TEXAS MANUFACTURING WATER USE

LONG-TERM PROJECTIONS

LP-193

Texas Department of Water Resources

November 1983

Published and distributed
by the
Texas Department of Water Resources
Post Office Box 13087
Austin, Texas 78711

TEXAS MANUFACTURING WATER USE
LONG-TERM PROJECTIONS

ABSTRACT

The Texas Department of Water Resources is required by law to project water requirements in the State for a 50-year period. These forecasted demands upon the water resources of the State are categorized according to purpose of use. This report presents documentation for the projected manufacturing water requirements shown in the draft planning report entitled Water for Texas-Planning for the Future. The draft planning report was released to the public in February 1983 for the purpose of receiving public input on the update and revision of the Texas Water Plan. The Department's Economics, Water Require-ments and Uses Section of the Planning and Development Division made the projections described herein according to several methods. The key feature of the work was consultation with industry representatives which produced valuable information about the anticipated future of each major water-using industry. All available long-term forecasts of industry growth were studied. The Depart-ment projected growth according to statistical methods, then likely economic events, such as the anticipated future slowdown in production of primary metals and fuels, were included in the final determination of future changes in indus-try outputs.

The report concentrates upon the five largest water-using industries: chemicals, petroleum, paper and pulp, metals, and food processing. The growth in industrial water use is projected to double by the year 2015 and almost triple by 2030. Chemicals production will require most of the manufacturing volume throughout the period. Total water use in Texas for manufacturing is forecasted to grow from 1.5 million acre-feet in 1980 to 4.4 million acre-feet by 2030.

This report was prepared by Mickey L. Wright and F.G. Bloodworth of the Economic Analysis Unit.

TABLE OF CONTENTS

Page

ABSTRACT iii

INTRODUCTION 1

INDUSTRIAL WATER USE PROJECTION PROCESS 4

Industrial Production Projection Methodology 6

Use of Bureau of Economic Analysis Projections 6
Manufacturing Production Growth Rate Projection Method 10
Special Treatment of the Houston Area 11
Three-Digit SIC Estimates 11

Future Manufacturing Water Use Efficiency Projections 13

OVERVIEW OF TEXAS MANUFACTURING INDUSTRY 17

Manufacturing Industry Description 17
Texas in the National Industrial Context 22
Recent Trends 24

ANALYSIS OF WATER USE BY THE MAJOR WATER USING INDUSTRIES 31

Processed Foods and Beverages (SIC 20) 31

Industry Description 32
Economic Characteristics 32
Recent Trends 34
Long-Term Outlook 36
Projection Data and Method 36
Projected Water Requirements 37

Paper Industries (SIC 26) 37

Industry Description 39
National Context of the Industry 40
Recent Trends 42
Long-Term Outlook 44
Projection Data and Method 44
Projected Water Requirements 47

Chemicals (SIC 28) 48

Industry Description 50
Economic Characteristics 54
National Context of the Industry 58
Recent Trends 59
Long-Term Outlook 62
Projection Data and Method 65
Projected Water Requirements 65

Page

Petroleum Refining (SIC 29) 66

Industry Description 68
Economic Characteristics 68
Recent Trends 71
Long-Term Outlook 76
Water Use Efficiencies in Refinery Operations 78
Projection Data and Method 79
Projected Water Requirements 81

Primary Metals (SIC 28) 82

Industry Description 84
Economic Characteristics 85
National Context of the Industry 86
Recent Trends 87
Long-Term Outlook 90
Projection Data and Method 91
Projected Water Requirements 93

CONCLUSION - PROJECTED MANUFACTURING WATER REQUIREMENTS 94

SELECTED REFERENCES 101

APPENDIX - Water Using Industries Referenced by Maps in Text 103

TABLES

1. Comparison of Compound Annual Growth Rates, Various Sources 7

2. Projected Reuse and Technology Parameters for Water Use Efficiency Adjustments 15

3. Leading Industries in Texas by Employment, Four-Digit SIC, 1980 .. 19

4. Shipments an Employment Related to Industrial Foreign Exports; Texas Manufacturers, 1980 21

5. Texas Shares of National Output by Indusry, 1972 and 1977 23

6. Historical Growth Ratesfor Two-Digit SIC Industries, Texas and National Comparisons, 1969 to 1979 25

7. Leading Growth Industries in Texas by Employment, 1977 to 1980 ... 26

8. Capital Expenditures of Major Water Using Industries in Texas, 1972 and 1977 28

9. Pulp and Paper Capacity and Water Use Projections (SIC 262 and 263), 1980 to 2020 by River Basin of Major Paper Mills 47

TABLE OF CONTENTS (continued)

Page

10. Texas Chemical Production Capacity as Relative to the National Total, 1980 60

11. Foreign Imports of Crude Oil to Texas Refineries 70

12. Post-1973 Historical Refinery Capacity Utilization, Texas 74

13. Capacity Utilization by Texas Refineries, Monthly, 1980 80

14. Leading Water-Using Industries in Texas by Volume of Annual Freshwater, 1980 96

15. Projected Manufacturing Water Requirements, Texas 97

16. Projections by Manufacturing Water Requirements by Industry, Texas, 1980-2030 98

17. Projected Growth Rates of Texas Manufacturing 99

FIGURES

1. General Process for Projecting Industrial Water Use 5

2. Historical Change in Texas Gross State Product and its Components 18

3. Locations of Food Processing Establishments (SIC 20) 33

4. Pulp and Paper Industries in Texas as of January 1, 1980 38

5. Growth-Harvest Relationship for Pine and Hardwood in Texas, 1970-1980 43

6. Major Chemical Industries in Texas as of January 1, 1980 49

7. Petrochemical Inter-Industry Relationships 51

8. Chemical Industry Pollution Control Capital Spending, U.S. 57

9. Refineries in Texas as of January 1, 1980 67

10. U.S. Real GNP and Energy Demand 73

11. Primary Metal Industries in Texas as of January 1, 1980 83

12. Oil Field Machinery Shipments and Exports 89

13. Projected Industrial Water Requirements 100

TEXAS MANUFACTURING WATER USE
LONG-TERM PROJECTIONS

INTRODUCTION

The Texas Department of Water Resources is required to project future water requirements for a 50-year planning period. Industrial water requirements are an important part of the State's total water demand. Use of water by manufacturing establishments in the production of durable and nondurable goods contributes to the livelihood of the Texas economy and, indeed, the international economy as well. Water, as an element in hundreds of manufacturing processes, can be critical to existing and potential industrial production. If its availability is limited, the result is loss of production, loss of jobs for people, decrease in personal income, and if widespread, economic declines of regional economies.

The importance of water, in terms of amount required to produce goods, varies widely among all manufacturing activities. Some processes require direct consumption as part of products, others require very little consumption but may use large volumes for cooling or cleaning purposes. In some manner or another water is passed through the industrial plants, sometimes inserted as a component of the product, but most often emerging in an altered state serving as a transporter of unwanted heat or suspended elements.

This report presents the data and reasoning underlying the Department's projections for the future of industrial water use in Texas until the year 2030. The long-term prospects for the State's industrial economy are analyzed, with consideration of all available data about the future position of the U.S. and Texas in the world economy so that current trends, historical biases, and short-sighted judgments do not overly influence the projections.

In developing these projections, the Department adopted a policy of consultation with industry representatives and industry-specific literature in order to make judgments about the reasonableness of anticipated future growth of the five industries identified as major water users. The overriding concern was to assure that the projections accounted for raw material supply and market demand for products, and for known impediments or opportunities for growth in each specific industry's economic context. Historical data were not ignored, nor were other strictly statistical projections; but research into resources, processes and potential markets for the important water-intensive industries uncovered information which rendered many of the mathematical models and extrapolations of recent trends inaccurate.

The projections of economic growth do not attempt to speculate on entirely new industries which may appear in the very long term (30 to 50 years). When the projected growth rates are increasing at a much more rapid pace than existing establishments can possibly match with capacity expansion, new plant locations and expansions in Texas are implied. There are no acceptable methods by which to accurately predict the eventual appearance of industries which are not now present. The projections concentrate on the likely future of existing Texas industry.

The following sections will cover the following: (1) characteristics of the manufacturing sectors and especially recent economic developments which may influence sector rates of production in the future; (2) methods, assumptions, data, and information used to project the growth component of future water use by industry; (3) resulting growth rates for minor water-using sectors and growth prospects for the five major water-using sectors; (4) projections of improved water use efficiencies leading to greater water conservation; and, (5) resulting water use projections data and discussions.

These projections are a part of the sum of State water requirements which includes water for agricultural use, municipal and commercial use, water rights protection, electric power generation, and environmental protection. In the very far future, the trends anticipated in this analysis may not occur due to wholly unforeseen changes in technology, consumer tastes, the international economy or other forces which can only be speculated about. They reflect a realistic basis upon which decisions can be made regarding water resource development as it pertains to industrial water availability. There are, in the projected growth rates ample allowances for the expansion of Texas industry.

