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Texas Water Development Board

TEXAS INDUSTRIAL WATER USE EFFICIENCY STUDY

FINAL REPORT

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Texas Water Development Board
Austin, Texas

Industrial Water Use Efficiency Study

INTRODUCTION

Pequod Associates, Inc., was retained by the Texas Water Development Board (TWDB, or the Board) to perform research on the industrial water usage of several groups of manufacturers in Texas. The following report summarizes the research methodology and results.

The primary purpose of the work was to develop time-dependent estimates of changes of future water use efficiency patterns for nine Standard Industrial Classification (SIC) categories. To support this study, Pequod obtained information on water usage and related water conservation information by means of questionnaires that were sent to manufacturing sites within the nine categories. Other quantitative information was also desired, such as water use parameters for specific products. This information was combined with Pequod's own database of related information and with its knowledge of the industries polled, to construct a table of conservation factors to be used by the Board to project the influence of conservation on water usage by the SIC groups studied.

Information was collected in considerable detail concerning employment, technologies practiced, raw materials and products, costs and self-evaluations of water-related and production technologies. Much of this information was previously unavailable in useful form to TWDB.

The nine SIC groups surveyed were:

SIC Group	Industry
201	Meat Products
208	Beverages
261/262	Pulp and Paper Mills
263	Paperboard Mills
281	Inorganic Industrial Chemicals
282	Plastics Materials and Synthetic Resins
286	Industrial Organic Chemicals
291	Petroleum Refining
3674	Semiconductors and Related Devices

The preceding groups were selected by TWDB because they are either known to be major consumers of water on the basis of annual reports to the Board, or, in the case of semiconductor products, because this industry adds considerable value to the Texas economy. Some of the industries are heavily concentrated, such as pulp and paper mills in northeastern Texas. Others are more widely distributed, such as chemicals and soft drinks.

Considerable information has already been compiled through TWDB's Form 0669B, in which manufacturers provide, on an annual basis, a report of types and amounts of water used, suppliers, employment, disposal methods, etc. However, these annual reports do not provide enough numerical and other information to support an improved basis for making water projections far into the future. In particular, they do not directly indicate the results, if any, of efforts at conservation. The present research was intended to establish linkages between conservation and the specifics of plant history, technology, costs, products, production levels, and other aspects of industrial operations.

Pequod anticipated a 25 percent return of questionnaires; the actual result was a 25 percent return, including 1 percent mis-classified and unusable.

EXECUTIVE SUMMARY

Pequod Associates, Inc. performed water research for the Texas Water Development Board designed to produce time-related conservation factors that could be applied to TWDB's projections of water usage, to indicate the expected improvement in the efficiency of water use arising from conservation practices.

Nine industrial water-using SIC groups were asked by questionnaire about their water usage, costs, conservation practices, investment requirements, technology and other water-related information. Of 365 questionnaires mailed, about 24 percent were used for analysis. Returns of questionnaires ranged from 14 percent (12 returns) to 60 percent (three returns) of the mailings to each industrial group.

Pequod recommends that the following table of conservation factors be used to project the effects of conservation. This table combines the experience of the reporting industries, Pequod's database for the same SIC groups, and other available information. It also incorporates Pequod's judgment concerning both the degree of conservation that may still be achieved and the number of years over which a series of large and small conservation measures will become effective in each of the SIC groups studied.

Conservation Factors Through 2010 Multiply Projections of Water Use by the Indicated Conservation Factors							
SIC Group	Industry	Overall Conservation Reduction	Years to Achieve	Annual Conservation Reduction	Conservation Factors		
					Year 1998	Year 2003	Year 2010
201	Meat Packing	.20	20	.01	.95	.90	.83
208	Beverages	.20	20	.01	.95	.90	.83
261/262	Pulp and Paper	.30	15	.02	.90	.80	.70
263	Paperboard	.25	15	.017	.92	.83	.75
281	Inorganic Chem	.20	20	.01	.95	.90	.83
282	Resins	.20	20	.01	.95	.90	.83
286	Organic Chem	.20	20	.01	.95	.90	.83
291	Refining	.20	20	.01	.95	.90	.83
3674	Semiconductors	.40	10	.04	.80	.60	.60

METHODOLOGY

The principal methodology of data collection was the use of detailed questionnaires concerning water use, conservation and costs. The idea was to ask enough questions to capture a level of detail that would provide not only numerical information, but significant insight into the way various industries respond to water issues. A further part of the study was to review and incorporate the water conservation information available in Pequod's files for each of the SIC groups, as well as pertinent literature and the experience and judgment of workers in the field.

With some trepidation, TWDB agreed that the wide-ranging questionnaire was likely to produce a great deal of previously unavailable information and that it might tend to inhibit some firms from answering at all. However, the extra effort to promote the return of questionnaires resulted in a response on target with Pequod's original projection.

Questionnaires were prepared in nine versions, differing only in those questions related to the specific technologies, raw materials and products each industry produced; all other questions were identical. (See Appendix A for text of the questionnaires.) In summary, questions were asked concerning:

- the history and major changes of the installation;
- employment;
- the technical nature of the operation;

- water use;
- water conservation;
- water treatment; and
- costs.

Some questions were self-evaluations to determine, in the firms' own opinion, how significant certain issues were relative to others in the same industry.

Of the 365 companies contacted (using lists provided by TWDB), 89 responded. Three of the questionnaires returned had been incorrectly classified as belonging to one of the SIC's of interest and were therefore not included in the study. Mailings took place in early and mid-June (the beginning of the vacation period) and returns were slow, some not arriving until the end of August.

Each return was reviewed for completeness by one or more members of Pequod's staff having specific knowledge of the industry represented. Where there were misconceptions in the answers (e.g., annual savings were reported by some firms for their water conservation efforts rather than installed cost), Pequod followed up by telephone or fax. We received calls from many of the firms concerning the way various questions were to be answered. Clarifications and fuller information were being returned to Pequod as late as August. This effort was considerable, as was the telephone campaign to encourage return of the questionnaires.

To facilitate recording and working with the information in the questionnaires, Pequod constructed a computer database. We also included information provided by TWDB, including water-report account numbers used by TWDB and a summary of annual data provided by all reporting firms on Form 0669B. Due to the high volume of information (both numerical and otherwise), each individual record in the database assumed a rather large size and was subdivided into several parts.

To maintain confidentiality of certain information (principally plant capacities and production levels), the responding firms were assured that Pequod would not publicize any such information. We agreed to return the original questionnaires to the responding firms and to delete capacity and production level information from transmittals to TWDB, except for aggregated data that do not disclose individual responses or information already available to the public.

QUESTIONNAIRES AND RETURNS

The following table summarizes the number of firms included in the mailing and the number of questionnaires returned.

Table 1
Summary of Questionnaires Mailed and Returned

SIC Group	Industry	Questionnaires		
		Mailed	Completed Returns	Percent Completed Returns
201	Meat Packing	80	13	16
208	Beverages	29	7	24
261/262	Pulp and Paper	5	2	40
263	Paperboard	5	3	60
281	Inorganic Chemicals	54	15	28
282	Plastic Resins	86	12	14
286	Organic Chemicals	28	12	43
291	Refining	41	13	32
3674	Semiconductors	37	9	24
Total		365	86	24

While a few firms returned the questionnaire immediately, most did not respond at all. The other firms that did participate took weeks to reply, some more than ten weeks. We were impressed that so many of the returns included information on capacities. Even more candid were statements concerning the most recent annual production levels. Several firms considered 1992 production level information confidential and did not include it. For some industries, such as paper, chemicals and refining, capacity information is published in standard directories and references, and is available to any interested party.

The titles of persons responsible for completing the questionnaires ranged from the owners and principal officers of some firms, to plant managers, to environmental officers, to interns. In the case of junior personnel, follow-ups established that their work had been checked before their supervisors permitted the completed questionnaires to be returned to Pequod. We found no correlation between the completeness with which the questionnaires were answered and the positions of the persons responsible for filling them out.

To learn whether the returned questionnaires fairly represented their SIC groups, Pequod compared them with the SIC's as defined in the manual published by the

U.S. Office of Management & Budget. We are satisfied that all major activities associated with each of the SIC's are represented.

WATER CONSUMPTION FOR SIC GROUPS STUDIED

General

This section includes water usage and other pertinent information for each SIC group studied. For each group, we will: 1) present, where practicable, parameters relating water consumption to product; 2) present other analyses of the information gathered during this survey.

Our quantitative analyses of water consumption are based on the questionnaires' reported quantities or the historical water use data furnished by TWDB, together with stated capacities and production rates achieved for 1992 or, in some cases, for 1987, a year we suggested for comparison with the production achieved in 1992.

