16.670	30.35	70.95	30.10	23.81
Plastic materials and resins	704.229	5.131	137.25	613.60	27.37	13.81
Cellulosic man-made fibers	209.801	48.088	4.36	20.83	4.30	1.37
Organic fibers, noncellulosic	392.335	151.969	2.58	28.06	2.82	1.16
Pharmaceutical preparations	70.621	15.385	4.59	104.73	7.36	1.11
Fertilizers	282.251	23.373	12.08	90.60	9.72	2.45
Petroleum refining	2,026.521	30.221	67.06	251.05	44.08	34.36
Cement, hydraulic	20.868	4.320	4.83	97.35	2.58	1.77
Blast furnaces and steel mills	394.549	29.050	13.58	95.13	18.66	6.76
Electrometallurgical products	22.732	1.827	12.44	65.81	25.64	5.07
Gray iron foundaries	35.396	10.254	3.45	15.23	2.86	1.82
Primary copper	78.473	33.218	2.36	9.85	2.23	1.18
Primary aluminum	65.519	15.723	4.17	10.10	3.50	1.66

[a] Billions of gallons per year: 1 bil gal = 3.7 GL.
[b] The recycling rate is obtained by dividing gross water use by intake.

Source: From Kollar, K.L. and MacAuley, P., 1980, Water requirements for industrial development, *J. Am. Water Works Assoc.*, vol. 72, no. 1. Copyright AWWA. Reprinted with permission.

SECTION 7H INDUSTRIAL WATER USE — WORLD

Table 7H.89 Water Intake in Manufacturing (MCM/yr) by Purpose of Initial Use and Industry in Canada, 1996

Industry Group	Number of Plants	Processing	Cooling, Condensing, and Steam	Sanitary Services	Other	Total Intake	%
Food	1,264	128.6	107.3	27.8	5.9	269.5	4.5
Beverages	121	38.4	29.0	4.6	1.1	73.1	1.2
Rubber products	96	3.6	7.7	0.9	0.1	12.3	0.2
Plastic products	486	5.9	5.9	1.3	0.2	13.3	0.2
Primary textiles	87	15.5	64.6	6.5	0.0	86.7	1.4
Textile products	47	12.8	1.8	0.4	0.1	15.0	0.2
Wood products	454	9.7	24.4	2.2	8.8	45.1	0.7
Paper + allied products	292	1,847.5	508.3	49.1	16.4	2,421.3	40.1
Primary metals	217	557.6	830.1	21.5	13.8	1,423.0	23.6
Fabricated metals	543	11.3	6.4	1.6	0.1	19.4	0.3
Transportation equipment	547	28.5	25.0	11.1	0.4	65.0	1.1
Nonmetallic mineral products	726	21.6	44.9	3.5	32.1	102.1	1.7
Petroleum + coal products	27	34.4	324.6	4.9	6.6	370.5	6.1
Chemicals + chemical products	599	220.9	879.8	10.9	9.7	1,121.3	18.6
Total	5,506	2,936.3	2,859.6	146.3	95.3	6,037.5	100.0
%		**48.6**	**47.4**	**2.4**	**1.6**	**100.0**	

Source: From Scharf, D., Burke, D., Villeneuve, and Leigh, L., 1996. Industrial Water Use 1996, Scharf, D., Burke, D.W., Villeneuve, M., and Leigh, L., Environmental Economics Branch, Environment Canada, 2002. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

Table 7H.90 Water Intake in Manufacturing (MCM/yr) by Source and Industry Group in Canada, 1996

		Fresh Water				Brackish Water			
			Self-Supplied			Self-Supplied			
Industry Group	Number of Plants	Public Supplied Municipal	Surface	Ground	Other	Ground	Tidewater	Other	Total Intake
Food	1,254	118.7	61.8	44.6	3.4	1.9	38.7	0.2	269.3
Beverages	121	49.0	16.1	8.1	0.0	0.0	0.0	0.0	73.1
Rubber products	96	8.2	1.3	2.4	0.5	0.0	0.0	0.0	12.3
Plastic products	482	7.0	4.8	1.2	0.1	0.1	0.0	0.0	13.2
Primary textiles	87	34.6	51.4	0.1	0.0	0.1	0.0	0.5	86.7
Textile products	47	13.1	0.0	2.0	0.0	0.0	0.0	0.0	15.0
Wood products	454	18.8	16.4	9.5	0.2	0.1	0.1	0.0	45.1
Paper + allied products	292	70.4	2,240.0	65.8	45.3	0.0	0.0	0.0	2,421.3
Primary metals	217	61.2	1,314.0	22.9	12.8	0.0	12.1	0.0	1,423.0
Fabricated metals	543	12.1	6.8	0.5	0.0	0.0	0.0	0.0	19.4
Transportation equipment	547	59.5	4.7	0.7	0.0	0.0	0.0	0.0	65.0
Non-metallic mineral products	725	19.5	36.3	9.9	36.0	0.0	0.4	0.0	102.1
Petroleum + coal products	27	11.4	249.0	2.5	1.3	0.0	102.1	4.2	370.5
Chemicals + chemical products	599	66.1	940.1	7.2	67.2	0.1	40.5	0.1	1,121.3
Total	5,491	549.6	4,942.5	177.3	166.8	2.3	193.9	5.0	6,037.4
%		**9.1**	**81.9**	**2.9**	**2.8**	**0.0**	**3.2**	**0.1**	**100.0**

Source: From Scharf, D., Burke, D., Villeneuve, and Leigh, L., 1996. Industrial Water Use 1996, Scharf, D., Burke, D.W., Villeneuve, M., and Leigh, L., Environmental Economics Branch, Environment Canada, 2002. Reproduced with the permission of the Minister of Public Works and Government Services, 2006.

Table 7H.93 Water Requirements for Selected Industries in the World

Industry, Product, and Country	Unit of Product (Ton, Except as Specified)	Water Required per Unit (L)
Food Products		
Bread or pastry, Belgium		1,100
Bread, United States		2,100–4,200
Bread, Cyprus[a]		600
Canned food		
Belgium		
Fish, canned		400
Fish, preserved		1,500
Fruit		15,000
Vegetables		8,000–80,000
Canada		
Fruits and vegetables[a]		10,000–50,000
Cyprus		
Citrus/tomato juice[a]		2,800
Grapefruit sections[a]		16,000
Peaches/pears[a]		10,000–15,000
Grapes[a]		30,000
Tomatoes, whole[a]		2,000
Tomato paste[a]		21,000
Peas[a]		10,000
Carrots[a]		16,000
Spinach[a]		30,000
Israel		
Citrus fruits[a]	Ton of raw citrus	4,000
Vegetables[a]		10,000–15,000
United States		
Apricots		21,200
Asparagus		20,500
Beans, green		9,300
Beans, lima		69,800
Beets, corn and peas		7,000
Grapefruit juice		2,800
Grapefruit sections		15,600
Peaches and pears		18,100
Pork and beans		9,300
Pumpkin and squash		7,000
Sauerkraut		950
Spinach		49,400
Succotash		34,800
Tomato products		20,500
Tomatoes, whole		2,200
Industry average, fruits, vegetables, and juices (1965)[a]		24,000
Meat		
Meat freezing, Cyprus[a]	Ton of carcass	500
Meat freezing, New Zealand		3,000–8,600
Meat packing, United States[a]	Ton of prepared meat	23,000
Meat packing, Canada[a]	Ton of carcass	8,800–34,000
Meat products, Belgium	Ton of prepared meat	200
Sausage factory, Finland		20,000–35,000
Sausage factory, Cyprus[a]		25,000
Slaughtering, Finland	Ton, live weight	4,000–9,000
Slaughtering, Cyprus[a]	Ton of carcass	10,000
Meat preserving, Israel[a]	Ton of prepared meat	10,000
Fish		
Fresh and frozen fish, Canada[a]		30,000–300,000
Canned fish, Canada[a]		58,000
Canning and preserving fish, Israel[a]	Ton of raw fish	16,000–20,000
Poultry		
Poultry, Canada[a]	Ton	6,000–43,000
Chickens, Israel[a]	Ton of dressed chicken	33,000
Chickens, United States[a]	Per bird	25
Turkeys, United States[a]	Per bird	75
Milk and Milk Products		
Butter		
New Zealand[a]		20,000