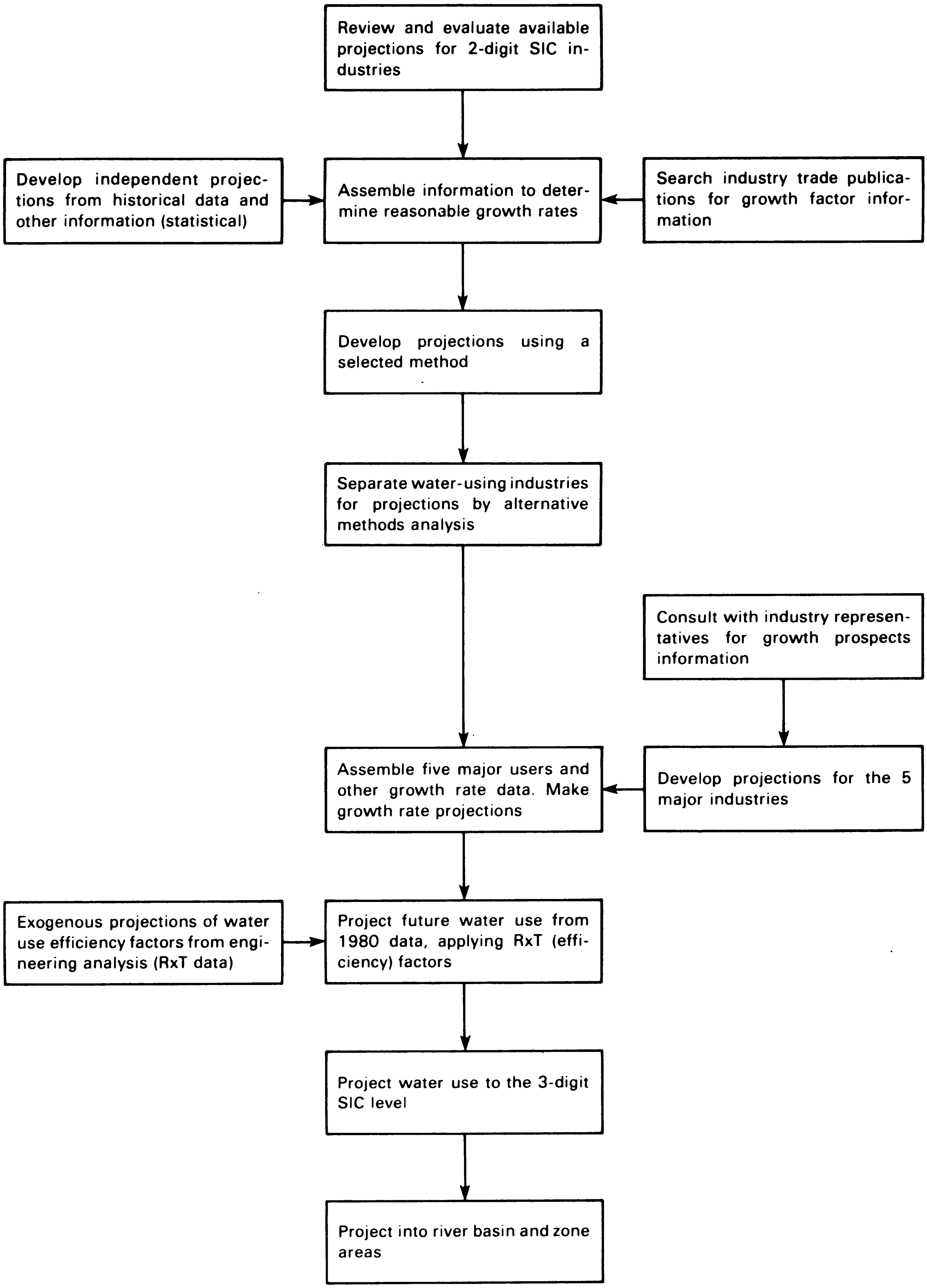
INDUSTRIAL WATER USE PROJECTION PROCESS

Projecting the future growth of Texas manufacturing involved several separate analyses. The general approach was to gather all available information about the long-term potential for industrial growth in production, considering estimates from public agencies, private sector economists, industry experts and internal Department data. Figure 1 shows an overview of the process, outlining the steps necessary to arrive at the future water requirement estimates.

The initial task was the development of growth rates for each two-digit Standard Industrial Classification (SIC) industry in Texas. Concurrently, information about recent trends in production, technological changes in processes, and anticipated future product markets and other types of developments which impact growth potentials for the major water using industries was gathered. This information included industry trade journals, research studies and direct contact with personnel in the industries. Long-term growth rates based on historical data and the results of regression equations were estimated by economists in the Department in order to judge a range of future growth paths in a strictly statistical analysis. These data provided insights into areas where adjustments and new information were needed, specifically, the extremely high rates projected for some industries by regression results which were not realistic in regard to known limitations in production capacity of some industries such as paper and pulp, petroleum refining, and metals.

Growth rates for selected water-intensive industries were then estimated separately using differing approaches. These industries were paper, metals and petroleum refining. The chemicals and food processing industries, estimates followed the methodology for all other industries (discussed below) because the initial estimates of growth provided reasonable projections when all industry information was assessed.

Figure 1.—General Process For Projecting Industrial Water Use.



Working from water use data for the 1980 base year, analysts calculated both the growth rates and the technological water use efficiency factors. Water volumes were then projected into three-digit SIC industry subdivisions from the two-digit SIC totals and then into the geographical areas of the State where industries are located.

Industrial Production Projection Methodology

Projections for future growth rates in production (physical volume of products) of Texas industry by economists outside of the Department revealed occasional disagreements in the anticipated future for some industries. By most estimates, however, the near-term (20 year) future of the manufacturing sector as a whole is for continued growth at a rate much faster than the national average (Table 1). Attention to major water-using industries show some wide differences of outlook among the projections. Table 1 includes the results of the projection methodology adopted by the Department (the Economic Analysis Unit's GPO/INCOME projection series, last column).

Use of Bureau of Economic Analysis Projections

No economic projections are available at the State level for the long-term future (50 years) except those provided by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). The latest series (OBERS, 1980) were received at the Department in early 1982. These projections of employment and income by industrial sector are produced periodically for purposes of long-range planning and are used regularly by private business, government agencies, and other organizations needing information about the far future because of the nature of problems to be studied, especially water resource

Table 1. Comparison of Compound Annual Growth Rates, Various Sources.

SIC	Chase Econometrics a/ Texas Value Added 1971-80 Historical	Chase Econometrics a/ Texas Value Added 1980-1990	Plaut, BBR-UT Texas Gross Product Originating b/ 1980-1990	Plaut, BBR-UT Texas Gross Product Originating b/ 1990-2000	BEA Texas Income by Industry c/ 1978-1990	BEA Texas Income by Industry c/ 1990-2000	DRI National Indexes of Industrial Produc. d/ 1981-1990	DRI National Indexes of Industrial Produc. d/ 1990-1995	EAU Employment Ratio Series f/ 1980-1990	EAU Employment Ratio Series f/ 1990-2000	EAU GPO/Income Projection Series f/ 1980-1990	EAU GPO/Income Projection Series f/ 1990-2000
20 Foods	4.72	3.10	3.0	0.6	3.13	2.76	2.40	1.92	3.35	3.20	2.38	2.64
22 Textiles	7.20	2.41	--	--	1.58	1.95	2.74	1.28	5.85	4.73	0.83	1.84
23 Apparel	4.26	5.53	--	--	4.97	3.43	2.60	0.73	5.48	4.37	4.20	3.31
24 Wood	7.40	6.32	--	--	4.78	3.56	3.42	0.07	5.16	4.06	4.01 e/	3.44 e/
25 Furniture	2.05	4.30	--	--	4.61	3.83	4.20	2.49	5.71	4.29	3.84	3.70
26 Paper	5.38	4.36	8.2	6.8	5.41	3.74	2.46	2.36	--	--	--	--
27 Printing	5.71	4.06			5.13	3.72	2.41	2.58	4.52	3.94	4.36	3.60
28 Chemicals	16.60	6.64			5.71	3.91	4.32	3.56	4.93	4.17	4.94	3.79
			7.6 1/	3.1 1/								
29 Petroleums	6.50	0.63	--	--	3.44	2.52	0.41	0.84	--	--	--	--
30 Plastics	8.16	8.09	--	--	6.78	4.23	6.23	3.89	3.52	2.42	6.00	4.11
32 Glass/Stone	4.38	4.10	--	--	5.52	3.97	4.18	2.02	4.32	3.84	4.74 e/	3.86 e/
33 Primary Metal	2.22	1.80	3.4	1.3	5.78	4.54	2.59	0.74	4.66	4.34	5.01	4.42
34 Fab. Metal	6.18	6.57	4.9	3.9	7.15	4.91	4.16	2.87	4.68	3.89	6.37	4.79
35 Non Elec. Mach.	14.03	5.66	9.5	6.1	7.92	4.71	5.08	4.00	3.70	3.07	7.13	4.59
36 Elec. Mach.	13.36	5.44	5.9	3.9	8.02*	4.74	5.25	4.05	5.99	4.72	7.62	4.62
37 Trans. Equip.	7.22	3.47	2.5	1.5	3.93	3.10	5.12	2.97	5.13	4.76	3.12	2.93
38 Instruments	--	--	7.8 2/	6.5	6.43	4.93	4.74	3.40	--	--	5.66	4.80
39 Miscellaneous	--	--	5.5 3/	4.4	5.96	4.23	2.71	2.26	5.76	4.13	5.19	4.11

-- Not projected
* 1985-1990 CAGR-7.54
1/ Petroleum and chemicals.
2/ Other non-durables: textiles, apparels, printing, plastics.
3/ Other durables: wood, furniture, glass and stone, misc. manufacturing, instruments.
a/ Chase Econometrics, Inc. Long-Term Regional Forecasts. Volume III. Third Quarter 1981.
b/ Plaut, Thomas R. A Supply-Side Model of the Texas Economy and Economic and Population Forecasts to Year 2000. Bureau of Business Research (BBR) University of Texas, Austin. Pub. No. BP 82-2, March, 1982. This series is under revision as of Summer, 1982.
c/ U.S. Bureau of Economic Analysis. "Regional Projections of Employment, Income and Population." Computer print-out data, Fall 1981.
d/ Data Resources, Inc. U.S. Long-Term Review. Winter 1981-82. Trend Long Forecast. Indexes of Industrial Volumes of Output.
e/ Other information in addition to this method were used for the final projected growth roles in these industries.
f/ Economic Analysis Unit (EAU), Planning & Development Division, Texas Department of Water Resources. These series were based on two different variables, employment ratio of an industry to total manufacturing employment and an estimate of the income received by industry, as projected by BEA for Texas.

issues. The BEA data are based upon statistical analysis and projection models which account for each state's position in the national economic future (details of BEA's methodology are discussed below).

Use of BEA as a basic data source gave estimates of all the two-digit SIC industry growth rates. The Department independently projected paper and petroleum refining growth rates (SIC 26 and 29). BEA projections of total industrial output were adjusted to account for the removal of those two industries from the calculation process.