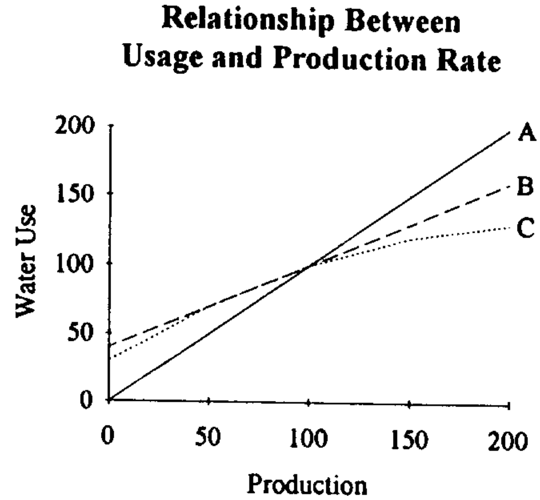
Variation of Water Use with Production Rate

Pequod attempted to gain some insight into the pattern of water use at a site by going beyond a detailed analysis of process and water use. We asked the firms directly to estimate the water consumption for a 50 percent increase or decrease, and for a doubling of production. This question left it to the responding firms, who have detailed information of a depth we could not ask for, to make the projections.

Projections of increased or decreased water usage as a function of increases or decreases in production generated interesting and potentially useful answers. Oil refiners, who operate very large materials-processing installations, generally felt that water usage would be *proportional* to production, for a given feedstock and technology. Others indicated that the relationship would be *linear* with production, while a few others indicated that they would expect the next block of production to require a *decreased unit consumption* of water for the next increment of production. The latter two types of projections obviously assume that there is a certain base usage of water apart from the direct requirements for production.

In most cases, though not in the largest process-type plants, water usage was expected to vary linearly with changes in production rate, indicating that the manufacturing plant has a significant base-load water consumption that is not directly influenced by production.

Examples of the three types of responses are illustrated below:



A = Proportional
B = Linear
C = Decreasing Unit Consumption

Water Use by SIC Groups

201 Meat and Poultry Packing

Questionnaires were returned by one or more firms in the beef, poultry, margarine, hides, frozen foods and pork businesses. Some packing firms expressed their capacities in pounds rather than in head or birds. We used three pounds as an average weight of one whole chicken (there were no other birds reported).

For major beef processing operations, about 310 gallons are consumed per head. For major chicken operations, about 1.5 gallons are used per pound. Hide processing uses 770 gal/ton and margarine uses 0.13 gallons per pound.

Most of these firms indicated that they required little or no change to reach the state of the art for their type of operation and little change to reach the state of the art for water treatment. Finally, they regard water cost and availability as of considerable significance for their business. They reported relatively large sewage treatment costs compared with most other SIC groups.

In this SIC category, water consumption is expected to vary linearly with throughput. The consensus is that for a doubling of production, only a 50 percent rise in water would be expected. For a 50 percent change in production (up or down), only a 25 percent change in water usage would be expected.

We saw no significant relationship between the age of the plant and the water consumption for the industry. There has been relatively rapid industrialization of these operations in the past few years, and most major plants are apparently relatively new.

208 Beverages

Two principal subgroups exist here: soft drinks and brewing. These industries practice wholly different technologies.

Questionnaires were returned by firms in the brewing and soft drink (both carbonated and non-carbonated) industries. Soft drink bottlers express their capacity in cases; for this analysis, we have used a capacity of 2.25 gallons (24 containers, 12 ounces each) per case. Actually, with the increase in larger sizes such as 20 ounce (3.75 gal/case), 1 liter (3.17 gal/case) and 3 liter containers (4.76 gal/case), the average size of the "case" is changing, but the 12 ounce container still predominates. In brewing, capacity is expressed in wine barrels of 31 gallons each.

These firms generally regard themselves as requiring little work to reach the state of the art for their industry in their basic technology and in their treatment of incoming water. They regard water cost and availability as of only moderate significance for their business.

The industry has a seasonal variation in production, as reported in the questionnaires and indicated indirectly in water usage in their annual reports to TWDB.

Soft drink plants expect water use to vary directly with production, while in brewing, a doubling of production is expected to require a rise of only 65 percent in water use; this indicates a substantial base load water consumption.

Based on the questionnaires it appears that a soft drink bottler ships about 65 percent of its incoming water as product. A brewery ships about 25 percent of its water intake as product. One brewery operates with about 5 percent less water per unit of production than five years ago. Production has risen in that period. Thus, the smaller water consumption could indicate both conservation and the benefits of larger-scale production.

Soft drink manufacturers clearly have fewer opportunities to conserve water than do brewers who have much more complex processing systems including significant cooling loads.

261/262 Pulp and Paper Mills

Little, if any, pulp is produced as a final product at any of these plants. Thus, it is SIC 262, the paper plants, for which we collected data. Firms expressed their capacities in tons of paper per year.

These firms generally regard themselves as requiring modest change to reach the state of the art for their industry in their basic technology. They believe, in general, that their treatment of incoming water is relatively modern. Finally, they regard the cost of water and of effluent charges as of low significance for their business.

A wood-based paper plant is using about 13,000 gal/ton; it expects water consumption to vary in proportion to production.

A paper plant operating on purchased pulp is using about 21,000 gal/ton; it expects only a 20 percent rise in water use for a doubling of production, and 10 percent or less variation for a 50 percent variation in production level. This indicates a significant base load water usage.

Despite the favorable self-evaluation of their technology, most of the responding plants consume significantly more water per ton of product than is representative of the state of the paper making art. A pulp-based plant in particular should be using less water per ton of product than a wood-based plant since the basic pulping requirement has been carried out elsewhere. This presupposes that the investments required for efficient technology are justified both by the marketplace and the fiber resources available to a new and modern mill. We did not investigate the factors that operate in the Texas economy as they relate to the paper industry, however.

Self-supplied water is obtained by the responding plants for less than 10 cents per thousand gallons. One plant reports a $3.5 million annual cost to treat 80 percent of its incoming water; this is about nine times the cost of acquiring the raw water.

263 Paperboard Mills

This industry differs from SIC 261/262 in that it is a producer of specialized heavy papers of many types and for many purposes. However, the SIC classification relates to final product, not to raw materials, so while a wood-based paper producer would be listed in SIC 262 and a wood-based paperboard producer would be listed in SIC 263, the physical and operational differences between plants in these SIC categories are not necessarily large.

Questionnaires were returned by plants producing paperboard from wood, from recycled fiber and from both wood and recycled fiber. Firms expressed their capacities in tons.

A mill operating on wood consumes about 34,000 gal/ton, as reported during Pequod's follow-up of the questionnaire. One mill operating on both wood and recycled fiber consumes over 30,000 gal/ton. These consumptions appears to be high, like the firms listed in SIC 261/262.

A plant operating only on recycled fiber uses 2,600 gal/ton. Its questionnaire notes that purchased water costs somewhat less than $1 per thousand gallons, but that its effluent charges are nearly $4 per thousand gallons. Clearly, this mill has an incentive to minimize its water consumption.

The water-efficient mill self-evaluated its practice of paperboard-making technology by indicating that little needed to be done to approach the state of the art. For this firm, that appears to be an accurate self-evaluation.

Another firm was the only one to self-evaluate its incoming water treatment technology; it was satisfied that essentially nothing more could be done. No firm expressed an opinion on the significance of water cost and effluent charges to its business.

In a wood-based mill, total water consumption is expected to vary in proportion to throughput, while in a plant operating on recycled fiber only, a 20 percent increase is expected for 50 percent more production and only 33 percent more water usage for a doubling of production. This indicates a significant base load water usage.

We found no correlation of water consumption with the year the plant was established.

281 Industrial Inorganic Chemicals

This is an industry with a wide variety of products, from simple industrial gases (e.g., atmospheric gases) to heavy inorganic commodity chemicals (e.g., acids, chlorine and alkalies). This SIC group is, like most "chemical" industry groups, so varied that water use cannot be simply linked to a single, simple measure of production. Nor are there "surrogate" parameters such as employment, because most inorganic chemical plants have relatively small staffs that are virtually constant whatever the level of production.

Questionnaires were returned by plants producing industrial gases, adsorbents, agricultural chemicals, pigments, chlorine, alkalies, reagents, salts and miscellaneous chemicals. Firms expressed their capacities in many different units, consistent with the historical practices in their various segments of the industry. These units include tons, millions of cubic feet, barrels, cylinders and pounds.

Pequod found no consistency in these firms' self-evaluations of their basic technology and also none regarding the significance of water treatment and the significance of water cost and of effluent charges to their businesses.

The largest of the inorganic chemical plants expect water consumption to vary in proportion to throughput. This indicates a relatively small base load water usage.

Heavy concentrations of the inorganic chemical industry are along the Gulf Coast where saline water is available for cooling. To the extent that this water is used, it costs only the incremental power and the capital charges for the pumping equipment. There is little incentive to conserve this type of water because most of it is used for non-contact cooling without significant change.

Most plants now have adopted close control over cooling tower and boiler blowdown to minimize discharges, and they believe that they manage their operations efficiently with regard to water.

In large inorganic chemical plants, total water consumption is expected by the responding firms to vary in proportion to throughput. Smaller plants and those in the industrial gases business tend to see a flatter response of water use with production, indicating a significant base load.

282 Plastics Materials and Synthetic Resins

This industry produces massive amounts of some products, but also includes low-volume, specialized products. The products are so varied that no single, simple parameter of water usage can represent it. Nor are there "surrogate" parameters such as employment, because most of these plants have relatively small staffs that are present in virtually unchanged numbers whatever the level of production.