(Continued)

Table 7H.93 (Continued)

Industry, Product, and Country	Unit of Product (Ton, Except as Specified)	Water Required per Unit (L)
Cheese		
Cyprus[a]		10,000
New Zealand[a]		2,000
United States[a]		27,500
Milk		
Belgium	1,000 L	7,000
Finland		2,000–5,000
Israel[a]		2,700
Sweden		2,000–4,000
United States[a]		3,000
Milk powder		
New Zealand[a]		45,000
South Africa		200,000
Whey, United States[a]		10,000
Dairy products, general, Canada[a]		12,200
Ice cream, United States[a]		10,000
Yogurt, Cyprus[a]		20,000
Sugar		
Denmark[a]	Ton of sugar beets	4,800–15,800
Finland	Ton of sugar beets	10,000–20,000
France[a]	Ton of sugar beets	10,900
Germany, Federal[a]	Ton of sugar beets	10,400–14,000
Great Britain[a]	Ton of sugar beets	14,900
Israel[a]	Ton of sugar beets	1,800
Italy[a]	Ton of sugar beets	10,500–12,500
Republic of China[a]	Ton of sugar cane	15,000
United States[a]	Ton of sugar beets (range)	3,200–8,300
United States[a]	Ton of sugar beets (average)	6,000
Beverages		
Beer		
Belgium	Kiloliter	7,000–20,000
Canada[a]	Kiloliter	10,000–20,000
Cyprus[a]	Kiloliter (incl. cleaning bottles)	22,000–30,000
Finland	Kiloliter	10,000–20,000
France[a]	Kiloliter	14,500
Israel[a]	Kiloliter	13,500
United Kingdom[a]	Kiloliter	6,000–10,000
United States	Kiloliter	15,200
Whiskey, United States[a]	Kiloliter of proof spirit	2,600–76,000
Distilled spirits, Israel[a]	Kiloliter	30,000
Wine, France[a]	Kiloliter	2,900
Wine, Israel[a]	Kiloliter	500
Miscellaneous Food Products		
Chocolate confectionery, Belgium		15,000–17,000
Gelatin (edible), United States		55,100–83,500
Maize (wet milling), United States	Liter of maize	15.0–25.5
Maize syrup, United States	Liter of maize	3.8–4.3
Wheat milling, Cyprus[a]		2,000
Wheat milling, Israel[a]		700–1,300
Potato flour, Finland	Ton of potatoes	10,000–20,000
Potato starch, Canada[a]	Ton of starch	80,000–150,000
Macaroni, Cyprus[a]		1,200
	Hectoliter of raw material	1,000–12,000
		840

3. US EPA, Technology Transfer Seminar Publication Pollution Abatement in the Fruit and Vegetable Industry. Volume 2: In Plant Control of Process Wastewater. July 1977. (EPA 1977)

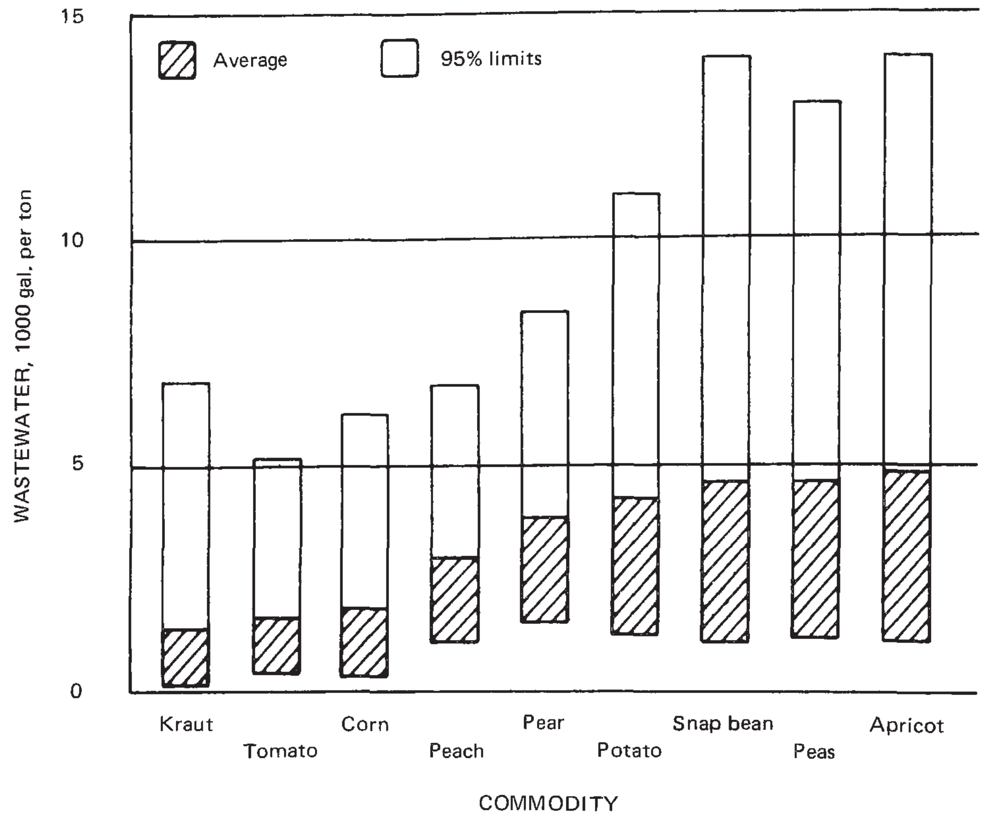

Figure III-1. Generated wastewater, average and 95% limits.