The methods used by BEA to project regional growth rates include a series of calculations used to distribute national estimates to state and sub-state levels. Changes in labor productivity, projected by the U.S. Bureau of Labor Statistics (BLS), and information from industry specialist economists are incorporated in the long-term projections.

National projections of total labor force, employment by sector, annual hours of production, and output per man-hour (productivity) used by BEA were developed by BLS. Productivity projections strongly influence the resulting growth rates in output. Projections of these economic variables were developed through five major steps: (1) projection of the aggregate national economy using a statistical model; (2) disaggregation of gross national product (GNP) to detailed demand categories; (3) distribution of each demand category to producing sectors; (4) projection and use of an input-output table to estimate details of industry output; and, (5) projections of industries' output per man-hour, annual hours of production, and employment. Industry projections are based on a set of assumptions about the potentials of growth and anticipated government policies. The BEA economic model uses these assumptions to develop projections of raw materials supply, potential GNP growth and the resulting personal income flows. The income flows are used by the model for projecting a demand component of the GNP.

Projected demands for manufactured products are distributed among 162 different industries. Production coefficients in input-output models, showing materials and services required to manufacture goods, are projected based on expected changes in technology, product types and capital, raw materials and labor availability. Output for each industry is then projected through the use of the projected interindustry tables. Projections of industry employment, annual hours, and output per man hour are derived on the basis of each industry's projected output and employment requirements.

The Bureau of Economic Analysis estimates of GNP also use projections of annual hours of production and output per man hour from BLS data. Personal income by industry is projected on the basis of projected GNP-to-earnings ratios.

State level projections were based on an economic base methodology, which divides the state economies into basic and service industries according to each industry's export market orientation. Earnings for each manufacturing industry defined as a basic industry was projected by historical trend analysis relating a state's share of earnings to the corresponding national industry's earnings. The method assumed that factors affecting the share historically will continue to affect it in the future, but dampens a state's accelerating growth in national share as the size of the state's economy increases. This assumption assures that no state will have an inordinately large or small share of the national market for any specific industry and that equilibriating forces in a state's economy over the long term will tend to reduce disparities in growth rates between the state and the nation.

Manufacturing Industry Production Growth Rate Projection Method

Two-digit SIC projections of industrial output are measured by gross product originating (GPO), which are data about the production level of the industries. Despite minor technical differences, GPO is essentially the same measure as value-added by manufacture. Of the total value of all goods and services created by every sector of the State's economy such as services, agriculture, or transportation, the portion produced by an industry (i) alone is the GPO for the industry, noted as GPO_i.

The BEA industry-specific projections for income in Texas were used to estimate future GPO_i. The following calculation procedure was used:

$$GPO_{it(Tx)} = GNP_t' \quad \frac{Y_{i(TX)}}{Y_{i(US)}}_{t}$$

where: $GPO_{(TX)}$ = gross product originating for the i-th industry in Texas, in constant dollars

GNP' = gross national product, adjusted by removing SIC 26 and 29 from the totals

$Y_{i(TX)}$ = income projection for the i-th Texas industry

$Y_{i(US)}$ = income projection for the i-th national industry,

t = decades, 1980 to 2030.

Growth rates were calculated based on the changes in GPO_i from decade to decade. The compound annual growth rates* (CAGR) were used to index base year output; that is, 1980 output was set to 1.0 and the magnitudes of future year index numbers vary in concert with CAGR. Three-digit SIC indexes

---

* Compound annual growth rates should not be confused with average annual change, percent increase or other measures of change in data. Seemingly low numbers, when compounded over long time periods, as in these analyses, result in large changes. For example, a doubling of physical output by an industry would occur over 20 years at a CAGR of only 3.53, a rate of 7.18 doubles output in 10 years (a 100 percent increase).

were calculated by the method explained below. The indexes were then combined with projections of future improvements in water use efficiency, or rates of use per unit of product (discussed in another section), to estimate total volumes of water required by industry.

Special Treatment of the Houston Area

Because roughly 40 percent of the total industrial water use in Texas is required by plants in the Houston metropolitan area, the Department made adjustments in State-total growth rates to account for differential growth rates at the two- and three-digit SIC level of aggregation. These separate growth rates were applied to the water use data for that region. Regression equations were used to calculate the area-specific CAGR's; the equations were based on historical data about the relationship between the area and the rest of the State, in industry employment and personal income from manufacturing sources.

Three-Digit SIC Estimates

Data at the three-digit SIC level for Texas manufacturing are limited. In some cases data exist for only the census years, in other cases annual data are not available entirely or are withheld to avoid disclosure of company finances. For those industries with data exclusions for two years or less, the missing values can be estimated by interpolating between the known values. This technique completed the data set.

To distribute the projected output of the major (two-digit SIC) industries among their component three-digit SIC industries, Department economists estimated regression equations for each of the industries. Value-added and employment data for each three-digit SIC industry for which data existed were obtained from the U.S. Census' <u>Annual Survey of Manufacturers</u> for the period 1960-1977. The value-added data were converted to constant 1972 dollars using producer price indexes by industry. The regression equations for each three-digit industry were estimated in the form:

$$GPO_{ij} = a_i + b_1 K_{(2\text{-digit})j} + b_2 \frac{M_i}{M_j}$$

where: GPO_{ij} = constant dollar value-added (a surrogate for GPO) for the i-th three-digit SIC component industry of the j-th two-digit SIC industry

a_i = intercept for the i-th three-digit industry

b_1, b_2 = regression coefficients for the i-th three-digit industry

$K_{(2\text{-digit})j}$ = growth index for the j-th two-digit SIC major industry

M_i = employment for the i-th three-digit industry

M_j = employment for the j-th two-digit industry

The Bureau of Economic Analysis' projection series for Texas included employment projections for each major (two-digit) industry: however, data about future employment for three-digit industries were not available, and thus had to be projected based on the historical relationship between employment at the two-digit level and employment at the corresponding three-digit level.

Projection results are reported in the concluding section of this report. Equation specifications, historical industrial data, analytical data, technical reports and results of alternative analyses are available at the Department.

Future Manufacturing Water Use Efficiency Projections

Part of the process for industrial water use projections is the estimation of future improvements in the way industries will use water. By changing equipment, processes or product mix, manufacturers can reduce the amount of water necessary for a given unit of output. Industry attention to cost savings from using less water point to measurable improvements in lowering water intake volumes.

At any given point in time, the amount of fresh water taken into a production facility will be a constant function of the number of final products produced. This relationship will hold true for each of the common water usage categories -- cooling water, boiler feed, process water, and sanitary water. Through time, however, the constancy of this water-to-product relationship will not hold true. Two forces, one economic in nature (continuous), the other institutional (discrete), operate to cause a reduction in the amount of water used for each unit of final product. In a usual market process, economic incentives inspire a manufacturer to devise ways to reduce the cost of producing a product. From the institutional perspective, water-quality laws, regulations, and standards (federal, state, and locally imposed) place restrictions on the quality of effluent. Water used in manufacturing must meet specified quality requirements before being discharged from a plant. Thus, to meet these institutionally imposed water quality standards a facility's wastewater must be pretreated before discharge, which in turn imposes an additional operating cost upon the manufacturer that must be recaptured in the value of his product.

Though the two forces derive from different origins, in practical impact on any manufacturer they both impose an economic cost of production. Like all costs, they must be pushed to their minimum possible economic level. A manufacturing operation has two means for minimizing the cost of water taken into its facility: (1) a net reduction in the volume of water used per unit of product; and, (2) multiple uses of a given volume of water once taken into the production process. The first of these means requires an improvement in technology -- modification in the mechanisms of production -- the second requires recirculation of water discharged from one phase of the production process and its reintroduction and use in another phase.

In a short period of time, neither the effects of improved technology (T) nor the effects of increased recirculation (R) could be expected to have much of an impact on reducing the amount of water intake to a manufacturing facility. Over an intermediate term, say, ten years, or a long term, 50 years, changes in R and T separately and the combined, multiplicative (RxT) effect will reduce manufacturing water intake volumes substantially, especially in three of the large water-using industries -- primary metals, paper and petroleum refining.

Engineering studies estimated the potential for manufacturing water intake reductions as a consequence of the combined (RxT) effect under two distinguishable conditions. Estimates of change in the (RxT) parameter were made for only the five largest water-using industries, since they account for nearly all of total manufacturing water use in Texas, and then only for those in this group where some potential for reduction is possible. The first condition for estimating water intake reduction potential was limited to (T) values that are economically feasible (i.e., cost effective) and (R) values mandated by law and feasible in an engineering sense. These reductions, expressed as percentage reductions in water requirements per unit of product, are presented in Table 2, by industry and by decade. The second set, also shown in Table 2, result from imposing the condition of potential reduction possible from the manufacturer's use of the best available technology without

Table 2. Projected Reuse and Technology Parameters for Water Use Efficiency Adjustments.

Year	Petroleum Refining	Organic Chemicals, Plastics, and Synthetic Resins	Pulp and Paper	Iron and Steel
	Data used for most likely efficiency assumptions a/			
1980	0	0	0	0
1990	10	3	11	17
2000	11	7	36	38
2010	19	7	36	38
2020	19	7	36	38
2030	19	7	36	38
	Data used for high efficiency assumptions b/			
1980	0	0	0	0
1990	50	30	11	50
2000	69	35	36	90
2010	69	38	36	98
2020	69	39	36	98
2030	70	39	36	98

a/ Projected percentages of reduction in total water intake, best available technology and cost effective, calculated by: $RxT_{1980} \div RxT_{future} \times 100$.

b/ Projected percentage reduction in total water intake, best available technology and cost effective, calculated by:

$RxT_{1980} \div R^*xT^*_{future} \times 100$ (R* and T* are estimates without economic restrictions).

regard for economic feasibility (i.e., need not be cost effective). This latter set then would represent minimum foreseeable water use under ideal conditions. Realistically, the cost effective estimates represent the likely future improvement in industrial water use efficiencies.