Questionnaires were returned by plants of the following types: polypropylene, polyethylene, elastomers, injection molding resin, polyvinyl chloride , polyolefin catalyst and two producers of more specialized chemicals. Firms expressed their capacities in pounds and tons.

Polyethylene plants used mostly purchased surface water. A plant built several decades ago requires 1.2 gallon per pound of product. A plant built about ten years ago and not substantially expanded in capacity since, requires 0.3 gallon per pound of polyethylene. These figures are suggestive, though not conclusive, of a relationship between plant age and water consumption. However, processes have changed and been improved over this period, so the disparity may arise from technical causes.

Similarly, polypropylene plants reporting sufficient data indicate that one plant requires 0.33 gallons per pound of product, while a plant built about twenty years later requires 0.2 gallons per pound. Again, there may have been changes in production technology that account for the difference in unit water consumption.

For elastomer plants returning questionnaires, an earlier plant consumes 1.1 gallons per pound of product, while a later plant requires 4.5 gallons. This is a disparity that only closer study might explain.

No other instances occurred where sufficient reliable data were collected to indicate a relationship between water usage and age.

A polyvinyl chloride plant uses 1.1 gallons per pound of product.

These firms regard themselves as requiring little to moderate work to reach the state of the art for their industry in their basic technology. They rate themselves similarly with regard to their technology for incoming water treatment. They are generally not very concerned about the cost of water or of effluent charges for their business.

In these plants, total water consumption is expected by the responding firms to vary linearly with throughput. Hence the parameters reported are for plants as they are presently equipped and practice their technology. They expect a 50 percent change in production rate to change water consumption by 30 percent and a doubling of production to require 60 percent more water. This indicates a significant base load water usage.

Based on their answers, most large plants are conscious of their water usage and attempt to operate efficiently with regard to water.

286 Industrial Organic Chemicals

This SIC group includes products so varied that no single parameter of water usage can represent it. Nor are there "surrogate" parameters such as employment, because some of the large plants have relatively small staffs that are present in virtually unchanged numbers whatever the level of production.

Questionnaires were returned by plants of the following types: specialty chemicals, agricultural chemicals, monomers, resins, solvents, lubricants, mineral oil and others. Firms expressed their capacities in terms of pounds, gallons and tons, in accordance with the historical trade practices of their respective industries.

One major producer of monomers consumes about 8 gallons per pound of product. A resin producer (resins are produced downstream from monomers) uses 0.7 gallons per pound of resin. The distinction between monomers and resins is important, since monomer production is frequently a low-yield chemical operation involving large energy transactions and losses of both energy and materials, while the production of resins is frequently much simpler and more efficient. The range of water consumptions that Pequod calculated for this group is as high as 3 gallons per pound of product.

These firms generally regard themselves as requiring relatively little work to reach the state of the art for their industry in their basic technologies. They believe, in general, that their treatment of incoming water is close to the state of the art required. Finally, they regard water cost and the cost of effluent charges as of considerable significance for their business.

In these plants total water consumption is expected by the responding firms to vary in proportion to throughput. For a doubling of production they expect a 70 percent rise in water use and for a 50 percent variation in production, a 35 percent change in water use. This indicates a significant base load water usage.

Because the products are so varied in the group of questionnaires returned, we were unable to ascertain whether the age of the plant is significant with regard to water consumption.

Most plants now have adopted some measures to minimize discharges and manage their operations with reasonable efficiency with regard to water.

291 Petroleum Refining

This SIC group is not totally homogeneous despite the fact that TWDB's mailing list contains only one four-digit SIC code (2911). Two firms in the gas business and a producer of both chemicals and a processed hydrocarbon product are also carried under SIC 2911. Another returned questionnaire was from a petrochemical plant processing hydrocarbons but not refining crude, though classified in SIC

2911. All the returned questionnaires were considered in our analysis of water conservation, since all represented firms were correctly classified within the 291 SIC group.

All of the refineries expressed their capacities in barrels of crude processed per day.

Most of these firms form a quite homogenous group of petroleum refineries (with the exceptions mentioned above), but no two members of the group have precisely the same raw materials, equipment or product slate. An important point is that even though these installations may be similar in refinery products, they may differ very significantly in the proportions of various non-fuel hydrocarbon products, the type of crude processed (the sulfur content and gravity), the state of the art of their individual processing units, the degree of reliance on on-site power operations, the presence of integrated downstream chemical derivatives production, the perceived economic and technical importance of water, and other details important to an understanding of water usage. Putting the members of the group on a strictly comparable basis would be a very detailed study in itself and would probably require an analysis of every major process unit within the refineries. The important observation is that virtually any of these facilities is a grouping of individual water users with wide-ranging characteristics.

One should use great caution in comparing and correlating water usage, even though it might seem reasonable to suppose that there are regional differences in the cost and availability of water that would result in significant differences, between regions, in the unit consumption of water per barrel of refinery throughput.

Pequod has performed a sub-study of this group by using refinery capacity information published annually in *Oil & Gas Journal*. We assigned each of the State's refineries to one of four regions for analysis. Region 1 is centered on Beaumont/Port Arthur; Region 2 on Houston; Region 3 on Corpus Christi; and Region 4 includes all other locations in the state, all of which are inland. With the 1991 water consumption information furnished by TWDB, we calculated average water consumption for the four regions per barrel of crude distillation capacity; we do not have the 1991 operating rates, but it is reasonable to assume that the refineries operate at an average of 90 percent of capacity over a year's time. The published list of refineries allowed Pequod to correlate all the state's refineries, not just those that responded to the questionnaires.

The following table presents the results of this sub-study.

Table 2 Water Consumption in Texas Refineries			
Region	**Principal Location**	**Number of Refineries**	**Water Usage Gallons/BBL Capacity**
1	Beaumont	4	96
2	Houston	9	91
3	Corpus Christi	7	35
4	All Other	8	49

The averages in Table 2 were established after discarding one or two outlying data points for each region. The reasons for anomalously low or high water usage would require inquiry beyond the scope of this study. Within each region, we saw no correlation with plant size; a larger refinery would not necessarily use less water per barrel of crude capacity than a smaller.

There are distinct differences between Regions 1 and 2 as a group, and Regions 3 and 4 as a group, in terms of unit water consumption per barrel of crude distillation capacity. Regions 1 and 2 are considered to have more abundant and lower priced water supplies.

The wide spread of values of the parameter *gallons/barrel* is probably the result of several factors.

1. There may be underlying raw materials considerations, operational philosophies or equipment limitations. Different crudes and a distinctly larger scale of operation in the coastal refineries are examples of this.

2. Some plants incorporate utility operations that have widely divergent water requirements. The presence of large steam and power plants, or of cogeneration facilities, or of significant integration of the production and utility processes, are examples of these factors.

3. Some plants, especially the larger ones, tend to have more downstream production of petrochemicals. These chemical operations in some cases account for large amounts of water used.

4. The site-selection process normally directs facilities that require abundant water into those areas that have it.

The Region 4 refineries have a more limited variation in unit water consumption per barrel than the refineries in the three coastal regions. They are generally smaller and they do not have the wide range or tonnages of chemical products produced in the other Regions; these refineries concentrate more on the fuel products. There is less justification for large size and complexity in utility operations. There is some production of derivatives in Region 3, but this does not seem to result in the higher water consumptions that derivatives-producing refineries in Regions 1 and 2 exhibit.

These firms generally regarded themselves as requiring a modest level of work to reach the state of the art for their industry in their basic technology. They vary with regard to their treatment of incoming water: several believe it is not subject to much improvement, while others indicate that they are far from adequately dealing with water technology. Finally, they regard the cost of water and of effluent charges as of considerable significance for their business.

In refineries, total water consumption is expected by the respondents to vary in proportion to throughput. This indicates that there is a relatively small base load water usage.

We have looked for a relationship between refinery age and water consumption, but any such relationship is probably masked by other factors, such as the extent to which there are on-site downstream chemical processing and utility operations.

Most plants now have adopted measures to manage their operations more efficiently with regard to water.

3674 Semiconductors

This SIC group is very homogeneous because it is a four-digit SIC code.

The responding firms expressed their capacities in terms of wafers, slices, starts or devices. Wafers or slices produced by others are processed in groups in the usual semiconductor production system. However, there is no uniform standard for the number of wafers or slices in a group, nor one defining how many "devices" are produced within or on a wafer.

The larger firms generally believe they require little work to reach the state of the art for their industry in their basic technology, but the smaller firms are certain they need to do much more. They believe, in general, that their treatment of incoming water leaves something to be desired. The larger firms are more concerned about the cost of water and effluent charges than the smaller firms.

The semiconductor industry's typical plant produces ultra-pure water at great expense. Larger plants will be more aware of the large absolute total cost of processed water and will be conscious of the opportunity for cost-effective investment to reduce those costs. Smaller plants, because of the relatively larger impact of fixed costs, will regard water costs as less significant than other costs. But the total quantities of water used in the semiconductor industry are much smaller than those used in large chemical process, refinery or pulp and paper plants.