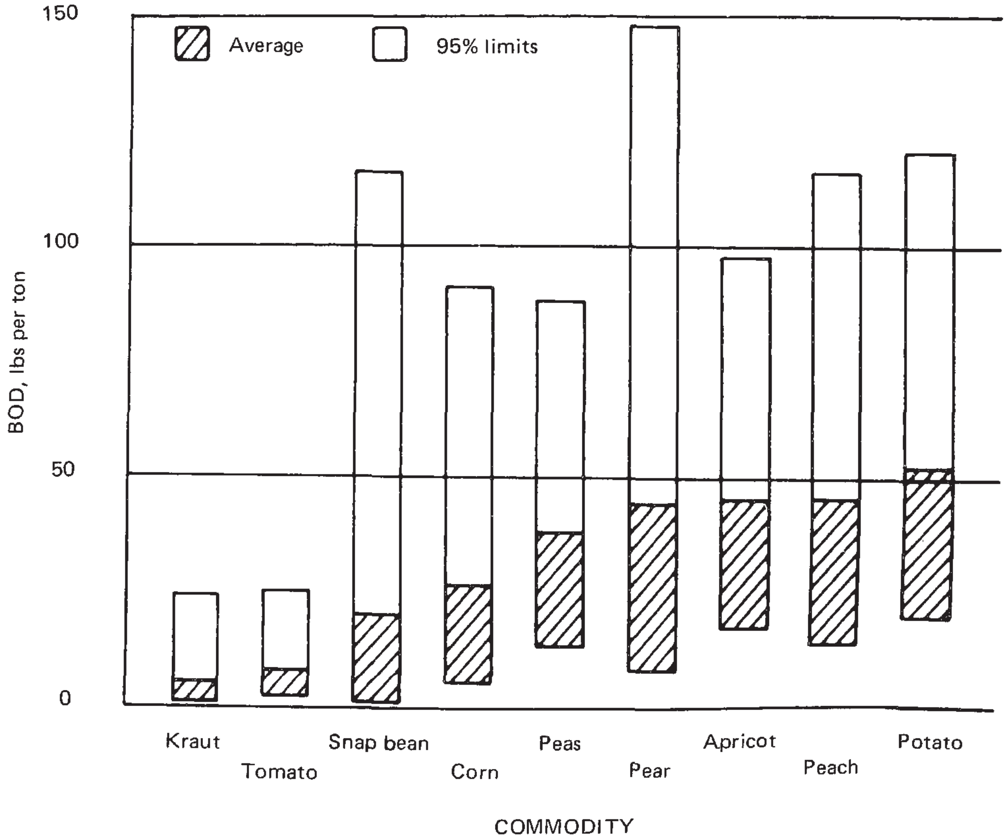

Figure III-2. Generated BOD, average and 95% limits.

Table III-1.—*Wastewater and generated pollution loads by commodity*

	Wastewater 1000 gallons/ton			BOD pounds/ton			TSS pounds/ton			Temp.	pH
	ave	95% limits		ave	95% limits		ave	95% limits		ave	ave
Apple	3.2	.2	17	22	4.4	64	6.3	.5	30	54	5.6
Apricot	4.9	1.1	14	45	17	98	9.9	4.0	22	76	8.0
Asparagus	8.6	1.4	31	5	.6	26	7.5	4	13		
Dry bean	9.8	1.1	44	75	16	238	59	(2	130)[a]		6.8
Snap bean	4.7	1.1	14	20	.7	116	7.0	.3	63	70	7.3
Beet	4.0	.8	12	44	5	217	26	2	116		7.9
Berry	3.5	.4	16	24	5.2	77	16	(1	57)[a]		
Broccoli	8.8	1.6	32	16	2.1	54					
Cauliflower	11	(1.7	23)[a]	18	(2	49)[a]					
Carrot	4.0	.8	13	31	9.6	80	17	2.0	72	63	8.7
Cherry	4.8	.4	27	15	2.4	75	.8	(.5	1)[a]		
Citrus	4.3	.4	16	16	(1	45)[a]	6.0	(2	10)[a]	79	6.5
Corn	1.9	.3	6.2	27	4.8	91	12	2.1	44	77	5.6
Grape	2.8	.3	13								
Lima	7.3	1.4	24	58	6.0	240	50	2.7	332		
Mushroom	9.6	1.7	33	20	8.8	40	10	4.2	22		
Okra	5.0	1.3	15								
Onion	6.8	(.2	17)[a]								
Pea	4.7	1.2	13	38	13	88	12	1.3	67	70	6.0
Peach	3.0	1.1	6.8	45	13	116	9.1	1.8	30	72	9.6
Pear	3.9	1.5	8.4	44	8.6	147	8.7	1.7	29		7.0
Peppers	4.6	.9	16	32	(5	50)[a]	58	(1	170)[a]		
Pickle	4.6	.8	19								
Pineapple	1.7			16	7.4	31	9.9	3.5	24	92	6.8
Plum	4.9	.4	23	11	(3	19)[a]	4.4	(.3	11)[a]		6.8
Potato	4.3	1.2	11	52	19	120	44	3.8	250		
Pumpkin	2.9	.4	11	32	9.2	87	6.7	(2	12)[a]		6.3
Sauerkraut	1.4	.1	6.9	6.0	.9	24	.6			65	6.4
Spinach	7.3	1.5	23	13	3.5	37	4.6	1.7	11		
Sprouts	10.1	(4.8	20)[a]	25	(5	75)[a]					
Squash	6.0	1.1	22	20			14				
Sweet potato	4.0	.3	23	60	24	130	34				
Tomato	1.7	.4	5.2	8.6	2.0	26	8.4	.3	66	79	7.9
Turnip	7.3	2.4	18								

[a] "Limits" in parentheses are reported maxima and minima.

PREPARATION PROCEDURES AND EQUIPMENT

PRODUCT STYLE

The kind of products made from a given commodity influences the amount of wastewater and the generation of pollutants. An example of this influence is found in figure III-3, in which the generation of BOD is compared to the percentage of peeled style tomatoes; on the average, the more peeling, the more BOD. The relationship is highly significant in spite of the wide probability limits. In a recent study, slicing apples, slicing snap beans, peeling tomatoes, and

4. US EPA, Office of Water and Hazardous Materials. Development Document for Interim Final and Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Fruits, Vegetable and Specialties Segment of the Canned and Preserved Fruits and Vegetables Point Source Categories. October 1975 (EPA 1975)

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)

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

5. a. CA DWR. Bulletin No. 124-3 “Water use by Manufacturing Industries in California 1979.” 1982. (DWR 1982)