OVERVIEW OF TEXAS MANUFACTURING INDUSTRY

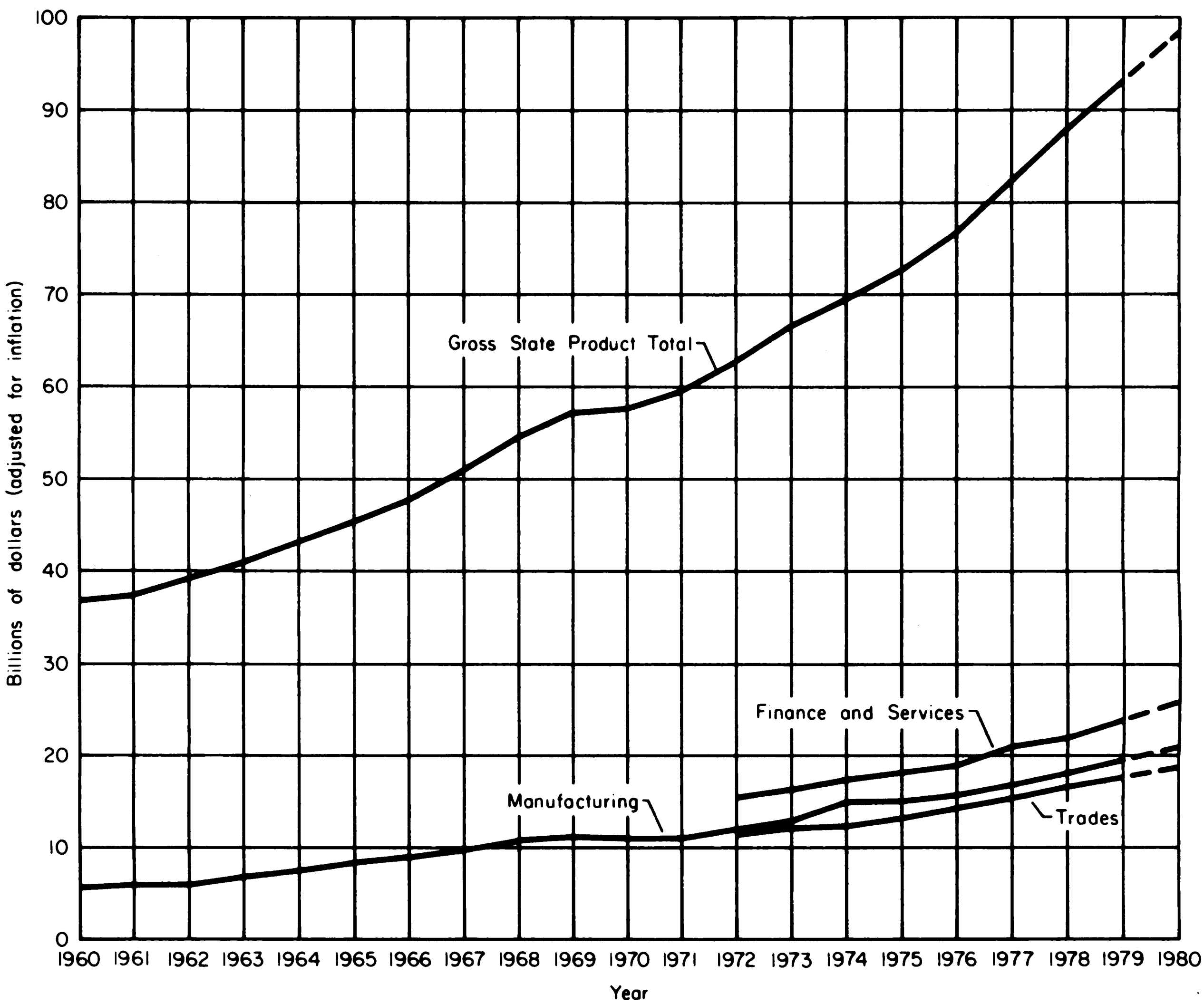
Texas' manufacturing industry is an important determinant of the general economic growth of the State at the present time. Product shipments create revenue for manufacturers which determines the level of wages, salaries and other personal income for over one million Texas citizens. The influence upon the rest of the State's economy is significant, since innumerable other types of businesses -- services, utilities, communications, finance and transportation, for example -- are involved in supplying manufacturers with goods and services necessary to produce their products. The Department estimates that manufacturing production influences other economic activities by more than three times the value of the direct output.

Manufacturing Industry Description

Growth of Texas manufacturing has been strong throughout the last two decades. Total output by the Texas economy in gross values of production has increased more than two-fold in constant dollar terms since 1960. Manufacturing has contributed to this growth by a three-fold increase, as have other sectors such as trades, services and finance (Figure 2). The dominant industries in the manufacturing sector of Texas are petroleum related. The influence of oil and natural gas mining have influenced heavily the direct supplier and spin-off industries which provide the tools, equipment, chemicals, and other goods used in drilling, maintaining and transporting oil and gas production. However, other industries are becoming strong. Specifically, Texas' electronics, aircraft, and machinery sectors have grown enough to rank among the top industries in Texas.

The leading industries, measured by number of employees, also include apparel and food processors (Table 3). When measured by gross value of

Figure 2.—Historical Change in Texas Gross State Product and its Components



Gross State Product - The value of all goods and services produced in Texas.

Manufacturing - Gross product originating (value added) from the manufacturing component of the State's economy.

Source: Texas Economic-Demographic Forecasting Model (TEDFM) Bureau of Business Research, University of Texas at Austin, 1982

Table 3. Leading Industries in Texas by Employment, Four-Digit SIC, 1980.

SIC	Description	Total Employment
3533	Oil field machinery	63,515
3674	Semiconductors & related devices	48,898
3721	Aircraft	45,011
2911	Petroleum refining	37,232
2869	Industrial organic chemicals	34,385
2711	Newspapers	25,300
3079	Miscellaneous plastic products	22,685
3599	Machinery, except electrical	21,078
2328	Men's and boy's work clothing	18,347
2327	Other men's and boy's clothing	16,024
3312	Blast furnaces and steel mills	15,945
3573	Electronic computing equipment	15,640
2752	Commercial printing	15,541
2011	Meat packing plants	15,271
3662	Communication equipment	14,922

*Includes all part-time, administrative and production workers, monthly average.

SOURCE: Texas Employment Commission.

product (value of shipments) the leading industry groups, in order, are: (1) petroleum refining, (2) chemicals, (3) food and beverages, (4) machinery, and (5) primary metals. In terms of value-added, or the amount of product value created by fabrication, the top five industries are: (1) chemicals, (2) petroleum refining, (3) machinery (except electrical), (4) food processing, and (5) fabricated metals. The petroleum and chemical industries accounted for over 35 percent or $20 billion of the State's estimated total $57 billion in value-added by manufacturer in 1980.

Texas industry produces a multitude of products which are marketed throughout the world. The primary location of market demand, however, is in U.S. population centers in the Midwest and industrial belts in the East. Petroleum-based, semi-finished products are shipped over extensive water, rail and pipeline networks to second- and third-stage processors in other states. Overall, an estimated 75 percent of petroleum and petrochemical products are used by U.S. markets. About 55 percent of all manufactured goods are transported to external, national markets.

Foreign exports accounted for 12.3 percent of all shipments in Texas in 1980. Some industries, however, are more heavily involved with foreign markets than others. Leading exporters in terms of the portion of output shipped overseas include primary metals, chemicals, machinery and electronic equipment. Each of these export more than 18 percent of their shipments (by value) to foreign areas (Table 4).

Much of Texas manufacturing is located in the two largest metropolitan areas, Houston-Galveston and Dallas-Fort Worth, both in parts of the Trinity River basin. Combined, they account for almost 58 percent of the State's manufacturing value-added. Other major manufacturing centers include San Antonio, Beaumont-Port Arthur, Austin and El Paso. Resource-based industries

Table 4. Shipments and Employment Related to Industrial Foreign Exports; Texas Manufacturers, 1980.

SIC	Industry Group	Manufacturers's Shipments: Total a/	Direct Exports b/	Supporting Exports c/	Total Export Related d/	Total Export Related as % of Shipments
		(million dollars)				
20	Food & kindred prdts.	16,316.4	986.5	284.1	1,270.6	7.7
22	Textile mill prdts.	421.0	12.4	34.0	46.4	11.0
23	Apparel	2,610.7	71.9	113.2	185.1	7.0
24	Lumber & wood	2,380.6	105.9	143.8	249.7	10.4
25	Furniture & fixtures	717.8	9.5	6.4	15.9	2.2
26	Paper & allied prdts.	2,266.5	48.5	170.3	218.8	9.6
27	Printing & publishing	2,802.1	11.9	36.0	47.9	1.7
28	Chemicals & allied prdts.	27,065.1	3,238.3	3,306.2	6,544.5	24.1
29	Petroleum & coal prdts.	57,363.4	838.5	1,768.2	2,606.7	4.5
30	Rubber & plastics	2,212.6	75.6	171.1	246.7	11.1
31	Leather & leather prdts.	340.5	12.3	1.4	13.7	4.0
32	Stone, clay & glass	3,639.6	27.2	165.5	192.7	5.2
33	Primary metals	7,348.0	762.2	1,267.3	2,029.5	27.6
34	Fabricated metal prdts.	7,156.0	373.1	376.8	749.9	10.4
35	Machinery, except electric	12,397.7	2,464.9	524.7	2,989.6	24.1
36	Electric equipment	6,223.4	731.4	394.4	1,125.8	18.0
37	Transportation equipment	7,086.9	555.9	403.6	959.5	13.5
38	Instruments	956.6	112.0	30.7	142.7	14.9

a/ Value of shipments, domestic and export.
b/ Includes only the value of manufactured products exported by the producing plants.
c/ Includes shipments of components, parts, etc., used by plants producing the export product.
d/ Sum of direct and supporting exports.