Semiconductor manufacturers expect their total water consumption to be linear with production. They expect a doubling of production to require a 30 percent increase in water usage and a 50 percent variation in production to require a 15 percent change in water use. This indicates a significant base load water usage.

WATER CONSERVATION FOR SIC GROUPS STUDIED

Conservation Measures Adopted by Responding Firms

Pequod asked that responding firms address a number of general and specific questions concerning conservation, including individual measures, savings achieved, cost of individual measures, economic criteria, overall savings from conservation programs, trends in water usage and anticipated water-related projects at the individual sites.

We asked whether any one of a series of specific examples of conservation measures was practiced. This gave respondents the opportunity to answer easily by checking the item. The conservation measures adopted by all the responding firms are summarized in the following table.

Table 3
Conservation Measures and Investments, by SIC
Reported on Survey Questionnaires

Conservation Measure	SIC	Number of Measures Reported	Water Conserved in Million Gallons per Year	Total $ Investment for Each SIC Group
Recycling Cooling or Process Water	201	3	7.0	14,000
	208	1	8.5	16,000
	261/262	1	365	NR
	281	2	33,000	40,000
	282	1	500	NR
	291	4	167	156,000
	3674	4	56	14,000

Sequential Reuse	201	1	0.5	5,000
	208	1	41	77,000
	261/262	1	730	NR
	282	1	40.5	10,000
	286	1	26	20,000
	291	4	320	403,000
	3674	3	55	26,000
Improved Control Systems	201	2	6.2	35,000
	208	1	20	38,000
	281	1	200	1,000,000
	282	2	302	25,000
	291	3	234	149,000
Dry Cooling	201	1	1.3	NR
	208	1	3	6,000
	261/262	1	7.3	NR
	282	1	25.6	20,000
	291	1	NR	3,000,000
Changed Cleanup Procedures	201	3	12.5+	NR
	281	1	0.26	NR
	282	1	36.5	NR
	291	3	7.1	1,752,000
Changed To/From Continuous Processing	3674	1	2.8	NR
Changed/Reduced Flow Rate	201	6	46+	6,500
	208	1	3.2	6,000
	281	1	0.13	500
	286	1	8.8	15,000
Automatic Shutoffs	201	2	16.9	7,000
	281	1	3.7	5,000
	286	1	5.3	2,000
Smaller Tanks, Sinks		NR		
Lower Flow Settings	201	2	0.03	5,000
	261/262	1	18.3	25,000
	291	1	0.1	5,000
Leak Monitoring and Repair	201	2	0.26	26,000
	281	1	0.03	500
	282	1	11.37	3,000
	286	1	105	NR
Changed Irrigation Practices	281	1	0.03	NR
	3674	1	0.3	8,000
Production Shutdown/Relocation	282	1	730	110,000

NR = None Reported

A review of Table 3 and of the underlying detail presented in the database leads to the following observations.

1. The returned questionnaires reported remarkably few water conservation measures undertaken, or we did not present sufficient choices.

2. Some switches have been made to alternative water supplies to obtain a better or cheaper source or one with fewer restrictions, but these were not conservation measures even if sometimes there were incidental savings in consumption.

3. Conservation measures often achieved quite small savings relative to total water consumption.

4. Many conservation measures cost very little, ranging from zero to $10,000 and rarely over $50,000. Measures of a given type vary greatly in cost and in terms of savings achieved.

5. Many measures are likely to have been undertaken for non-economic reasons.

6. Not all measures reported were assigned a cost and some of the largest claimed savings were not associated with a cost.

After many follow-up conversations with responding firms it became clear that in many, if not all, cases, the responding persons had no complete file of all water-related activities undertaken at their sites within the past ten to fifteen years. Personnel assignments have changed, and those now reporting have often not been in their present positions very long. Many acknowledged that their knowledge of conservation measures was incomplete, and that the overall savings claimed were estimates based on only most recent measures. Consequently, Pequod concludes that underreporting is significant, both as to individual measures and as to the cumulative effects of conservation measures previously undertaken. This is significant with regard to future conservation programs, especially by those not heretofore committed to conservation.

Recycling as a Conservation Measure

Recycling is not widely practiced in the sense of reusing water for another purpose, either by rerouting or by first treating and then reusing. Cooling towers are the principal "recycling" operation reported, and in cooling towers, this recycling is simply a part of the cooling process in use at the plant.

Questions on recycling produced little information. However, the semiconductor industry reported a relatively large number of water conservation steps involving sequential use of water and recycling. It also reported a large relative savings from its investments in conservation. It is important to note that their cost of water is the highest of any of the groups studied.

Investment Considerations

In addition to questions on specific conservation measures, the questionnaires asked about the investment criteria applied to conservation. Where investments for water conservation are made on an economic basis, the criteria were predictably varied. Most of the desired simple payback periods were 2 to 3 years, but some were as high as 8 or as low as 1. Desired returns on investment in water conservation similarly varied from 15 percent to 100 percent. Many firms reported no criteria, possibly because they lack any formal criteria. It is possible also that the responding personnel knew of none. However, questionnaires giving no information on the subject of investment criteria were just as likely to have been completed by people in executive positions as not.

Quite a few firms simply said that environmental considerations alone or in combination with some social obligation to reduce water flows (especially those that result in effluents requiring treatment) were enough to justify conservation. It is also possible that some conservation efforts are undertaken to reduce uncertainties in water supply systems, thus making them insurance costs rather than conservation.

Economic justification for water conservation investments is obviously hard to generate when the price of water is relatively low and the demand for a short payback of two to three years operates. This seems to be true even in those cases where responding firms indicated some substantial effluent treatment charges.

Although very little investment was reported in conservation, the criterion for water-related investment was essentially the same as for any other type, with very few exceptions. We may conclude that water is conserved not basically for economic reasons. Other reasons given for conservation investments were an environmental ethic and/or an environmental necessity.

We conclude from the returned questionnaires that investments in water conservation are judged by the same economic standards as other investments, and since at present the purchase or self-production of water is not a major economic cost, water conservation is unlikely to attract capital when there are opportunities to invest in production facilities.

Supply and/or Receiving Stream Limitations on Conservation

Oil refineries and most large chemical plants have large cooling loads. In general, these cooling loads are dissipated by evaporative cooling towers through which the water circulates a number of times before the concentration of solids (original solids plus the residues of water treatment) requires a blow down. The flow of water being circulated is thus usually several times the flow of makeup water.

Evaporation of water from cooling towers thus results in an increase in dissolved solids concentration. In some cases, a receiving stream may be unable to receive a concentrated blowdown without exceeding acceptable concentrations of solids. This would occur where the loss of volume by evaporation in the cooling tower operation has been so great that the receiving stream has insufficient volume to accept the solids that originally came from it.

One firm responded that as long as it continued to receive water from its particular municipal supplier, it could not reduce its water consumption. This reflects an awareness of the supply's solids content and an operation that closely approaches the technical limits of cooling tower operation. Although no other report was as explicit, we believe that this situation is common.

Total Reported Effect of Conservation Measures Adopted

Pequod also asked how large a relative saving had been achieved by all conservation measures undertaken relative to what would have been the consumption if prior practices had been continued. This question was designed to provide an alternative method of answering the conservation question and to allow respondents to include the effects of options not mentioned in the questionnaire. The following Table 4 gives the claimed average saving for each SIC group.

Table 4
Overall Reported Conservation Savings

SIC Group	Industry	Percent Saved by all Conservation Measures
201	Meat Packing	17
208	Beverages	25
261/262	Pulp and Paper Mills	10
263	Paperboard Mills	none
281	Inorganic Chemicals	23
282	Resins	32
286	Organic Chemicals	4
291	Petroleum Refining	17
3674	Semiconductors	29

Note that firms in SIC 263 claimed no specific measures and also said that, overall, no savings had been effected. This must reflect a lack of urgency on this topic. The table shows that SIC 286 firms claimed a few measures, and they probably should have summarized the cumulative effect of those measures by claiming something greater than 4 percent. The other SIC groups claimed what appear to be reasonable percentages. These overall percentages agree fairly well with Pequod's experience for these industries.

A Conservation Model Based on Regional Differences in Water Usage

It may be argued that the significant differences in water usage are based on actual and perceived differences in water cost and availability, and that the refineries in Regions 1 and 2 may ultimately experience the water cost and availability that Regions 3 and 4 do now. Thus, Regions 3 and 4 would be a model for Regions 1 and 2.

However, because more of the refineries in Regions 1 and 2 (and to a lesser extent Region 3) produce downstream products than in the other Regions, how much of the water consumption in Regions 1 and 2 is actually for refining rather than for production of downstream products would be difficult to establish with the information presently available. Also, some refineries expect to process higher-sulfur crudes to consume larger fractions of the barrel (converted to heat) in the thrust toward higher octanes through more intensive refining processes and greater use of oxygenates and to meet environmental requirements. The questionnaires did not produce enough information to quantify individual or regional differences in water consumption arising from these factors, but we think that they account for a significant portion of the regional differences.