TABLE 1

RANGE OF REPORTED ANNUAL WATER USE BY INDUSTRY GROUP IN 1979

IN MILLONS OF GALLONS

1 MILLION GALLONS = 3.7854 MEGALITRES

SIC CODE	INDUSTRY GROUP	TOTAL NO. OF PLANTS	PLANTS REPORTING WATER INTAKE						
			TOTAL	GROSS INTAKE IN MILLION GALLONS PER YEAR					
				UNDER 0.1	0.1 - 1	1 - 10	10 - 100	100 - 1000	OVER 1000
201	MEAT PRODUCTS	234	95	8	16	38	28	5	0
202	DAIRY PRODUCTS	147	69	7	16	11	21	14	0
203	PRESERVED FRUITS AND VEGETABLES	323	196	8	33	43	51	58	3
204	GRAIN MILL PRODUCTS	179	92	18	34	27	12	1	0
205	BAKERY PRODUCTS	266	100	16	41	31	9	3	0
206	SUGAR AND CONFECTIONARY PRODUCTS	80	44	9	11	10	7	6	1
207	FATS AND OILS	61	29	2	2	10	14	1	0
208	BEVERAGES	322	206	40	43	60	51	12	0
209	MISC. FOODS AND KINDRED PRODUCTS	389	174	22	48	64	26	14	0
20	FOOD AND KINDRED PRODUCTS	2001	1005	130	244	294	219	114	4
212	CIGARS	2	0	0	0	0	0	0	0
213	CHEWING AND SMOKING TOBACCO	1	0	0	0	0	0	0	0
21	TOBACCO MANUFACTURES	3	0	0	0	0	0	0	0
221	WEAVING MILLS, COTTON	62	0	0	0	0	0	0	0
222	WEAVING MILLS, SYNTHETICS	47	0	0	0	0	0	0	0
223	WEAVING AND FINISHING MILLS, WOOL	3	0	0	0	0	0	0	0
224	NARROW FABRIC MILLS	10	0	0	0	0	0	0	0
225	KNITTING MILLS	101	0	0	0	0	0	0	0
226	TEXTILE FINISHING, EXCEPT WOOL	52	0	0	0	0	0	0	0
227	FLOOR COVERING MILLS	77	0	0	0	0	0	0	0
228	YARN AND THREAD MILLS	20	0	0	0	0	0	0	0
229	MISCELLANEOUS TEXTILE GOODS	82	1	0	1	0	0	0	0
22	TEXTILE MILL PRODUCTS	454	1	0	1	0	0	0	0
231	MEN'S AND BOYS' SUITS AND COATS	51	0	0	0	0	0	0	0
232	MEN'S AND BOYS' FURNISHINGS	313	0	0	0	0	0	0	0
233	WOMEN'S AND MISSES' OUTERWEAR	1275	0	0	0	0	0	0	0
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	40	0	0	0	0	0	0	0
235	HATS, CAPS, AND MILLINERY	20	0	0	0	0	0	0	0
236	CHILDREN'S OUTERWEAR	47	0	0	0	0	0	0	0
237	FUR GOODS	9	0	0	0	0	0	0	0
238	MISCELLANEOUS APPAREL AND ACCESSORIES	102	0	0	0	0	0	0	0
239	MISC. FABRICATED TEXTILE PRODUCTS	595	3	0	2	1	0	0	0
23	APPAREL AND OTHER TEXTILE PRODUCTS	2452	3	0	2	1	0	0	0
241	LOGGING CAMPS & LOGGING CONTRACTORS	153	0	0	0	0	0	0	0
242	SAWMILLS AND PLANING MILLS	214	56	0	16	15	15	8	2
243	MILLWORK, PLYWOOD & STRUCTURAL MEMBERS	713	1	1	0	0	0	0	0
244	WOODEN CONTAINERS	161	0	0	0	0	0	0	0
245	WOOD BUILDINGS & MOBILE HOMES	134	0	0	0	0	0	0	0
249	MISCELLANEOUS WOOD PRODUCTS	306	7	0	2	3	2	0	0
24	LUMBER AND WOOD PRODUCTS	1681	64	1	18	18	17	8	2

TABLE 2

REPORTED ANNUAL INTAKE BY INDUSTRY GROUP IN 1979

IN MILLIONS OF GALLONS
1 MILLION GALLONS = 3.7854 MEGALITRES

SIC CODE	INDUSTRY GROUP	NUMBER OF EMPLOYEES		FRESH WATER		RECLAIMED WATER	BRACKISH WATER	TOTAL INTAKE WATER
		TOTAL	REPORTING [1]	PURCHASED	SELF PRODUCED			
201	MEAT PRODUCTS	19281	9442	2342.	278.	0.	198.	2819.
202	DAIRY PRODUCTS	7977	4238	1222.	2900.	0.	1.	4122.
203	PRESERVED FRUITS AND VEGETABLES	46769	35757	7680.	14645.	1.	173.	22500.
204	GRAIN MILL PRODUCTS	8375	4993	562.	184.	0.	62.	809.
205	BAKERY PRODUCTS	21549	7499	1026.	17.	0.	0.	1043.
206	SUGAR AND CONFECTIONARY PRODUCTS	7465	5469	880.	4328.	0.	10240.	15447.
207	FATS AND OILS	2695	2644	367.	303.	0.	0.	670.
208	BEVERAGES	19652	12975	3000.	2890.	0.	4.	5894.
209	MISC. FOODS AND KINDRED PRODUCTS	25393	14332	3962.	1465.	5.	2050.	7481.
20	FOOD AND KINDRED PRODUCTS	159156	97349	21041.	27009.	6.	12728.	60785.
212	CIGARS	13	0	0.	0.	0.	0.	0.
213	CHEWING AND SMOKING TOBACCO	300	0	0.	0.	0.	0.	0.
21	TOBACCO MANUFACTURES	313	0	0.	0.	0.	0.	0.
221	WEAVING MILLS, COTTON	1077	0	0.	0.	0.	0.	0.
222	WEAVING MILLS, SYNTHETICS	740	0	0.	0.	0.	0.	0.
223	WEAVING AND FINISHING MILLS, WOOL	60	0	0.	0.	0.	0.	0.
224	NARROW FABRIC MILLS	296	0	0.	0.	0.	0.	0.
225	KNITTING MILLS	5967	0	0.	0.	0.	0.	0.
226	TEXTILE FINISHING, EXCEPT WOOL	1414	0	0.	0.	0.	0.	0.
227	FLOOR COVERING MILLS	5600	0	0.	0.	0.	0.	0.
228	YARN AND THREAD MILLS	1926	0	0.	0.	0.	0.	0.
229	MISCELLANEOUS TEXTILE GOODS	3404	88	0.	0.	0.	0.	0.
22	TEXTILE MILL PRODUCTS	20484	88	0.	0.	0.	0.	0.
231	MEN'S AND BOYS' SUITS AND COATS	3753	0	0.	0.	0.	0.	0.
232	MEN'S AND BOYS' FURNISHINGS	15436	0	0.	0.	0.	0.	0.
233	WOMEN'S AND MISSES' OUTERWEAR	49959	0	0.	0.	0.	0.	0.
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	4104	0	0.	0.	0.	0.	0.
235	HATS, CAPS, AND MILLINERY	719	0	0.	0.	0.	0.	0.
236	CHILDREN'S OUTERWEAR	1985	0	0.	0.	0.	0.	0.
237	FUR GOODS	172	0	0.	0.	0.	0.	0.
238	MISCELLANEOUS APPAREL AND ACCESSORIES	3182	0	0.	0.	0.	0.	0.
239	MISC. FABRICATED TEXTILE PRODUCTS	20017	332	2.	0.	0.	0.	2.
23	APPAREL AND OTHER TEXTILE PRODUCTS	99327	332	2.	0.	0.	0.	2.
241	LOGGING CAMPS & LOGGING CONTRACTORS	3571	0	0.	0.	0.	0.	0.
242	SAWMILLS AND PLANING MILLS	18499	8596	587.	12767.	98.	212.	13665.
243	MILLWORK, PLYWOOD & STRUCTURAL MEMBERS	21294	32	0.	0.	0.	0.	0.
244	WOODEN CONTAINERS	4600	0	0.	0.	0.	0.	0.
245	WOOD BUILDINGS & MOBILE HOMES	7383	0	0.	0.	0.	0.	0.
249	MISCELLANEOUS WOOD PRODUCTS	8356	288	19.	97.	0.	36.	152.
24	LUMBER AND WOOD PRODUCTS	63703	8916	606.	12865.	99.	248.	13817.

[1] NUMBER OF EMPLOYEES IN THE SURVEY.

NOTE : ZEROS MAY INDICATE VALUES BETWEEN 0 AND 1 OR INCONCLUSIVE VALUES.