SOURCE: U.S. Department of Commerce, Bureau of the Census. 1980 Annual Survey of Manufacturers. "Origin of Exports of Manufactured Products." M80(AS)-6.

such as paper, steel (and other metals) and natural gas processing plants are located near raw material supplies. Transportation facilities (ports, canals, highway and rail connections) determine the locations of much of the State's manufacturing activities. Nearness to markets and life style amenities for workers also influence industrial location decisions.

Texas in the National Industrial Context

Manufacturing output is a major part of total economic growth in many subregions of the State. However, in most industrial classifications, Texas does not have a share of national output that matches its population share (just over six percent of U.S. production). The following manufacturing industry categories in Texas produce more than six percent of respective U.S. output: chemicals (13 percent of the U.S. total value of shipments), petroleum products (26 percent), and cement and stone (over six percent). The rest of the industries (except textiles) which do not produce a proportionate share, have grown in national importance, however (Table 5). New defense contracts, let since 1977, are currently increasing the transportation equipment share, primarily due to military orders for aircraft.

More than 50 percent of the U.S. petroleum and petrochemical output capacity for products is located in Texas and the State's share of national output is growing. The dominance of oil and gas related production continues. In the fastest growing industry, electronics, the State's share of U.S. production is remaining about the rate shown in Table 5 for the 1972-1977 period. In 1980 just over 4.8 percent of the total U.S. industry shipments (SIC 36) were from Texas, an increase of 0.7 percent over the 1977 share.

Table 5. Texas Shares of National Output by Industry, 1972 and 1977*.

Two-Digit SIC	Industry	Percent of U.S. Value Added by Industry 1972	1977	Change
20	Food & kindred products	4.82	5.42	+0.68
22	Textile milling	4.20	0.85	-3.35
23	Apparel & other textiles	4.09	5.01	+0.92
24	Lumber & wood	3.58	4.35	+0.77
25	Furniture & fixtures	3.26	3.42	+0.16
26	Paper & allied prod.	2.62	2.99	+0.37
27	Printing & publishing	3.26	3.63	+0.37
28	Chemicals & allied products	9.84	12.89	+3.05
29	Petroleum & related products	23.10	25.55	+2.45
30	Rubber & misc. plastics	3.00	3.73	+0.73
31	Leather products	1.52	2.54	+1.02
32	Stone, glass & clay	4.85	6.05	+1.20
33	Primary metals	3.37	4.57	+1.20
34	Fabricated metals	4.05	4.91	+0.86
35	Machinery, except electrical	3.86	5.75	+1.89
36	Electrical machinery & equipment	3.07	4.09	+1.02
37	Transportation equipment	3.17	3.15	-0.02
38	Instruments & related products	1.67	2.32	+0.65
39	Misc. manufactured products	2.16	2.48	+0.32

* The 1977 data are the latest complete industrial reports available.

SOURCE: The U.S. Bureau of the Census. 1977 Census of Manufacturers, Texas and General Summary.

Recent Trends

Manufacturing production has grown at a much faster annual rate of increase in Texas than nationally. During the last decade, Texas' gross product originating from manufactured goods increased at an average annual rate of 5.6 percent, compared with a national rate of 2.9 percent (Table 6). The leading types of growth industries were rubber and plastics, machinery (primarily oil drilling-related), chemicals, and miscellaneous products. In terms of sectors which are outpacing the national growth, the leaders were electronics, stone, clay, and glass, rubber and plastics, machinery and miscellaneous manufactured products. The very fast growth rates of some sectors are due to a low base year output which quickly doubles and triples as new manufacturing facilities expand rapidly, such as in the semi-conductor part of the electronics industry. Lower growth rates for large-volume, older industries such as petroleum refining and primary metals still represent substantial volumes of product; however, except for the transportation equipment manufacturers, every sector grew at rates which increased real output by at least 32 percent over the past decade.

Since 1977, the fastest growth industries have been in electronics, oil field machinery and aircraft (Table 7). Electronics-related manufacturers (SIC 36 and the computer industry in SIC 35) increased employment by over 38 thousand in the three-year period. By 1980, semi-conductors (SIC 3674), oil field machinery (3533), aircraft (3721), electronic components (3679), and electronic computing equipment (3573) -- the five fastest growth industries employed about 19 percent of all manufacturing workers.

Water-using industries also showed recent growth, especially organic chemicals (SIC 2869) which added over 4.7 thousand employees since 1977; others include plastic products, cement and concrete, and miscellaneous food preparation. In general, however, the intensive water-using industries did not grow nearly so rapidly as low water-using industries.

Table 6. Historical Growth Rates for Two-Digit SIC Industries, Texas and National Comparisons, 1969 to 1979.

SIC	Industry	Annual Growth Rates, 1969-1979, in Gross Products Originating[a/] U.S.	Texas	Texas Difference
20*	Food & kindred products	2.58	4.17	+1.59
22	Textile milling	3.27	5.43	+2.16
23	Apparel	3.50	8.20	+4.90
24	Lumber & wood	3.42	7.48	+4.06
25	Furniture & fixtures	2.89	3.51	+0.62
26*	Paper	2.89	5.79	+2.87
27	Printing & publishing	1.32	4.10	+2.78
28*	Chemicals	4.81	7.43	+2.62
29*	Petroleum refining	3.71	2.79	-0.92
30	Rubber & plastics	3.50	9.29	+5.79
32	Stone, clay & glass	1.84	5.76	+7.60
33*	Primary metals	1.10	4.39	+3.29
34	Fabricated metals	1.67	6.14	+4.47
35	Machinery	4.07	9.90	+5.83
36	Electronics	4.41	3.67	+9.26
37 pt	Motor vehicles	3.71	1.66	--
37 pt	Other transportation equipment	3.10		
38	Instruments	4.14	4.72	+0.58
39	Misc. manufacturing	3.05	8.57	+5.52
	All manufacturing	2.89	5.61	+2.72
	GNP[b/] - GSP[c/]	3.12	5.13	+2.01

* Major water using industries in Texas

a/ Represents constant dollar value added and is the industry's contribution to GSP or GNP

b/ GNP - Gross national product for all industries and services

c/ GSP - Gross state product for all Texas economic activity

SOURCES: U.S. Department of Commerce. 1982 U.S. Industrial Outlook for 200 Industries with Projections for 1986. Bureau of Industrial Economics: Washington, 1982.

Plaut, Thomas R., Bureau of Business Research, University of Texas at Austin. Data provided were used in the Texas Economic-Demographic Forecasting Model (TEDFM).

Table 7. Leading Growth Industries in Texas by Employment, 1977 to 1980

SIC	Industry Description	Major 2-Digit Sic Group	Increase in Employment
3674	Semiconductors & related devices	Electronics	20,817
3533	Oil field machinery	Machinery	17,017
3721	Aircraft	Trans. Equip.	8,705
3679	Electronic components	Electronics	8,203
3573	Electronic computing euqipment	Machinery	7,230
2328	Men's and boy's work clothing	Apparel	7,009
3599	Machinery, n.e.c.*	Machinery	5,909
2752	Commercial lithographic printing	Printing & pub.	5,330
2869	Industrial organic chemicals	Chemicals	4,762 a/
3443	Fabricated plate work	Metal products	3,596
3444	Sheet metal work	Metal products	3,402
3079	Misc. plastic products	Rubber & plastics	3,166 b/
2711	Newspapers	Printing & pub.	3,103
3494	Valves & pipe fittings	Metal products	2,879
3731	Ship building & repairing	Trans. Equip.	2,868
3724	Aircraft engines & parts	Trans. Equip.	2,502
3743	Railroad equipment	Trans. Equip.	2,497
3273	Ready-mix concrete	Stone, clay, glass	2,264 b/
3448	Prefabricated metal buildings	Metal products	2,056
2099	Food preparations, n.e.c.*	Food	1,811 a
3823	Process control instruments	Instruments	1,722
3555	Printing machinery	Machinery	1,667
2339	Women's and misses' outerwear	Apparel	1,661
2352	Hats & caps	Apparel	1,653
3531	Construction machinery	Machinery	1,611
3579	Office machines, n.e.c.*	Machinery	1,604
3312	Blast furnaces & steel mills	Primary metals	1,553 a/
3693	X-ray apparatus & tubes	Electronics	1,399
2732	Book printing	Printing & pub.	1,389
3069	Fabricated rubber products, n.e.c.*	Rubber & plastics	1,375

* n.e.c. -- not elsewhere classified, or miscellaneous
a/ Among large water using industries.
b/ Among the moderate-to-large water using industries.

SOURCE: Texas Employment Commission.

By 1977, constant dollar capital expenditure by manufacturers increased by 2.7 times the total of 1972. Recent increases in announced plant locations have raised the rate of new plant and equipment additions, although data are not current enough to specify the totals of expenditures. On average, the rate of growth in capital expenditures in the five major water-using industries (food products, paper, chemicals, petroleum refining and primary metals) generally has been as high as the rest of the manufacturing industry; chemicals and petroleum refining have been higher, and food, paper and metals have been below the average for all manufacturing (Table 8). The most intense capital expenditure growth among the water-using industries was in chemicals (SIC 38), a magnitude of increase of 3.8 times the 1972 level of 1977 in constant dollars. However, an estimated 12 to 20 percent of the expenditures (depending upon the type of chemical product processes) were for pollution abatement equipment, which does not necessarily increase the volume of production capacity of the plants. Recent industrial expansion reports have indicated a slowing of plant and equipment expenditures in most of the major water-use industries.

In summary, recent growth trends are indicating substantial increases in the Texas manufacturing industrial base. Some water-using industries are contributing to the growth, yet low water intensive manufacturers are experiencing the most rapid expansions. The current strong growth, at a rate much faster than the national average, is a response to shifts in the geographic location of U.S. manufacturing and a sudden demand for oil and gas exploration products worldwide. As rapid population growth continues, the buildup of regional markets for Texas' industrial outputs will tend to diversify the composition of growth industries. The basic (first-stage) processing industries, traditionally strong in Texas, such as primary metals, petroleum

Table 8. Capital Expenditures of Major Water Using Industries in Texas, 1972 and 1977[a].