Wastewater Treatment as a Stimulus to Conservation

Wastewater treatment methods were described in many questionnaires in considerable detail, but Pequod did not see indications that wastewater considerations have been of significance in conserving water. For instance, some firms reported very large expenditures for effluent charges (including volume charges apart from charges for BOD and solids), but have large water consumptions. Presumably, reducing the water consumption would at least have the effect of reducing volume charges for effluents, if not for BOD and solids. But there is no evidence from the questionnaires that any program of reduced water use has been undertaken to reduce effluent volume charges.

Conservation Information From Other Sources

This study was to combine information from additional sources with information derived from questionnaires. The principal additional source is Pequod's database of industrial water conservation.

Pequod's database contains 23 reports of industrial water conservation studies bearing on the SIC groups addressed in this report. There are a total of 73 conservation measures recommended.

Pequod's database of water surveys is summarized in the following table.

Table 5
Pequod Database for Water Conservation

SIC Group	Industry	Number of Firms Surveyed	Number of Conservation Measures Recommended	Percent Saved by all Conservation Measures
201	Meat Packing	2	4	15
208	Beverages	4	14	6
261/262	Pulp and Paper Mills	1	4	60
263	Paperboard Mills	2	4	3
281	Inorganic Chemicals	1	0	0
282	Resins	0	0	0
286	Organic Chemicals	4	16	40
291	Petroleum Refining	2	9	25
3674	Semiconductors	8	20	40
Total		23	67	

The table indicates that Pequod studied semiconductor firms eight times, organic chemicals four times and beverages four times, making the composite percentages reasonably good indicators for water conservation in those industries.

Water conservation studies have also been conducted by other firms and by public agencies. The studies are generally not published and are not available to others. This considerable experience base is largely unavailable to others.

Pequod also conducted a computerized literature search of industrial databases to determine what specific water conservation measures had been reported for the SIC's of interest. Only a few entries were found that indicated reasonably close matches to the subject matter of interest. More of the articles found were for the pulp and paper industry than for any other.

Conservation Factors

In this section of the study we will combine two classes of information: 1) the numerical target of a trend toward conservation, and 2) a rate of change.

Our review of available information for the nine SIC groups studied, taking into consideration the conservation measures reported in the returned questionnaires, Pequod's database of related information, and the experience and judgment of Pequod's staff and of others consulted, is expressed in Table 6. The factors in this table should be applied to predictions that are made based simply on historical trends of water consumptions for these industries.

Table 6 has been constructed by first establishing what overall reduction of water usage could be expected for a specific industry. This brings together all sources of information available and is the result of Pequod's experience in water conservation in general as well as in specific industries.

Second, we considered the period of time over which the reductions in water use could be expected. For SIC 3674, we expect the very high cost of processing water and the generally aggressive business posture of this industry to achieve the projected 40 percent reduction in ten years. For the other industries, we forecast slower achievement of reduction, reflecting their more mature character.

Finally we considered what model to use for the pace of the conservation effect. We chose the simplest, merely a straight-line effect. That is, we assumed that the conservation effect is achieved in equal amounts over the period of time specified. Alternative methods of applying the projected overall conservation effect, especially those modeled on the "learning curve" principle, in which there is a constant annual percentage, appeared to us to be more elegant than could be justified. However, it is obvious that if a firm is still operating at the end of the projection period, it will still be learning how to reduce all of its production factors, including the cost of water, water processing and effluent treatment.

Table 6 Conservation Factors Through 2010 Multiply Projections of Water Use by the Indicated Conservation Factors							
SIC Group	Industry	Overall Conservation Reduction	Years to Achieve	Annual Conservation Reduction	Conservation Factors		
					Year 1998	Year 2003	Year 2010
201	Meat Packing	.20	20	.01	.95	.90	.83
208	Beverages	.20	20	.01	.95	.90	.83
261/262	Pulp and Paper	.30	15	.02	.90	.80	.70
263	Paperboard	.25	15	.017	.92	.83	.75
281	Inorganic Chem	.20	20	.01	.95	.90	.83
282	Resins	.20	20	.01	.95	.90	.83
286	Organic Chem	.20	20	.01	.95	.90	.83
291	Refining	.20	20	.01	.95	.90	.83
3674	Semiconductors	.40	10	.04	.80	.60	.60

When Conservation Measures Are Adopted

Pequod concludes that the most likely time in most industries for any major water conservation measure to be undertaken is when a new project is begun. This was expressed by one refiner in the returned questionnaire as: "Changes were instituted when newest crude distillation unit was built."

Generalizing from this, conservation measures should be expected when there is a major change, reconstruction or addition to a plant. At that time, the various technical, economic, environmental and social considerations are combined and reflected in the design of the project. A strong or growing market for the products of the plant will justify further technological and operational improvements, some of which will be related to water and other utilities. However, if there is weakness in the market, there will be few if any investments made except for those that directly assist in maintaining the business' ability to survive.

An exception is where the cost of water is exceedingly high, as in the semiconductor industry where processing to produce water of required purity becomes a major cost consideration. In such circumstances, the industry will undertake water-related projects that do not directly achieve changes in production of semiconductors.

Another possible exception is where effluent charges are so great that major projects to reduce water consumption would be undertaken to reduce those charges. In this survey, we have not encountered reports that any conservation project was undertaken for this purpose.

Trends in Water Conservation

Answers to the question about water efficiency measures planned or desired did not furnish usable information. Finally, answers to a question concerning the direction the industry is taking were often couched in very general terms, such as "...use of the Continuous Improvement Program...". A more pointed question might have elicited specific technical goals from the responding firms.

General Conclusions Concerning Conservation

On the whole, we perceive two fundamentally different ways to achieve reduced water use. The first is the *incremental method* - savings are achieved as they are recognized as possible and economic. They are incidental to the larger considerations of operation and business and are usually achieved when convenient. The second is the *facility design method* - incorporation of economical designs in the use of water within the manufacturing process as well as in the utility process. Only those industries and firms that expect their investments to pay back over a normal facility lifetime will undertake major projects that produce water conservation effects of this type. In most industries there will be a mixture of the two types of conservation effects, as some firms make major investments while others gradually improve existing facilities.

The life of major equipment is frequently measured in decades rather than in years. A generation may elapse between major installations of a given kind, as in a paper mill, a chemical plant or a petroleum refinery, where a process may be made obsolete over a couple of decades. Since it appears that it is the major project rather than the accumulation of minor measures that accounts for the difference in water usage between groups of manufacturing plants, we should expect to see distinct steps in the pattern of water usage for a given plant over the years (where other factors such as business fluctuations do not mask the effects of technical changes). Superimposed over these steps would be the cumulative effect of incremental changes of the type reported in the questionnaires. But for any industry group consisting of more than a few members, there should be a gradual change toward lower consumption.

Why are so few conservation measures reported and undertaken by the firms themselves? It may be a lack of expertise and focus, since they are dedicated to production of industrial commodities and not to utility operation. It may be a combination of economic elements. For instance, the return on investment in conservation projects might be too low when expressed as a percent annual return or in years required for simple payback. Obviously, the cost of water is a factor in determining economic viability of a project and we observe that in many cases the incremental cost of water is reported to be low. However, it seems likely too that most industrial installations reflect the technology at the time they were designed, and incorporated most of the cost-effective ideas then available. What is left after this technological commitment is only the opportunity to fine-tune the manufacturing and utility processes, and these efforts respond to economic opportunities rather than to conservation principles. In fact, the opportunities in many manufacturing plants to improve their profitability by conserving on their raw materials are normally greater than the opportunities to cut costs by reducing water consumption.

ADDITIONAL INFORMATION IN THE RETURNED QUESTIONNAIRES

While the primary purpose of the study was to develop conservation factors that would support better predictions of water usage in the nine industrial groups of interest, additional information was requested of, and often supplied by, the responding firms.

Three quarters of the firms to which questionnaires were sent did not respond at all. One sent a letter declining to return its questionnaire.

Considerable variation showed up in the thoroughness with which firms approached the questionnaire. Some large firms and some very small firms provided sketchy answers, while others provided virtually textbook-like detail. Some potentially useful historical information was returned relating to plant age and the recent installation of major changes in production and water technologies.

Pequod noted that the employment figures returned are not always consistent with the annual water-use reports filed with TWDB by the same firms.

There is a very large range of cost incurred for effluent treatment, ranging from nil in some cases to several million dollars annually.

Some firms returned copies of their water flow diagrams, as requested in the questionnaires, while others did not. Some indicated that they had no such diagram, though normally one would expect those firms to have prepared them as part of their discharge permits. We used our diagrams to check the proper units of consumption, since some of the responding firms' tabulated information was unclear. Also, the diagrams supplied more precise information on the recirculation of water and the intricacy of local arrangements than did the answers to the questionnaires.

Self-evaluations did not prove very useful. We see little consistency in how an SIC group regards its approach to water usage. That may be an accurate reflection of affairs. Nor did we see close correlation between a firm's self-evaluation and its water consumption per unit of capacity. This was particularly true in the paper industry.