REPORTED ANNUAL WATER INTAKE BY TYPE OF USE AND INDUSTRY GROUP IN 1979

SIC CODE	INDUSTRY GROUP	NUMBER OF EMPLOYEES		WATER INTAKE (million gallons)				WATER INTAKE (megalitres)			
		TOTAL	REPORTING[1]	COOLING	PROCESSING	SANITARY	TOTAL	COOLING	PROCESSING	SANITARY	TOTAL
201	MEAT PRODUCTS	19281	9442	328.	2207.	169.	2703.	1241.	8353.	639.	10234.
202	DAIRY PRODUCTS	7977	4238	1032.	2938.	77.	4046.	3906.	11120.	291.	15317.
203	PRESERVED FRUITS AND VEGETABLES	46769	35757	3611.	18010.	555.	22176.	13670.	68174.	2101.	83945.
204	GRAIN MILL PRODUCTS	8375	4993	96.	513.	46.	655.	364.	1943.	174.	2480.
205	BAKERY PRODUCTS	21549	7499	27.	552.	97.	677.	104.	2090.	367.	2561.
206	SUGAR AND CONFECTIONARY PRODUCTS	7465	5469	9649.	5485.	66.	15199.	36522.	20763.	251.	57535.
207	FATS AND OILS	2695	2646	190.	442.	37.	669.	719.	1675.	141.	2534.
208	BEVERAGES	19652	12975	1573.	2947.	203.	4724.	5956.	11157.	769.	17882.
209	MISC. FOODS AND KINDRED PRODUCTS	25393	14332	3280.	3379.	140.	6798.	12415.	12791.	529.	25735.
20	FOOD AND KINDRED PRODUCTS	159156	97349	19785.	36473.	1390.	57648.	74895.	138065.	5262.	218222.
212	CIGARS	13	0	0.	0.	0.	0.	0.	0.	0.	0.
213	CHEWING AND SMOKING TOBACCO	300	0	0.	0.	0.	0.	0.	0.	0.	0.
21	TOBACCO MANUFACTURES	313	0	0.	0.	0.	0.	0.	0.	0.	0.
221	WEAVING MILLS, COTTON	1077	0	0.	0.	0.	0.	0.	0.	0.	0.
222	WEAVING MILLS, SYNTHETICS	740	0	0.	0.	0.	0.	0.	0.	0.	0.
223	WEAVING AND FINISHING MILLS, WOOL	60	0	0.	0.	0.	0.	0.	0.	0.	0.
224	NARROW FABRIC MILLS	296	0	0.	0.	0.	0.	0.	0.	0.	0.
225	KNITTING MILLS	5967	0	0.	0.	0.	0.	0.	0.	0.	0.
226	TEXTILE FINISHING, EXCEPT WOOL	1414	0	0.	0.	0.	0.	0.	0.	0.	0.
227	FLOOR COVERING MILLS	5600	0	0.	0.	0.	0.	0.	0.	0.	0.
228	YARN AND THREAD MILLS	1926	0	0.	0.	0.	0.	0.	0.	0.	0.
229	MISCELLANEOUS TEXTILE GOODS	3404	88	0.	0.	0.	0.	0.	0.	1.	1.
22	TEXTILE MILL PRODUCTS	20484	88	0.	0.	0.	0.	0.	0.	1.	1.
231	MEN'S AND BOYS' SUITS AND COATS	3753	0	0.	0.	0.	0.	0.	0.	0.	0.
232	MEN'S AND BOYS' FURNISHINGS	15436	0	0.	0.	0.	0.	0.	0.	0.	0.
233	WOMEN'S AND MISSES' OUTERWEAR	49959	0	0.	0.	0.	0.	0.	0.	0.	0.
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	4104	0	0.	0.	0.	0.	0.	0.	0.	0.
235	HATS, CAPS, AND MILLINERY	719	0	0.	0.	0.	0.	0.	0.	0.	0.
236	CHILDREN'S OUTERWEAR	1985	0	0.	0.	0.	0.	0.	0.	0.	0.
237	FUR GOODS	172	0	0.	0.	0.	0.	0.	0.	0.	0.
238	MISCELLANEOUS APPAREL AND ACCESSORIES	3182	0	0.	0.	0.	0.	0.	0.	0.	0.
239	MISC. FABRICATED TEXTILE PRODUCTS	20017	332	0.	0.	2.	2.	0.	0.	7.	7.
23	APPAREL AND OTHER TEXTILE PRODUCTS	99327	332	0.	0.	2.	2.	0.	0.	7.	7.
241	LOGGING CAMPS & LOGGING CONTRACTORS	3571	0	0.	0.	0.	0.	0.	0.	0.	0.
242	SAWMILLS AND PLANING MILLS	18499	8596	3713.	5584.	81.	13379.	14057.	36281.	307.	50645.
243	MILLWORK, PLYWOOD & STRUCTURAL MEMBERS	21294	32	0.	0.	0.	0.	0.	0.	0.	0.
244	WOODEN CONTAINERS	4600	0	0.	0.	0.	0.	0.	0.	0.	0.
245	WOOD BUILDINGS & MOBILE HOMES	7383	0	0.	0.	0.	0.	0.	0.	0.	0.
249	MISCELLANEOUS WOOD PRODUCTS	8355	288	71.	77.	4.	152.	268.	292.	15.	574.
24	LUMBER AND WOOD PRODUCTS	63702	8916	3784.	5661.	85.	13531.	14325.	36572.	322.	51219.

[1] NUMBER OF EMPLOYEES INCLUDED IN THE SURVEY

NOTE: ZEROS MAY INDICATE VALUES BETWEEN 0 AND 1 OR INCONCLUSIVE VALUES.