SIC	Industry	Intra-industry Ranked in Value Added, 1977	Capital Expenditures [d] 1972	Capital Expenditures [d] 1977	Relative to Value Added [c] 1972	Relative to Value Added [c] 1977	Adjusted Ratio of Change in Expenditures 1972 to 1977[d]	Capacity Expansion Ratio [e]
			(million of dollars)		(percent)			
20	Food & Kindred Products		109.5	251.9	6.4	8.3	1.62	1.30
201	Meat products	2	19.3	46.5	7.5	9.3	1.70	1.23
202	Dairy products	7	14.7	16.0	10.5	7.0	.77	.67
203	Processed fruits & vegetables	6	6.7	17.9	5.2	7.2	1.88	1.40
204	Grain mill products	5	13.6	33.8	6.5	10.7	1.75	1.64
205	Bakery products	4	10.4	15.7	5.8	4.5	1.06	.79
206	Sugar, confectionary products	9	3.4	14.4	6.2	14.1	2.99	2.29
207	Fats and oils	8	6.0	13.7	6.4	7.2	1.61	1.11
208	Beverages	1	23.3	72.8	6.6	10.2	2.20	1.54
209	Miscellaneous food products	3	12.1	21.1	4.1	5.4	1.23	1.33
26	Paper & Allied Products		57.7	178.2	16.9	26.9	2.18	1.59
262	Papermills, except building paper mills	3	12.1	66.6	12.6	41.6	3.88	3.30
263	Paperboard mills	4	6.5	64.7	12.8	41.6	7.02	3.28
264	Miscellaneous converted paper, except containers & boxes	2	32.8	15.2	39.2	8.9	.32	.22
265	Paperboard containers & boxes	1	6.1	31.7	5.7	18.0	3.67	3.18
266	Building paper	f/	.2	f/	5.4	f/	f/	f/
28	Chemicals & Allied Products		414.3	2269.2	13.0	31.0	3.87	2.39
281	Industrial inorganic chemicals	3	45.6	146.6	21.2	33.6	2.27	1.58
282	Plastics materials, synthetic fibers & other synthetic materials	2	62.9	435.0	13.2	44.3	4.88	3.36
283	Drugs	8	2.2	6.5	6.0	5.7	2.08	.95
284	Soaps, cleansers & other toilet preparations	6	5.3	6.1	4.2	3.3	.81	.78
285	Paints & allied products	7	3.4	38.8	3.3	21.7	8.05	6.55
286	Industrial organic chemicals	1	274.8	1480.1	14.0	31.1	3.80	2.22
287	Agricultural chemicals	5	10.5	124.3	9.0	38.7	8.35	4.29
289	Miscellaneous chemical products	4	9.6	31.8	6.3	9.7	1.08	1.54

(continued)

Table 8. Capital Expenditures of Major Water Using Industries in Texas, 1972 and 1977[a/] (continued).

SIC	Industry	Intra-industry Ranked in Value Added, 1977	Capital Expenditures [b/] 1972	Capital Expenditures [b/] 1977	Measures of Capital Expenditures: Relative to Value Added [c/] 1972	Relative to Value Added [c/] 1977	Adjusted Ratio of Change in Expenditures 1972 to 1977[d/]	Capacity Expansion Ratio[e/]
			(million of dollars)		(percent)			
29	Petroleum & Coal Products		190.3	1031.7	14.2	24.72	3.82	1.73
291	Petroleum refining	1	187.4	1021.5	14.7	25.1	3.84	1.70
295	Paving and roofing		1.5	6.2	3.0	6.9	2.92	2.28
299	Miscellaneous petroleum & coal products		1.4	4.0	9.7	20.5	2.01	2.11
332	Primary Metals	--	81.1	288.2	10.3	16.8	2.51	1.63
331	Blast furnaces, steelworks	2	36.8	175.2	11.4	30.0	1.86	2.62
332	Iron & steel foundries	3	7.5	18.0	6.6	9.1	1.69	1.38
333	Primary nonferrous metals	1	27.8	75.0	11.5	10.3	1.90	.90
334	Secondary nonferrous metals	5	1.2	5.4	4.3	15.1	3.18	3.52
335	Nonferrous rolling & drawing	4	5.6	6.6	9.9	6.1	.83	.62
336	Nonferrous foundries	6	.8	2.4	7.5	6.7	2.12	.90
339	Miscellaneous primary metals	7	1.4	5.6	13.2	22.4	2.82	1.70

a/ Capital expenditures are the annualized total value of plant and durable equipment purchased.
b/ Expenditures are in current dollars for both years.
c/ Capital expenditures as a percent of current dollar value added for each year. This is a measure of the productive capacity expansion relative to the production of the industry. Higher values indicate an expansionary posture for the industry.
d/ The 1972 to 1977 ratio of change in real capital expenditures, calculated by deflating the 1977 values by the GNP implicit price deflator.
e/ The change in capital expenditures divided by the change in value added. A value near 1.00 indicates an industry with a stable trend in production capacity expansion; higher or lower than 1.00 indicates accelerating or decelerating capacity expansion, relative to historical output.
f/ None reported.

SOURCE: U.S. Bureau of the Census. 1972 Census of Manufacturers and 1977 Census of Manufacturers, Texas.

refining and paper are not anticipated to share in continuing growth. Each of these industries are discussed individually in the following sections of this report.

ANALYSIS OF WATER USE BY THE MAJOR WATER USING INDUSTRIES

In Texas manufacturing water use is concentrated in five industrial groupings: chemicals, petroleum refining, paper, primary metals, and food products, in decreasing order of water use volumes. Each major water using industry in Texas has economic characterisics which impinge upon the future prospects for use of water. Since as much as 90 percent of industrial use is accounted for by these manufacturers, a detailed analysis of their future growth potential is necessary in order to accurately project total State industrial demands. Methods which ignore the realities of the international economic context in which these industries exist will not produce realistic or acceptable results.

In the following sections rationales behind the Department's water use projections are given. These take account of future growth prospects analyzed by industry experts, industry-specific literature, very recent detailed analyses completed by the U.S. Bureau of Industrial Economics, and other information specific to Texas industry.

Projection methods and assumptions were different for each industry. These are discussed, along with the resulting estimates of volumes of water required in the 50-year planning period of 1980 to 2030.

Processed Foods and Beverages (SIC 20)

More than 1500 establishments process food products in Texas, 35 percent are very small plants of less than five employees, 25 plants are large operations, employing over 500 people. The industry employs almost 89 thousand people. Food processing as a whole is widespread but there are concentrations of plants in the population centers near consumer markets (Fig. 3). SIC 20 includes all establishment manufacturing converted agricultural produce, from meat to candies, and establishments producing beverages. The largest component industries in value added are beverages and meat products, accounting for over 40 percent of annual projection in the industry.

The industry is classified as one of the five major water-using industries, but is the smallest of the group, using only about 20 percent of the total water volume in chemicals, the largest. Water is necessary in the industry for washing, cooling and consuming as part of the product.

Industry Description

Types of processing vary, depending upon the product, but the processes generally involve cleaning, cooking, packaging and delivery. Beverages production requires incorporation of large portions as part of the product. Use of capital, labor, energy and water per unit of product also vary widely.

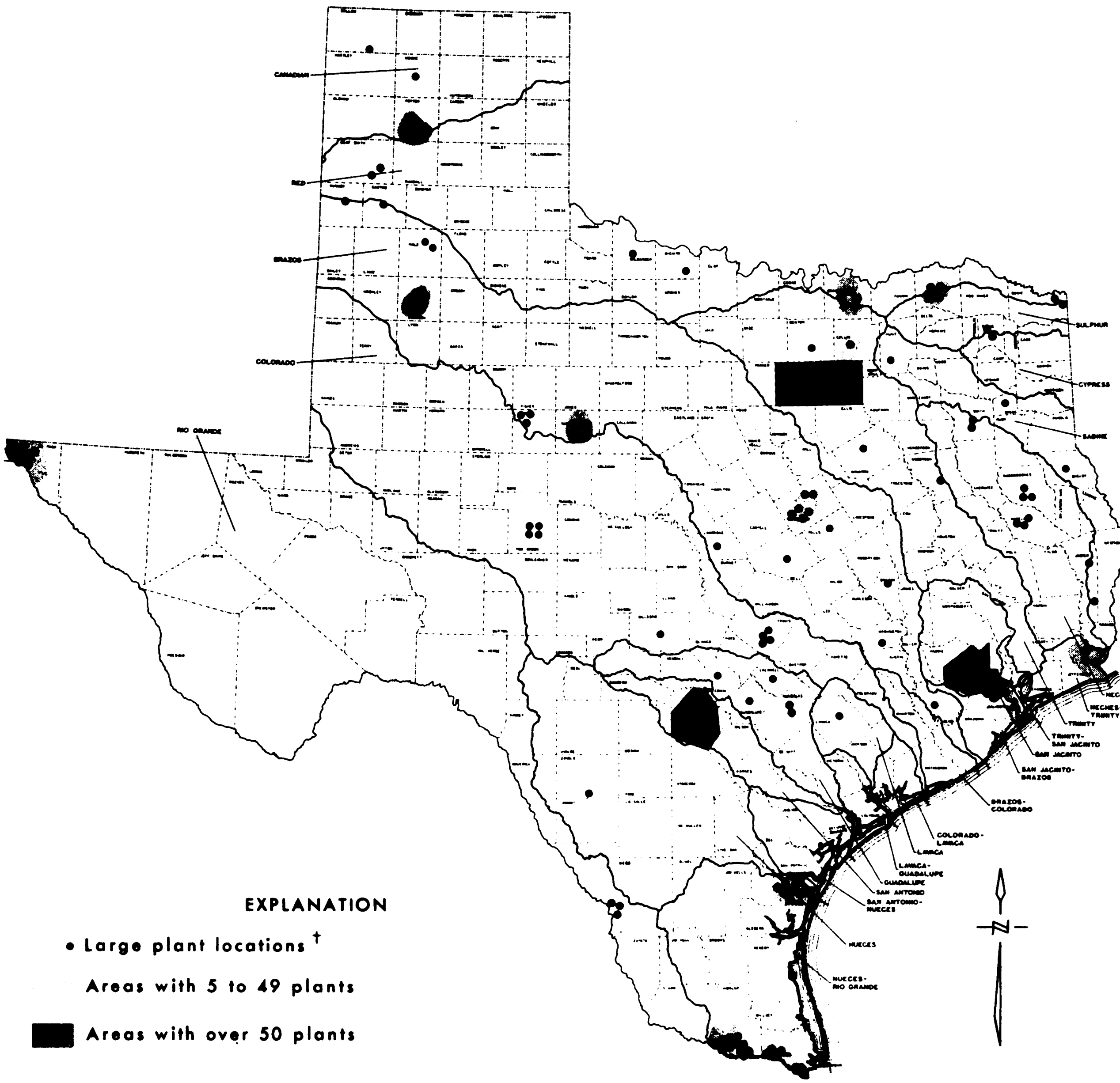
Because of antiquated processing practices, many plants require expensive renovations to remain competitive. Most operations have long-standing ties to the State's extensive wholesale distribution system either as part of their organization (vertical integration) or by business ties.