Nearly all firms felt that both their present and future water supplies were adequately assured. Here it may be inferred that if a firm were seriously concerned about adequacy of future supplies, it would have returned its questionnaire and made the point. So future adequacy is apparently not a concern of these SIC groups at present.

Lastly, the questionnaire asked for further information should any responding firm wish to provide some. Pequod set up a field in the database to record additional information. Almost no one supplied additional information.

A return of nearly 25 percent on a questionnaire program like this is quite good. It validates TWDB's decision to ask for considerably more information than would simply support the development of water usage parameters. Pequod believes that a basis has been established for further studies employing the questionnaire technique to expand on the new knowledge base.

FURTHER STUDIES

Clues exist in the database and in TWDB's records that could lead to further useful information. For instance, one major soft drink bottler doubled its capacity in 1988, and although no reports were filed for the period immediately before or after this change, its annual water consumption essentially doubled. This is what would ordinarily be expected. In the early 1980's, the same firm showed a ten-fold increase in water consumption one year, followed by a fall-back to the customary range the next year and for several additional years. The reasons for the large increase and for the subsequent decrease are not available. Learning these reasons might be instructive. For instance, a major but temporary non-process change, such as in cooling operations, could account for the abrupt changes in water usage.

Sources of information on capacities and outputs of pulp and paper plants and of petroleum refineries have already been cited in this report. Similar information exists for other industries in the industrial literature as well as in government reports. With the use of TWDB's records, these sources can be used to test the validity of the responding firms' projections of how much their water use would be affected by increases or decreases in production.

Individual studies on a more penetrating basis could lead to better understanding of how the usage parameters have varied and will vary in the future at specific plants or for specific technologies. For instance, if the records of production and of process technology were available over say a decade or two for a specific refinery, the water required for a unit of production could more closely be determined. This would provide another basis for the development of conservation factors.

CONCLUSIONS

Conservation Factors

Based on our review of the questionnaires and databases with conservation and usage information, as well as expert judgment, we recommend the use of conservation factors for the nine industrial SIC groups studied. These factors should be applied to the projections that would otherwise be made by extrapolating current water consumptions. (See Table 6, Conservation Factors.)

Confidentiality of Questionnaire Contents

Without a thorough investigation, Pequod is unable to say that a concern for continued confidentiality is what motivated most firms not to respond to the questionnaires they received. As noted, only one letter of declination was received, and only a few noted or stated during telephone calls that they especially wished Pequod to note their concern for confidentiality.

Efficacy of Questionnaires

Questionnaires are a practical tool for collecting detailed information from users of water. However, no study was performed to validate the information returned to Pequod, nor was effort exerted to confirm that the information voluntarily supplied is equivalent to information on non-reporting users in the same SIC groups. Publications and the files of TWDB can provide only a partial validation.

Detailed Comments on Specific Types of Questions

Self-evaluations generate responses without reliable pattern. The form of such questions must be improved if they are to be useful.

Employment has been suggested and useful elsewhere as a surrogate for production levels or capacity. This survey indicates that actual capacities are available not only from published sources, but also from firms reasonably relying on the confidentiality of the survey firm. Questions on employment therefore are not productive in terms of generating water use parameters and they should be dropped from further studies unless needed for another more direct use.

We asked about **anticipated changes** in products and in raw materials. No useful information was elicited by these questions. However, several firms mentioned that previous changes in raw materials had influenced their water consumption, so a questions based on history would be useful in understanding the historical record of water use at a given site.

Regarding **operating labor**, many continuous process plants operate around-the-clock and one chemical process plant indicated that it operates some units for five years between shutdowns. We learned that in many such plants, the operating personnel work 12 hour shifts. Our question about shifts worked assumed 8 hour shifts. To learn what fraction of the time per day, per month or per year a plant operates, the question should be asked more directly and in this form rather than with reference to shifts.

Questions asking about **treatment of incoming water** did not generate useful responses. Many respondents indicated that they filter and chlorinate incoming water or otherwise used technology that could reasonably be expected by knowledgeable people in the field.

We asked about what point in the process the fresh or freshly treated **water enters, and where water leaves** the process. The answers varied from "at the beginning" or "at the end" to somewhat detailed references to their water use balance diagrams, but the information developed was not useful in determining usage parameters.

Questions relating to **water conservation** uncovered surprisingly little overt action to conserve water.

Sampling Strategy

Since the total population of the nine SIC groups was polled, no selection was performed. The population of some groups is relatively small in Texas and the degree of reliability of conclusions based solely on the Texas population may be limited. An expansion of the industrial water use survey to other states, collecting much more data than is possible in Texas, could provide more reliable consumption parameters, even though some business, tax, price and other dissimilarities would exist from state to state.

Identification of Firms by SIC

Two limitations of the SIC type of classification are, first, that even a four-digit SIC code necessarily includes a variety of manufacturing firms and, more importantly, that the SIC code is assigned based on the final product of the plant. Thus, plants that are technically very similar may be classified differently. For example, in the pulp/paper/paperboard industry (SIC's 261, 262 and 263), a manufacturing plant may produce pulp from wood, paper from wood or paperboard from wood (questionnaires were returned from all three types of plants in this survey), yet their operations are very similar. Another example is the chemical industry, in which there are many steps from ultimate raw material to final product. As in the paper industry, a final step may convert the previous material into a product that makes the manufacturing plant fall into a different SIC, but the technical difference between the plants on the whole may be minor.

Economic Justification for Conservation

The cost of water has historically been too low to provide an economic justification for water conservation, even when the cost of sewage treatment is added. Payback periods demanded in conservation projects are apparently the same as for production investments; that is, they generally fall into the two- to three-year range.

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PART ONE

Text for SIC Group 201

Form 201

TEXAS WATER DEVELOPMENT BOARD
SUPPLEMENTAL SURVEY OF WATER USE

conducted by

PEQUOD ASSOCIATES, INC.
1881 Kaiser Avenue
Irvine, California 92714
(714) 253-3533
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Contact: Irwin B. Margiloff, P.E.

This survey is a supplement to the annual Form 0669B that is distributed by the Water Use and Projections Unit of the TWDB. The purpose of this survey is to study and quantify factors that determine water consumption in order to make projections of water availability and use, and to assure industry a continuing adequate supply for production.

Please send the completed questionnaire to Pequod Associates, Inc. at the above address.

Company Name ____

Company Address ____

____

Name and title of the person answering this questionnaire

____

Telephone ____________________ **Fax** ____________________

I. HISTORICAL DATA

1.1 What was the year of . . .

the start of operations at this site? ______

the last major capacity change? ______

what size was the change?

____

the last major process or technical change? ______

what was the change?

____

the last major water-related improvement? ______

what was the improvement?

____

II. LABOR FORCE

2.1 Does the work force at this site include corporate-type operations such as administration, sales, marketing, warehousing and distribution?

Yes ______ No ______

2.2 Please show how **production** employment has changed in the last five years. Production employment includes production supervision.

Production Employment

Year	Full Time	Additional Full Time Equivalent
1992	______	______
1991	______	______
1990	______	______
1989	______	______
1988	______	______

III. PROCESS TECHNOLOGY

3.1 What are your principal products? Please check off as many as you produce, and note any others.

_____	Bacon	_____	Horsemeat
_____	Blood Meal	_____	Lard
_____	Boxed beef	_____	Meat extracts
_____	Boxed meat	_____	Meat packing
_____	Canned meats, cooked	_____	Meat products
_____	Cured Meats	_____	Meats: beef, pork, lamb, mutton, veal
_____	Dried meats	_____	Pastrami
_____	Egg albumen	_____	Poultry, fresh, frozen, canned
_____	Egg substitutes made from eggs	_____	Processed meat: sausage, frankfurter, luncheon, bologna, spreads
_____	Eggs	_____	Pudding, meat
_____	Frozen meats	_____	Sausage casings
_____	Game, including rabbits	_____	Smoked meats
_____	Ham	_____	Variety Meats
_____	Headcheese	Other	_______________
_____	Hides and skins	Other	_______________

3.2 What changes in products do you anticipate, and when?

____

____

3.3 What units are the conventional measure of capacity of your plant, and of your industry? (e.g. tons/year, barrels/day, standardized product/8-hour shift, or some other)

____

3.4 What is the nominal capacity of your plant?

____

3.5 What percent of plant capacity was achieved in 1992? _____ %

3.6 If 1987 production was 100 percent, what level of production was achieved in 1992? _____ %

If you must refer to a different base year, what is it? _____

3.7 For each month of 1992, please estimate the percentage of the year's production during that month.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
____	____	____	____	____	____	____	____	____	____	____	____

3.8 If the 1992 capacity was outside the range you consider normal for your plant, please describe briefly what caused the rate to be different and whether water was a related factor.