TABLE 5

REPORTED ANNUAL FRESH WATER INTAKE, RECIRCULATION, AND DISCHARGE IN 1979

IN MILLIONS OF GALLONS
1 MILLION GALLONS = 3.7854 MEGALITRES

SIC CODE	INDUSTRY GROUP	TOTAL NO. OF EMPLOYEES	RECIRCULATION					DISCHARGE		
			EMPLOYEE REPORTING [1]	INTAKE	RECYCLED	GROSS USE	RECYCLE RATE	EMPLOYEE REPORT	INTAKE	WATER DISCHARGE
201	MEAT PRODUCTS	19281	4374	1569.	2033.	3602.	2.	9442	2620.	2196.
202	DAIRY PRODUCTS	7977	2765	3050.	2890.	5940.	2.	4238	4122.	3431.
203	PRESERVED FRUITS AND VEGETABLES	46769	30364	20762.	28668.	49430.	2.	35757	22327.	18691.
204	GRAIN MILL PRODUCTS	8375	2227	486.	520.	1006.	2.	4993	746.	499.
205	BAKERY PRODUCTS	21549	2825	280.	969.	1249.	4.	7499	1043.	432.
206	SUGAR AND CONFECTIONARY PRODUCTS	7465	4720	5148.	12353.	17500.	3.	5204	4106.	2692.
207	FATS AND OILS	2695	2144	385.	1662.	2047.	5.	2644	670.	358.
208	BEVERAGES	19652	8208	4036.	5621.	9657.	2.	12975	5890.	4211.
209	MISC. FOODS AND KINDRED PRODUCTS	25393	3960	2957.	5109.	8066.	3.	14332	5431.	3973.
20	FOOD AND KINDRED PRODUCTS	159156	61587	38673.	59824.	98497.	3.	97084	46956.	36472.
212	CIGARS	13	0	0.	0.	0.	0.	0	0.	0.
213	CHEWING AND SMOKING TOBACCO	300	0	0.	0.	0.	0.	0	0.	0.
21	TOBACCO MANUFACTURES	313	0	0.	0.	0.	0.	0	0.	0.
221	WEAVING MILLS, COTTON	1077	0	0.	0.	0.	0.	0	0.	0.
222	WEAVING MILLS, SYNTHETICS	740	0	0.	0.	0.	0.	0	0.	0.
223	WEAVING AND FINISHING MILLS, WOOL	60	0	0.	0.	0.	0.	0	0.	0.
224	NARROW FABRIC MILLS	296	0	0.	0.	0.	0.	0	0.	0.
225	KNITTING MILLS	5967	0	0.	0.	0.	0.	0	0.	0.
226	TEXTILE FINISHING, EXCEPT WOOL	1414	0	0.	0.	0.	0.	0	0.	0.
227	FLOOR COVERING MILLS	5600	0	0.	0.	0.	0.	0	0.	0.
228	YARN AND THREAD MILLS	1926	0	0.	0.	0.	0.	0	0.	0.
229	MISCELLANEOUS TEXTILE GOODS	3404	88	0.	6.	6.	18.	88	0.	0.
22	TEXTILE MILL PRODUCTS	20484	88	0.	6.	6.	18.	88	0.	0.
231	MEN'S AND BOYS' SUITS AND COATS	3753	0	0.	0.	0.	0.	0	0.	0.
232	MEN'S AND BOYS' FURNISHINGS	15436	0	0.	0.	0.	0.	0	0.	0.
233	WOMEN'S AND MISSES' OUTERWEAR	49959	0	0.	0.	0.	0.	0	0.	0.
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	4104	0	0.	0.	0.	0.	0	0.	0.
235	HATS, CAPS, AND MILLINERY	719	0	0.	0.	0.	0.	0	0.	0.
236	CHILDREN'S OUTERWEAR	1985	0	0.	0.	0.	0.	0	0.	0.
237	FUR GOODS	172	0	0.	0.	0.	0.	0	0.	0.
238	MISCELLANEOUS APPAREL AND ACCESSORIES	3182	0	0.	0.	0.	0.	0	0.	0.
239	MISC. FABRICATED TEXTILE PRODUCTS	20017	231	1.	0.	1.	1.	332	2.	2.
23	APPAREL AND OTHER TEXTILE PRODUCTS	99327	231	1.	0.	1.	1.	332	2.	2.
241	LOGGING CAMPS & LOGGING CONTRACTORS	3571	0	0.	0.	0.	0.	0	0.	0.
242	SAWMILLS AND PLANING MILLS	18499	5489	13153.	15220.	28372.	2.	8596	13453.	8735.
243	MILLWORK, PLYWOOD & STRUCTURAL MEMBERS	21294	0	0.	0.	0.	0.	32	0.	0.
244	WOODEN CONTAINERS	4600	0	0.	0.	0.	0.	0	0.	0.
245	WOOD BUILDINGS & MOBILE HOMES	7383	0	0.	0.	0.	0.	0	0.	0.
249	MISCELLANEOUS WOOD PRODUCTS	8356	271	113.	78.	191.	2.	288	116.	18.
24	LUMBER AND WOOD PRODUCTS	63703	5760	13265.	15297.	28563.	2.	8916	13569.	8753.

[1] NUMBER OF EMPLOYEES INCLUDED IN THE SURVEY.
NOTE: ZEROS MAY INDICATE VALUES BETWEEN 0 AND 1 OR INCONCLUSIVE VALUES.

TABLE 6 (CONTINUED)

ESTIMATED ANNUAL TOTAL FRESH WATER USE BY COUNTY AND MAJOR INDUSTRY GROUP IN 1979

SIC CODE	MAJOR INDUSTRY GROUP	NUMBER OF PLANTS		NUMBER OF EMPLOYEES		FRESH WATER USE		
		TOTAL	REPORTING [1]	TOTAL	REPORTING [2]	MEGALITRES	MILLION GALLONS	ACRE FEET
TEHAMA								
20	FOOD AND KINDRED PRODUCTS	3	2	162	68	229.	61.	186.
24	LUMBER AND WOOD PRODUCTS	13	1	1410	114	137.	36.	111.
25	FURNITURE AND FIXTURES	2	0	22	0	1.	0.	1.
27	PRINTING AND PUBLISHING	4	0	118	0	7.	2.	6.
28	CHEMICALS AND ALLIED PRODUCTS	1	0	6	0	4.	1.	3.
30	RUBBER & MISC. PLASTICS PRODUCTS	2	0	28	0	6.	2.	5.
32	STONE, CLAY, & GLASS PRODUCTS	1	0	10	0	41.	11.	33.
35	MACHINERY, EXCEPT ELECTRICAL	2	0	25	0	1.	0.	1.
37	TRANSPORTATION EQUIPMENT	1	0	18	0	2.	1.	2.
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	1	0	10	0	0.	0.	0.
	TOTAL	30	3	1809	182	429.	113.	348.
TRINITY								
20	FOOD AND KINDRED PRODUCTS	0	1	0	1	2.	1.	2.
24	LUMBER AND WOOD PRODUCTS	6	1	249	144	48.	13.	39.
32	STONE, CLAY, & GLASS PRODUCTS	2	1	46	1	187.	49.	152.
	TOTAL	8	3	295	146	237.	63.	192.
TULARE								
20	FOOD AND KINDRED PRODUCTS	27	19	1912	2114	11790.	3115.	9558.
22	TEXTILE MILL PRODUCTS	2	0	330	0	9.	2.	7.
23	APPAREL AND OTHER TEXTILE PRODUCTS	3	0	518	0	18.	5.	15.
24	LUMBER AND WOOD PRODUCTS	26	2	1345	374	421.	111.	341.
25	FURNITURE AND FIXTURES	7	0	101	0	7.	2.	6.
26	PAPER AND ALLIED PRODUCTS	2	0	160	0	50.	13.	41.
27	PRINTING AND PUBLISHING	17	0	1471	0	55.	15.	45.
28	CHEMICALS AND ALLIED PRODUCTS	8	0	109	0	57.	15.	46.
29	PETROLEUM AND COAL PRODUCTS	1	0	10	0	44.	12.	36.
30	RUBBER & MISC. PLASTICS PRODUCTS	8	2	147	55	68.	18.	55.
31	LEATHER AND LEATHER PRODUCTS	1	0	20	0	2.	1.	2.
32	STONE, CLAY, & GLASS PRODUCTS	19	2	331	87	447.	118.	363.
33	PRIMARY METAL INDUSTRIES	5	1	380	204	320.	85.	260.
34	FABRICATED METAL PRODUCTS	11	2	787	72	192.	51.	155.
35	MACHINERY, EXCEPT ELECTRICAL	34	1	1138	194	72.	19.	58.
36	ELECTRIC AND ELECTRONIC EQUIPMENT	11	1	1345	474	119.	32.	97.
37	TRANSPORTATION EQUIPMENT	5	0	439	0	45.	12.	37.
38	INSTRUMENTS AND RELATED PRODUCTS	1	0	10	0	1.	0.	1.
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	3	0	168	0	11.	3.	9.
	TOTAL	191	30	10721	3575	13729.	3627.	11130.
TUOLUMNE								
20	FOOD AND KINDRED PRODUCTS	2	2	32	10	32.	8.	26.
23	APPAREL AND OTHER TEXTILE PRODUCTS	1	0	8	0	0.	0.	0.
24	LUMBER AND WOOD PRODUCTS	9	1	693	415	765.	202.	620.
25	FURNITURE AND FIXTURES	1	0	24	0	1.	0.	1.