Economic Characteristics

Almost 60 percent of the industry's products are for direct personal consumption, the rest are for further processing. The industry product demands are thus subject to changes in consumer tastes, the total population, age

Figure 3

Locations of Food Processing Establishments (SIC 20)*



†Plants with over 100 employees in areas outside of concentrated processing activity

*Plants with over 20 employees

(and other) characteristics of the population, and income levels. Only about two percent of national food production is exported to foreign markets, yet Texas producers export about seven percent of their output (mostly meats).

Demand for food is generally non-cyclical, therefore processors are able to maintain sales and profits during economic slowdowns. Profit margins are generally quite low compared with other industries, averaging around three percent (compared with five percent for all manfuacturing). Rising farm product prices heavily affect some but not all food industries. Many processors cannot absorb large cost increases for farm product raw materials, so they are usually recovered by higher food prices. The meat industry is especially sensitive to livestock prices.

Markets for Texas processors are generally within neighboring states. However, several larger firms have market areas extending throughout the nation. Projections of population growth in the Texas and nearby states will determine the future growth of most of the industry.

Meat products (SIC 201) use the most water, followed by beverages. These manufacturers face very different market structures. The meat industry exports much of its output for national distribution to consumers or to third-stage industries in other states for further processing. Beverage markets are located primarily within the State but also in nearby states, following population distributions.

Recent Trends

Since 1975 the national food processing industry has not grown appreciably because per capita food consumption has remained almost constant, while population growth has not increased rapidly. In Texas, however, rapid population increases have benefitted the industry greatly. From 1974 to 1980 value-added in SIC 20 increased by 42 percent in constant dollars in Texas. Employment in the industry increased by ten percent, as state population increased by 20 percent. The output performance of the industry is better than the national average in most respects due to regional market strength. New plant locations in recent years are following national demographic shifts -- the general migration away from the north and northeast to Texas and other southwestern states.

There was a decline in per capita meat consumption in the U.S. of about four percent from 1976 to 1980. High prices, erratic supplies, consumer preferences for and availability of substitute protein sources have contributed to the decline. The industry has been plaqued by plant closures because of low plant utilization rates during periods of low cattle slaughter. Foreign imports of red meat products have doubled in value since 1972.

The beverages category (SIC 208) consists of alcoholic and non-alcoholic products. The average, per-person consumption of alcoholic beverages in the U.S. has risen steadily in the last 20 years; shipments increased at a compound rate of 4.5 percent a year from 1972 to 1981. In Texas the growth rate in shipments has been about one percent a year higher than the national rate. Increased consumption of beer among younger age grups is contributing largely to growth of the industry; per capita consumption by all ages groups is trending upward at a two percent rate. National production continues to be dominated by a few companies. Foreign imports of malt beverages are increasing.

The bottled and canned soft drinks industry (SIC 2086) operates under a franchise system which tends to spread the industry over the entire market area. This system has not changed since the early years of inception. Even though consumption of soft drinks is increasing at a rate similar to the nation's economic growth, the trend in per capita consumption is lower than past years.

Long-Term Outlook

Projections show that the food and beverage industry in Texas is expected to increase output faster than the national average growth rate. Most of the industry will grow at slightly above the population growth rate for the State. No major increases in market demands outside the Southwestern U.S. are anticipated. Producers in foreign countries and other states are expected to offer enough competitive pressure to inhibit strong market expansion.

Over the long term, increases in the average age of the population will tend to lessen the per capita demand for food and beverages because of a generally lower amount of food consumption by older age groups compared to younger persons. This will cause a slackening in output by food processors since exports of products are not anticipated to grow.

The outlook for meats is for a slowing of growth and potential flattening of demand. Total consumption of red meat products is beginning to be affected by consumer preference for substitute sources of protein which causes declines in the current production growth rate; future rates are projected at about one percent annual growth.

Projection Data and Method

The series of growth projections used for low water-use manufacturers included SIC 20 estimates; these were adopted. The rates for food products industries were judged against population projections growth rates and were then accepted as reasonable. Total output of food processors is expected to triple by the 2030 (50-year) planning horizon, while population in the State is projected to more than double.

Projected Water Requirements (SIC 20)

Industrial water requirements for the food and kindred industry totaled 110.2 thousand acre-feet in 1980. Water requirements for the industry are projected to increase at an annual rate (compounded) of 2.3 percent to the year 2000, resulting in an increase over present annual use of 65.0 thousand acre-feet. By the year 2030, approximately 328 thousand acre-feet of water requirements by the industry are estimated, representing an increase of 217.9 thousand acre-feet of annual use; food product industry use will be an estimated 7.5 percent of the State's projected total of industrial water requirements.

Water Requirements (SIC 20)
Food and Beverages

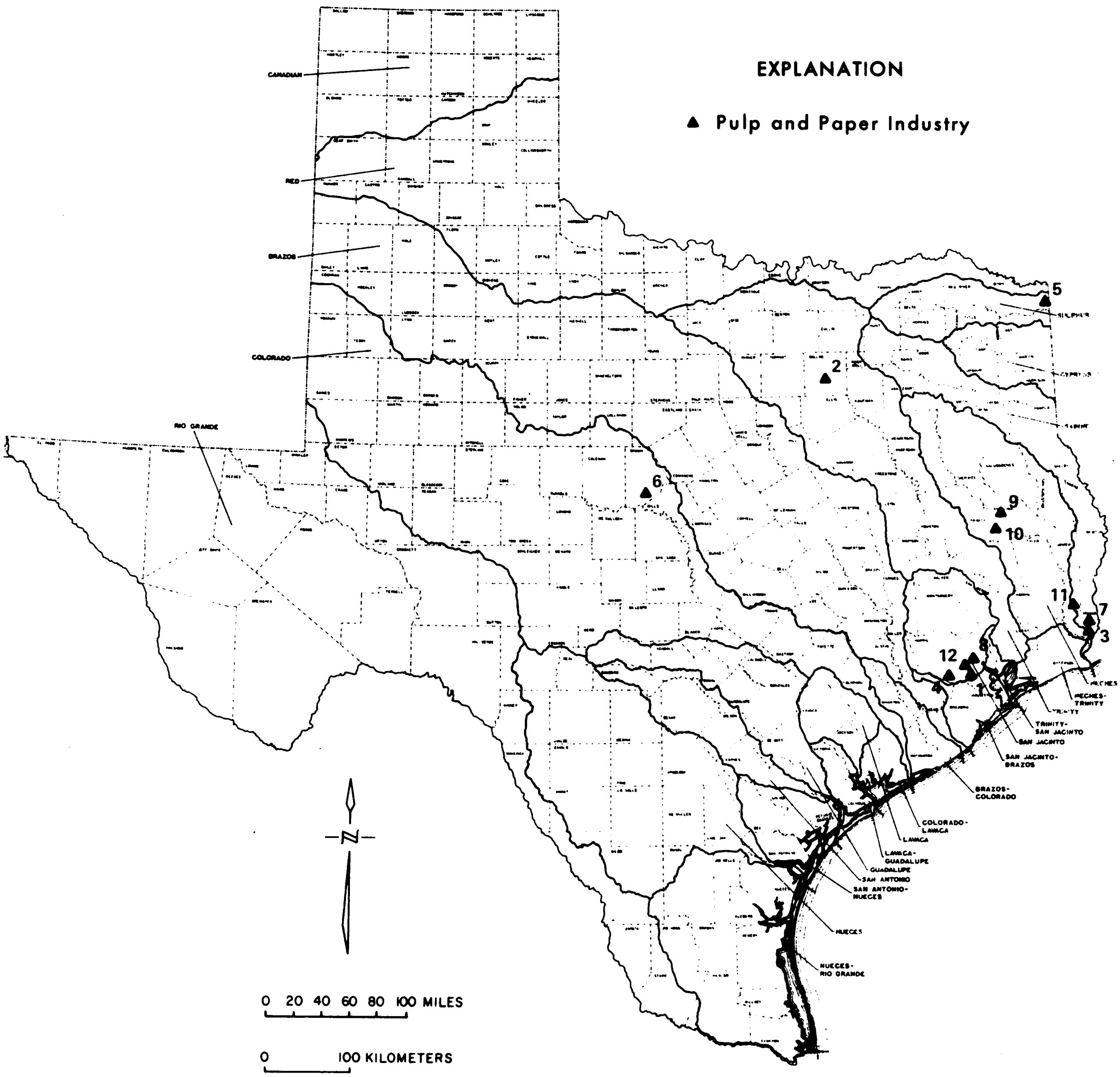
1980	1990	2000	2010	2020	2030
		(thousands of acre-feet)			
110.2	138.4	175.5	116.5	267.5	328.2

Paper Industries (SIC 26)

The Texas paper industry is located entirely in the eastern portion of the State (Figure 4). The classification includes paper mills, converted paper product mills (such as gummed paper), paperboard container factories and some small producers of other types of paper products. Employment in paper production is 21 thousand workers. Industries in SIC 26 are large users of

Figure 4

Pulp and Paper Industries in Texas as of January 1, 1980



water, both in terms of use per unit of production and in total volume of use, since production processes involve transporting large amounts of soluble wastes from cellulose fiber or carrying insoluble pollutants for disposal. Water is also used for cooling, boiler feed, vacuum seals and sanitary purposes.