____

____

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

_____ Canning
_____ Cooking
_____ Curing
_____ Dressing
_____ Drying
_____ Extracting
_____ Hide and skin processing
_____ Mixing
_____ Pickling
_____ Processing
_____ Sausage making
_____ Slaughtering
_____ Smoking
other ____________________

3.10 When comparing your technology or methods to those in your industry, how much change, if any, is required <u>in your plant</u> to reach the state of the art?

no change/0 1 2 3 4 5 6 7 8 9 10/great change

3.11 What are your principal raw materials? Examples:

_____	Eggs and egg products	_____	Processing chemicals
_____	Food products	_____	Solvents
_____	Live animals including game	_____	Spices
_____	Preserving materials	other	__________________

3.12 Have raw materials changed since your plant started operations?

Yes _____ No _____

If Yes, how has the change affected water usage and quality?

____

____

____

3.13 What changes in raw materials do you anticipate, and when?

____

____

3.14 In 1992, how many shifts per day did the plant operate? Please circle 0, 1, 2 or 3 shifts per day, by month.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3

3.15 If there was an annual shutdown, when did it occur and how long was it?

____

IV. WATER TREATMENT TECHNOLOGY

4.1 Is treatment of incoming water necessary at your plant?

Yes _____ No _____

If yes, please answer the remaining questions in this section.

4.2 Briefly describe the principal water treatment measures now in use at your plant for treatment of incoming water, and why they are necessary. Please estimate the consumption of each type of treated water.

____

____

____

4.3 In terms of general practice in your industry concerning the treatment of incoming water, how much change, if any, is required to reach the state of the art?

no change/0 1 2 3 4 5 6 7 8 9 10/great change

V. WATER USAGE

5.1 Form TWDB-0669B, "Survey of Ground and Surface Water Use for Calendar Year..." provides for a report of ground, surface, saline and sewage or wastewater use and water sales. It also requests you to distribute your usage of each of these categories of water supply to cooling, process, boiler feed, air conditioning, sanitary and other. If your report contained that information, you need not provide it here.

For each water source, please show the water use each month during 1992.

Water Source ______________________________________

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
____	____	____	____	____	____	____	____	____	____	____	____

VI. WATER EFFICIENCY

6.1 Indicate the approximate dates of water efficiency measures you have adopted at this plant.

Year	Water Efficiency Measure	Quantity Saved	Cost
_____	recycle cooling or process water	________	$________
_____	reuse sequentially in processes or between process and cooling	________	$________
_____	improved control systems	________	$________
_____	dry cooling or other processes	________	$________
_____	changed clean-up procedures	________	$________
_____	changed to/from continuous processing	________	$________
_____	changed/reduced nozzles and flow rates (could be for process or cleanup)	________	$________
_____	use automatic shut-offs	________	$________
_____	smaller tanks and sinks	________	$________
_____	lower flow settings	________	$________
_____	leak monitoring and/or repair	________	$________
_____	changed landscape/irrigation practices	________	$________
_____	production shutdowns/relocations	________	$________
_____	switched water sources	________	$________

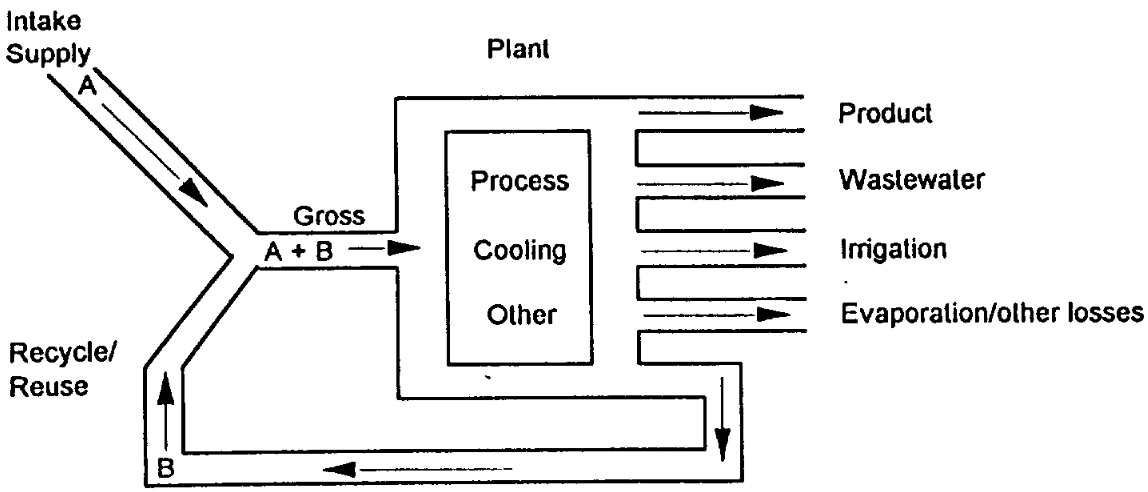
Comments and additional measures ______________________________

____

____

6.2 What percentage reduction do you estimate you have achieved by adopting these efficiency measures? _____ %

6.3 Please provide data on recycled water use for 1992. Refer to the following schematic which shows intake and recycled water. Show cooling and process recycling separately if possible.



	1992 Water Volume			
	Intake (A)	Recycled (B)	A + B	Units
Process	______	______	______	_____
Cooling, Condensing	______	______	______	_____
Others (specify)				
________________	______	______	______	_____

6.4 Do you treat water to make it suitable for recycling?

Yes _____ No _____

If yes, what treatment do you use?

____

____

6.5 What measures for water efficiency are you planning, or would you like to implement during the next five years? What are their anticipated savings and costs?

____

____

6.6 What is the payback period, investment rate or other numerical yardstick you apply to expenditures for water supply and efficiency?

_____ Payback _____ Years

_____ Return on Investment _____ %

_____ Other Criterion ______________________________

_____ None

6.7 What direction is your industry taking in water use efficiency and reduction?

____

____

VII. WASTEWATER

7.1 What wastewater treatments do you use at your plant? What contaminants do they deal with?

____

____

____

7.2 How do particular raw materials affect the quantity and quality of wastewater and the treatment methods required?

____

____

____

7.3 What direction is your industry taking regarding wastewater treatment?

____

____

____

VIII. WATER AVAILABILITY

8.1 Is your present water supply adequate?

Yes _____ No _____

8.2 Do you consider your future water supply adequate and assured?

Yes _____ No _____

8.3 What level of significance (considering all cost and technical factors) does the cost of water and of effluent charges (or treatment) have for your business at this location?

low/0 1 2 3 4 5 6 7 8 9 10/great

8.4 Briefly describe how your plans for this site are affected by considerations relating to water availability, cost, wastewater treatment or other water-related issues.

____

____

____

IX. COSTS

9.1 What is your average cost of water?

	Purchased	Self-Supply
Surface Water	$ ________	$ ________
Ground Water	$ ________	$ ________
Other Source (specify) ______________	$ ________	$ ________

Your cost of self-supplied water should include, if possible, all capital-related (return, interest, taxes, insurance, etc.) as well as operating and maintenance costs.
If capital-related costs are included, please check here. _____

9.2 If you must upgrade incoming purchased or self-supplied water to meet the requirements of your manufacturing process, please furnish:

percentage of purchased/self supplied water upgraded ________%

annual operating and maintenance cost $________

capital investment in water upgrading facilities $________

9.3 Please indicate data on effluent water.

Sewage District ________________________________

What is your annual cost for sewage service? $ ____________________

Are there charges for Volume?	Yes	_____	No	_____	$	____/____
for BOD?	Yes	_____	No	_____	$	____/____
for Suspended Solids?	Yes	_____	No	_____	$	____/____

9.4 Do you expect to have to treat effluent water more extensively before discharge?

Yes _____ If yes, when? ____________________________

No _____ why? ____________________________

9.5 Do you anticipate a rise in sewage or effluent charges?

Yes _____ If yes, when? ____________________________

No _____

X. SUPPLEMENTAL COMMENTS

Please give us any supplemental information you may have that would assist the Board to understand your concerns about water and to provide useful projections of water availability for industry. You may attach comments on a separate sheet.

PART TWO

Specific Questions for Individual SIC Groups

SIC 208
Beverages

3.1 What are your principal products? Please check off as many as you produce, and note any others.

- ______ Alcoholic mixed drinks
- ______ Beer, ale
- ______ Beverage bases
- ______ Bottled/canned soft drinks
- ______ Bottled/canned water
- ______ Brandy and brandy spirits
- ______ Brewer's grains
- ______ Carbonated waters
- ______ Colors for Bakers
- ______ Crushed fruits
- ______ Flavorings
- ______ Food Coloring
- ______ Fruit Juice Concentrates
- ______ Gin, rum, neutral spirits
- ______ Malt
- ______ Malt extract, liquors, etc.
- ______ Nonalcoholic cocktail mixes
- ______ Nonalcoholic cordials
- ______ Potable, medicinal alcohol
- ______ Porter/ale/stout
- ______ Syrups
- ______ Vodka
- ______ Whisky
- ______ Wine cellars
- ______ Wine coolers
- ______ Wines

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

- ______ Blending
- ______ Bottling and canning
- ______ Bottle/can production
- ______ Brewing
- ______ Carbonating
- ______ Concentration
- ______ Distillation
- ______ Extraction
- ______ Malting
- ______ Packaging
- ______ Membrane Separation

3.11 What are your principal raw materials? Examples:

______	Concentrates	______	Powders
______	Flavorings	______	Spirits
______	Fruits	______	Sugars
______	Grains	______	Syrup
______	Juices	______	Water
______	Malt	______	Wines
______	Other food ingredients		
______	Pastes		

SIC 261/262
Pulp and Paper Mills

3.1 What are your principal products? Please check off as many as you produce, and note any others.

______ Asbestos and asbestos-filled paper

______ Asphalt paper, sheathing

______ Bag paper

______ Blotting paper

______ Bond paper

______ Book paper

______ Building paper

______ Felts

______ Fiber pulp: wood, rags, wastepaper, linters, straw, bagasse

______ Greaseproof paper

______ Newsprint

______ Other papers

______ Printing papers

______ Pulp Mills

______ Pulp: soda, sulfate, sulfite, ground wood, rayon, semichemical

______ Wrapping paper

3.9 Indicate the major technologies or operations conducted at your plant.

NO EXAMPLES GIVEN.