1/ NUMBER OF PLANTS INCLUDED IN THE SURVEY.
2/ NUMBER OF EMPLOYEES INCLUDED IN THE SURVEY.

NOTE: ZEROS MAY INDICATE VALUES BETWEEN 0 AND 1 OR INCONCLUSIVE VALUES.

TABLE 7

ESTIMATED ANNUAL TOTAL FRESH WATER USE AND UNIT EMPLOYEE USE BY INDUSTRY GROUP IN 1979

SIC CODE	INDUSTRY GROUP	NUMBER OF PLANTS		NUMBER OF EMPLOYEES		FRESH WATER			UNIT USE/WORK DAY	
		TOTAL	REPORTING [1]	TOTAL	REPORTING [2]	MEGALITRES	MILLION GALLONS	ACRE FEET	LITRES	GALLONS
201	MEAT PRODUCTS	234	95	19281	9442	20249.	5349.	16415.	4647.	1228.
202	DAIRY PRODUCTS	147	69	7977	4238	29367.	7758.	23808.	16290.	4303.
203	PRESERVED FRUITS AND VEGETABLES	323	196	46769	35757	110538.	29201.	89614.	10458.	2753.
204	GRAIN MILL PRODUCTS	179	92	8375	4993	4737.	1251.	3841.	2503.	651.
205	BAKERY PRODUCTS	266	100	21549	7499	11350.	2998.	9202.	2331.	616.
206	SUGAR AND CONFECTIONARY PRODUCTS	80	44	7465	5469	26907.	7108.	21814.	15949.	4213.
207	FATS AND OILS	61	29	2695	2644	2587.	683.	2097.	4247.	1122.
208	BEVERAGES	322	206	19652	12975	33771.	8921.	27379.	7604.	2009.
209	MISC. FOODS AND KINDRED PRODUCTS	389	174	25393	14332	36394.	9614.	29505.	6342.	1675.
20	FOOD AND KINDRED PRODUCTS	2001	1005	159156	97349	275901.	72885.	223675.	7670.	2026.
212	CIGARS	2	0	13	0	1.	0.	1.	377.	100.
213	CHEWING AND SMOKING TOBACCO	1	0	300	0	26.	7.	21.	377.	100.
21	TOBACCO MANUFACTURES	3	0	313	0	27.	7.	22.	377.	100.
221	WEAVING MILLS, COTTON	52	0	1077	0	46.	12.	37.	188.	50.
222	WEAVING MILLS, SYNTHETICS	47	0	740	0	32.	8.	25.	188.	50.
223	WEAVING AND FINISHING MILLS, WOOL	3	0	60	0	3.	1.	2.	188.	50.
224	NARROW FABRIC MILLS	10	0	296	0	13.	3.	10.	188.	50.
225	KNITTING MILLS	101	0	5967	0	254.	67.	206.	188.	50.
226	TEXTILE FINISHING, EXCEPT WOOL	52	0	1414	0	60.	16.	49.	188.	50.
227	FLOOR COVERING MILLS	77	0	5600	0	238.	63.	193.	188.	50.
228	YARN AND THREAD MILLS	20	0	1926	0	68.	18.	55.	155.	41.
229	MISCELLANEOUS TEXTILE GOODS	82	1	3404	88	49.	13.	40.	64.	17.
22	TEXTILE MILL PRODUCTS	454	1	20484	88	762.	201.	618.	165.	43.
231	MEN'S AND BOYS' SUITS AND COATS	51	0	3753	0	132.	35.	107.	155.	41.
232	MEN'S AND BOYS' FURNISHINGS	313	0	15436	0	542.	143.	439.	155.	41.
233	WOMEN'S AND MISSES' OUTERWEAR	1275	0	49959	0	1753.	463.	1421.	155.	41.
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	40	0	4104	0	144.	38.	117.	155.	41.
235	HATS, CAPS, AND MILLINERY	20	0	719	0	25.	7.	20.	155.	41.
236	CHILDREN'S OUTERWEAR	47	0	1985	0	70.	18.	56.	155.	41.
237	FUR GOODS	9	0	172	0	6.	2.	5.	155.	41.
238	MISCELLANEOUS APPAREL AND ACCESSORIES	102	0	3182	0	112.	29.	91.	155.	41.
239	MISC. FABRICATED TEXTILE PRODUCTS	595	3	20017	332	404.	107.	329.	89.	24.
23	APPAREL AND OTHER TEXTILE PRODUCTS	2452	3	99327	332	3188.	842.	2584.	142.	38.
241	LOGGING CAMPS & LOGGING CONTRACTORS	153	0	3571	0	660.	174.	535.	818.	216.
242	SAWMILLS AND PLANING MILLS	214	56	18489	8596	108791.	28739.	88199.	26022.	6874.
243	MILLWORK, PLYWOOD & STRUCTURAL MEMBERS	713	1	21294	32	236.	62.	191.	49.	13.
244	WOODEN CONTAINERS	161	0	4610	0	196.	52.	159.	188.	50.
245	WOOD BUILDINGS & MOBILE HOMES	134	0	7383	0	157.	42.	127.	94.	25.
249	MISCELLANEOUS WOOD PRODUCTS	306	7	8356	288	12738.	3365.	10327.	6745.	1782.
24	LUMBER AND WOOD PRODUCTS	1681	64	63703	8916	122779.	32434.	99537.	8528.	2253.

1/NUMBER OF PLANTS INCLUDED IN THE SURVEY.
2/NUMBER OF EMPLOYEES INCLUDED IN THE SURVEY.

NOTE: ZEROS MAY INDICATE VALUES BETWEEN 0 AND 1 OR INCONCLUSIVE VALUES.