3.11 What are your principal raw materials? Examples:

______	Adhesives	______	Pulping chemicals
______	Asphalt	______	Rags
______	Linters	______	Solvents
______	Papermaking chemicals and materials	______	Wood
______	Pulp		

SIC 263
Paperboard Mills

3.1 What are your principal products?

NO EXAMPLES GIVEN.

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

_____ Bleaching

_____ Coating

_____ Cogeneration

_____ Coloring

_____ Deinking

_____ Printing

_ Recycling

_ Wastewater treatment

3.11 What are your principal raw materials? Examples:

_____ Chemical additives

_____ Commercial pulp

_____ Post-consumer fiber

_____ Secondary fiber

SIC 281
Inorganic Industrial Chemicals

3.1 What are your principal products? Please check off as many as you produce, and note any others.

_____ Acids

_____ Alkali metals

_____ Alkalies other than caustic soda

_____ Alkaline earth metals

_____ Carbon and charcoals

_____ Caustic soda

_____ Chlorine

_____ Dry ice

_____ Fissionable materials

_____ High purity inorganic chemicals

_____ Industrial gases

_____ Industrial inorganic chemicals (specify)

_____ Inorganic pigments (specify)

_____ Nitrogen compounds (excluding ammonia)

_____ Radioactive materials

_____ Rare earth salts

_____ Rocket propellants: solid inorganic

_____ Salts

_____ Tanning agents, synthetic inorganic

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

- _____ Burning
- _____ Calcining
- _____ Catalysis
- _____ Compression
- _____ Crushing
- _____ Crystallization
- _____ Dehydration
- _____ Dissolving
- _____ Electrolysis
- _____ Evaporation
- _____ Extraction
- _____ Size Reduction
- _____ Hydrogenation
- _____ Hydration
- _____ Ion exchange
- _____ Leaching
- _____ Liquefaction
- _____ Melting
- _____ Neutralization
- _____ Oxidation
- _____ Precipitation
- _____ Reduction
- _____ Separation
- _____ Smelting

3.11 What are your principal raw materials?

NO EXAMPLES GIVEN.

SIC 282
Plastics Materials and Synthetic Resins

3.1 What are your principal products? Please check off as many as you produce, and note any others.

Resins (unfinished), or synthetic rubber or elastomers, or fibers consisting of any of the following types. Please indicate which apply to your plant:

______ Acrylic

______ Alkyd

______ Casein

______ Cellulose-based

______ Coumarone-indene and petroleum polymer

______ Phenolics and other tar acid-based

______ Polyamide, silicone, polyisobutylene, polyester, polycarbonate, acetal and fluorohydrocarbon

______ Polyethylene

______ Polypropylene

______ Rosin modified

______ Styrene

______ Urea and melamine

______ Vinyl

______ Fibers

 ______ manmade cellulosic

 ______ manmade organic (except cellulosic): acrylic, acrylonitrile, anidex, casein, elastomeric, fluorocarbon, linear esters, modacrylic, nylon, olefin, polyester, polyvinyl ester, polyvinylidene chloride, protein, saran, soybean fibers (textile), textured fibers and yarns, zein

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

- _____ Catalytic processes
- _____ Copolymerization
- _____ Crystallization
- _____ Dissolving
- _____ Extrusion
- _____ Liquid-phase polymerization
- _____ Solution polymerization
- _____ Suspension polymerization
- _____ Vapor-phase polymerization

3.11 What are your principal raw materials?

NO EXAMPLES GIVEN.

SIC 286
Industrial Organic Chemicals

3.1 What are your principal products? Please check off as many as you produce, and note any others.

General groups

______ Aroma and flavoring materials

______ Chemical warfare agents

______ Cyclic crudes and intermediates

______ Esters, amines, etc. of polyhydric alcohols and fatty acids

______ Glycols and similar alcohols

______ Natural gum and wood chemicals

______ Noncyclic chemicals: acids and salts

______ Plasticizers

______ Rubber processing materials

______ Solvents, including chlorinated

______ Synthetic tanning agents

Narrower Products Classes

______ Charcoal

______ Dyes and Pigments

______ Extracts

______ Methanol

______ Naval stores

______ Oils

______ Pitch and rosin

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

- _____ Addition
- _____ Chlorination
- _____ Crystallization
- _____ Cracking
- _____ Distillation
- _____ Esterification
- _____ Extraction
- _____ Halogenation
- _____ Hydration
- _____ Hydrogenation
- _____ Hydrolysis
- _____ Neutralization
- _____ Nitration
- _____ Oxidation
- _____ Rearrangement
- _____ Reduction
- _____ Saponification
- _____ Substitution
- _____ Sulfonation

3.11 What are your principal raw materials?

NO EXAMPLES GIVEN.

SIC 291
Petroleum Refining

3.1 What are your principal products? Please check off as many as you produce, and note any others.

- _____ Alkylates
- _____ Aromatics
- _____ Asphalt
- _____ BTX
- _____ Butadiene
- _____ Butylenes
- _____ Coke, petroleum
- _____ Diesel fuel
- _____ Distillate fuels
- _____ Ethylene by product
- _____ Fractionation products
- _____ Fuel gas
- _____ Gasoline
- _____ Gasoline blending plants
- _____ Jet fuels
- _____ Kerosene
- _____ LPG
- _____ Lubricants
- _____ Mineral oil and jelly
- _____ Naphtha
- _____ Naphthenic acids
- _____ Oils and greases
- _____ Paving materials
- _____ Petrolatums
- _____ Propylene by product
- _____ Residual fuel
- _____ Solvents
- _____ Tar
- _____ Waxes

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

_____ Alkylation
_____ Catalytic cracking
_____ Catalytic reforming
_____ Coking
_____ Crude distillation
_____ Fluid catalytic cracking
_____ Hydrocracking
_____ Hydrodesulfurization
_____ Hydrogenation
_____ Hydrotreating
_____ Polymerization
_____ Reforming
_____ Thermal cracking
_____ Vacuum distillation

3.11 What are your principal raw materials?

NO EXAMPLES GIVEN.

SIC 3674
Semiconductors and Related Devices

3.1 What are your principal products? Please check off as many as you produce, and note any others.

______	Diodes: laser, light emitting parametric, Schottky, tunnel variable capacitance, Zener	______	Silicon wafers, chemically doped
		______	Solar cells
		______	Strain gages
______	Gunn Effect, Hall Effect devices	______	Stud bases for semiconductor devices
______	Fuel Cells		
______	Logic modules	______	Switches, silicon control
______	Metal oxide silicon devices	______	Thermionic devices
______	Memories: RAM, ROM, magnetic bubble	______	Thermoelectric devices
		______	Thin film circuits
______	Microprocessors	______	Thyristors
______	Optical isolators	______	Transistors
______	Photoelectric cells	______	Ultraviolet sensors
______	Photoelectric magnetic devices	______	Wafers
______	Photovoltaic devices		

3.9 Indicate the major technologies or operations conducted at your plant and indicate any others not listed.

______	Crystallization	______	Metal joining
______	Cutting and polishing	______	Printing
______	Etching	______	Soldering
______	Glass forming and sealing	______	Water purification
______	Metal forming		

3.11 What are your principal raw materials?

NO EXAMPLES GIVEN.

DATABASE

The computerized database is being furnished to TWDB on diskettes. Pequod has removed information on capacities, on production as a percentage of capacity and on 1992 production in relation to 1987 from the files sent to TWDB, to respect the request of the participating firms for confidential treatment of this information.

OTHER SOURCES OF INFORMATION

1. **Texas Water Development Board** furnished computerized files of water consumption, by type and individual firm, for all firms in the SIC groups of interest for the years 1981 through 1991. TWDB also provided lists of Texas counties, river basins, watershed regions and other tabular information. In addition, the Board's staff has been very prompt in responding to all requests for assistance in identifying firms with changed names and in looking up statistical information in TWDB files.

2. **Published sources** were consulted as.follows:

   Chemical Economics Handbook, SRI International, Menlo Park, California

   Directory of Texas Manufacturers, 1993, Volumes 1 and 2. Bureau of Business Research, The University of Texas at Austin

   Oil & Gas Journal, December 22, 1992, PennWell Publishing Corp., Tulsa