5. b. CA DWR, Bulletin No. 124-2 Water Use by Manufacturing Industries in California 1970). March 1977. (DWR 1977)

TABLE 1

RANGE OF REPORTED ANNUAL WATER USE BY INDUSTRY GROUP IN 1970

(MILLION GALLONS)

1 MILLION GALLONS = 3785.4 CUBIC METRES

SIC CODE	INDUSTRY GROUP	TOTAL NO. OF PLANTS	PLANTS REPORTING WATER INTAKE						
			TOTAL	GROSS INTAKE IN MILLION GALLONS PER YEAR					
				UNDER 0.1	0.1 – 1	1 – 10	10 – 100	100 – 1000	OVER 1000
190	ORDNANCE AND ACCESSORIES	54	9	1	2	1	2	3	0
191	GUNS, HOWITZERS AND MORTARS	1							
192	AMMUNITION, EXCEPT FOR SMALL ARMS	29	4	0	1	0	1	2	0
193	TANKS AND TANK COMPONENTS	1	3	0	0	1	1	1	0
194	SIGHTING AND FIRE CONTROL EQUIPMENT	1							
195	SMALL ARMS	11	1	0	1	0	0	0	0
196	SMALL ARMS AMMUNITION	6	1	1	0	0	0	0	0
199	ORDNANCE AND ACCESSORIES, NEC	5							
200	FOOD AND KINDRED PRODUCTS	2461	601	39	151	175	152	76	8
201	MEAT PRODUCTS	315	79	2	19	29	23	6	0
202	DAIRY PRODUCTS	278	53	3	12	16	16	6	0
203	CANNED, CURED, AND FROZEN FOODS	508	129	4	22	26	32	44	1
204	GRAIN MILL PRODUCTS	221	59	7	28	15	7	2	0
205	BAKERY PRODUCTS	241	42	7	17	13	5	0	0
206	SUGAR	18	7	0	0	0	0	2	5
207	CONFECTIONERY AND RELATED PRODUCTS	119	28	4	8	11	4	0	1
208	BEVERAGES	332	96	9	16	27	34	10	1
209	MISC. FOODS AND KINDRED PRODUCTS	429	108	4	29	38	31	6	0
210	TOBACCO MANUFACTURES	4							
211	CIGARETTES	1							
212	CIGARS	3							
220	TEXTILE MILL PRODUCTS	252	52	4	37	6	5	0	0
221	WEAVING MILLS, COTTON	6							
222	WEAVING MILLS, SYNTHETICS	5	1	0	1	0	0	0	0
223	WEAVING AND FINISHING MILLS, WOOL	11	1	0	0	1	0	0	0
224	NARROW FABRIC MILLS	13	3	0	2	1	0	0	0
225	KNITTING MILLS	71	8	0	6	1	1	0	0
226	TEXTILE FINISHING, EXCEPT WOOL	24	3	0	1	0	2	0	0
227	FLOOR COVERING MILLS	52	13	1	9	1	2	0	0
228	YARN AND THREAD MILLS	8	2	0	2	0	0	0	0
229	MISCELLANEOUS TEXTILE GOODS	62	21	3	16	2	0	0	0
230	APPAREL AND OTHER TEXTILE PRODUCTS	2183	250	30	209	10	1	0	0
231	MEN'S AND BOYS' SUITS AND COATS	28	8	0	6	2	0	0	0
232	MEN'S AND BOYS' FURNISHINGS	186	26	1	22	3	0	0	0
233	WOMEN'S AND MISSES' OUTERWEAR	1202	127	13	113	1	0	0	0
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	55	7	1	6	0	0	0	0
235	HATS, CAPS, AND MILLINERY	30	1	1	0	0	0	0	0
236	CHILDREN'S OUTERWEAR	46	7	1	6	0	0	0	0
237	FUR GOODS	28	2	0	2	0	0	0	0
238	MISCELLANEOUS APPAREL AND ACCESSORIES	71	11	2	8	1	0	0	0
239	MISC. FABRICATED TEXTILE PRODUCTS	537	61	11	46	3	1	0	0
240	LUMBER AND WOOD PRODUCTS	1608	277	38	186	22	20	9	2
241	LOGGING CAMPS, + LOGGING CONTRACTORS	442	40	4	31	4	1	0	0
242	SAWMILLS AND PLANING MILLS	267	71	1	31	13	17	7	2
243	MILLWORK, PLYWOOD + RELATED PRODUCTS	423	94	17	74	2	1	0	0

TABLE 2

REPORTED ANNUAL WATER INTAKE BY INDUSTRY GROUP IN 1970

(MILLION GALLONS)
1 MILLION GALLONS = 3785.4 CUBIC METRES

SIC CODE	INDUSTRY GROUP	NUMBER OF PLANTS		FRESH WATER		BRACKISH WATER	TOTAL INTAKE WATER
		TOTAL	REPORTING	PURCHASED	SELF PRODUCED		
190	ORDNANCE AND ACCESSORIES	54	9	706	0	0	706
191	GUNS, HOWITZERS AND MORTARS	1					
192	AMMUNITION, EXCEPT FOR SMALL ARMS	29	4	571	0	0	571
193	TANKS AND TANK COMPONENTS	1	3	133	0	0	133
194	SIGHTING AND FIRE CONTROL EQUIPMENT	1					
195	SMALL ARMS	11	1	*	0	0	*
196	SMALL ARMS AMMUNITION	6	1	*	0	0	*
199	ORDNANCE AND ACCESSORIES, NEC	5					
200	FOOD AND KINDRED PRODUCTS	2461	601	12159	24705	7879	44743
201	MEAT PRODUCTS	315	79	1299	935	0	2235
202	DAIRY PRODUCTS	278	53	398	2091	0	2489
203	CANNED, CURED, AND FROZEN FOODS	508	129	4505	9808	1037	15351
204	GRAIN MILL PRODUCTS	221	59	297	253	111	663
205	BAKERY PRODUCTS	241	42	271	4	0	276
206	SUGAR	18	7	1031	7026	6680	14737
207	CONFECTIONERY AND RELATED PRODUCTS	119	28	81	2165	0	2247
208	BEVERAGES	332	96	2846	1638	0	4485
209	MISC. FOODS AND KINDRED PRODUCTS	429	108	1427	780	50	2258
210	TOBACCO MANUFACTURES	4					
211	CIGARETTES	1					
212	CIGARS	3					
220	TEXTILE MILL PRODUCTS	252	52	207	*	0	207
221	WEAVING MILLS, COTTON	6					
222	WEAVING MILLS, SYNTHETICS	5	1	*	0	0	*
223	WEAVING AND FINISHING MILLS, WOOL	11	1	3	0	0	3
224	NARROW FABRIC MILLS	13	3	4	*	0	4
225	KNITTING MILLS	71	8	23	0	0	23
226	TEXTILE FINISHING, EXCEPT WOOL	24	3	60	0	0	60
227	FLOOR COVERING MILLS	52	13	102	0	0	102
228	YARN AND THREAD MILLS	8	2	*	0	0	*
229	MISCELLANEOUS TEXTILE GOODS	62	21	14	0	0	14
230	APPAREL AND OTHER TEXTILE PRODUCTS	2183	250	93	0	0	93
231	MEN'S AND BOYS' SUITS AND COATS	28	8	7	0	0	7
232	MEN'S AND BOYS' FURNISHINGS	186	26	15	0	0	15
233	WOMEN'S AND MISSES' OUTERWEAR	1202	127	33	0	0	33
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	55	7	2	0	0	2
235	HATS, CAPS, AND MILLINERY	30	1	*	0	0	*
236	CHILDREN'S OUTERWEAR	46	7	2	0	0	2
237	FUR GOODS	28	2	*	0	0	*
238	MISCELLANEOUS APPAREL AND ACCESSORIES	71	11	2	0	0	2
239	MISC. FABRICATED TEXTILE PRODUCTS	537	61	30	0	0	30
240	LUMBER AND WOOD PRODUCTS	1608	277	1736	5807	*	7544
241	LOGGING CAMPS, + LOGGING CONTRACTORS	442	40	27	21	0	48
242	SAWMILLS AND PLANING MILLS	267	71	1634	4787	*	6421
243	MILLWORK, PLYWOOD + RELATED PRODUCTS	423	94	20	33	0	53

* indicates quantity between 0 and 1.
NOTE: Totals include quantities between 0 and 1