Industry Description

SIC 26 is divided by types of paper processing. The industry is typically vertically integrated, from marketing of final products to the primary woodcutting stage. There is pulp-making in Texas plants but the plants which have pulping operations are classified as paper manufacturers, based on the various types of finished or intermediate paper product which frequently masks pulping as a separate activity. Some companies are also engaged in coal, oil, and natural gas extraction on their land holdings, producing auxiliary revenues. There are six very large companies which account for most of the State's output in SIC 26.

The industry tends to grow at rates similar to the general economic growth in national output because of the wide spectrum of end products. For example, when demand for some types of paper, such as packaging is down, other types such as household towels may be in higher demand. Most pulp and paper outputs in Texas are related also to the general health of manufacturing activity, not only within the State but also nationally, and to a small extent internationally. Sectors such as building papers respond to the construction activities within the Southwestern region of the U.S. Since 1973, the industry in Texas has tended to grow at a slightly slower rate than Gross State Product.

Outputs by end-product classifications, noted by three-digit SIC, are about equally divided among paper mills (SIC 262), at 24 percent of total value-added in the industry; paperboard mills (SIC 263), 24 percent; converted paper products (SIC 264), 26 percent; and paperboard containers (SIC 265), 26 percent.

National Context of the Industry

Nationally, shipments of pulp and paper products industries totaled $82 billion in 1981. Shipments data are somewhat misleading, however, since the outputs of primary products (pulp/paper and board mills) serve as inputs to downstream segments of the industry and their value are included in finished product prices. Since 1945, the industry's primary productive capacity has been progressively concentrated in large new mills in the South. These mills are strategically located near the southern pine forests which serve as raw material for packaging and lower grades of paper needed in building and industrial operations. About 50 percent of the nation's pulp and paper industry is in the southern U.S. The next stage of processors, after milling, are converters of processed paper; these tend to locate near markets because of distribution economies.

The industry has been especially sensitive to progressively stricter clean water standards from all levels of government. The addition of toxic waste treatment and pollution abatement equipment has added increased capital costs to most plants. Paper producers are already increasing capital expenditures for the next set of clean water standards, due in 1983. Increases in long-term operating costs will tend to exert a slowing effect on the growth in paper production capacity even with a healthy product demand, since a portion of funds available for product output expansion will instead be used for required environmental pollution control equipment. International markets are developing rapidly because of the lower relative cost structure (even with pollution controls) in the U.S. than in foreign countries. The recent profit performance of the industry has been healthy, with the sales-to-net-fixed-assets ratio remaining in the 2.20 to 2.27 range since 1972 and net profits running from four to seven percent of sales. Industry growth rates in value of shipments averaged a 2.1 percent annual increase in the 1972-81 period.

Paper production in Texas is relatively unimportant in the national context. Shipments in 1980 accounted for 3.1 percent of the U.S. total for SIC 26. Texas' national share has increased slightly in recent years -- the 1977 U.S. Census of Manufacturers reported the Texas position was 3.0 percent of national shipments. Within the industry there are different concentrations of the national share in productive output. For example, Texas mills accounted for 3.7 percent of national shipments in paperboard containers and boxes (SIC 264), only 2.4 percent of converted paper products such as stationery or gummed labels, and over 4.7 percent of shipments in corrugated and solid fiber boxes (SIC 2653).

The markets for the Texas mills do not normally extend outside the southwestern region, yet an estimated 9.6 percent ($218 million in shipments) of Texas paper production is exported to foreign markets. Nearness to available timber resources is the primary reason for historical growth of the industry in Texas. Another important factor is ready availability of water supplies. Forests in East Texas are not a major supply area relative to the major national resources, located in the southeastern and northwestern parts of the U.S.

Recent Trends

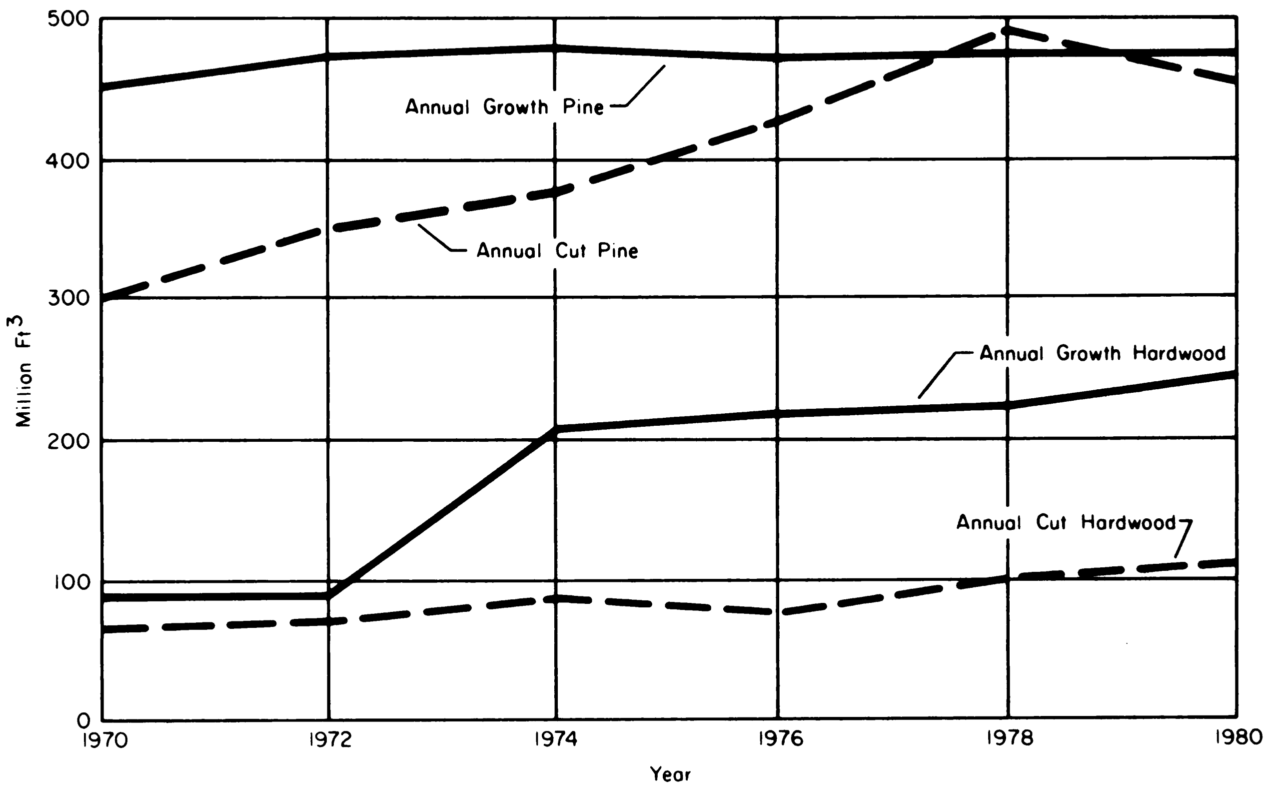
Demand for Texas paper products has been maintained in the past decade because of an increasingly productive industrial base, population growth in the market area for Texas paper products and the ability of producers to deliver product in this market area quicker and relatively cheaper than can competitors in the rest of the nation and world.

In 1978, the realities of the resource limits which impinge on this industry's future in Texas became evident. Since then the harvest-to-growth relationship tilted on the harvest side: more pine was harvested than was being grown (Figure 5). However, the smaller amount of hardwood cut remains less than annual hardwood growth. Only a slowdown in harvesting can reverse the eventual depletion of timber resources if no improvements in the timber supply are made. The trend for new timber production is relatively flat, however.

As in the rest of the nation, Texas paper manufacturers increased capital expenditures during the late seventies. Although most of this expenditure was for increasing production capacity, a measurable portion (10 to 20 percent) was for pollution abatement which does not generally increase the output capacity of the plants.

Employment in the industry increased by only 2,200 from 1972 to 1977 and by 1,200 from 1977 to 1980, from a 1972 total of 17.6 thousand, showing the capital-intensive nature of the industry, since real value of product increased about 30 percent faster than employment during the period 1972 to 1980.

Figure 5.—Growth-Harvest Relationship for Pine and Hardwood in Texas, 1970-1980



Long-Term Outlook

Considering the structure, market orientation, and resource base for this industry, the Department concluded that future constraints on growth in paper production in Texas are indicated. The industry is unique to other manufacturers in that its long-term future can be predicted much more accurately by fully considering the future supply of timber resources. The future volume of raw material within the economical harvest area of existing and proposed mills can be calculated by accounting for the growth and life spans of trees and acreage available for planting.

Recently the harvest of timber has begun to outpace replacement needs. The demand for Texas paper product is relatively strong and steadily increases. Productive capacity is continuing to be added, increasing the annual cut of timber. These forces lend even more pressure to a negative harvest-to-growth ratio, shortening the long-term supply of raw material. Faced with dwindling total supplies, paper mill operators cannot afford to import raw timber from distant forests -- the industry locates in heavily forested regions to minimize costs for timber.

Thus, the long-range outlook is for a decreasing growth in output for SIC 26. An anticipated growth in production at a rate slower than gross output for the entire Texas economy is projected until 2000. Then, resource limitations cause the industry to grow at a much slower pace, with output growth relatively constant each year until 2030.

Projection Data and Methods

The Department's reviews of industry data and information from forest research organizations showed that softwood production for paper and all other uses will increase in response to available processing capacity and product demand from 427 million cubic feet per year (mcf/yr) in 1980 to about 525 mcf/yr in 2000 and to 650 mcf/yr in 2030. The resource depletion assumed by these rates of growth is zero, that is, in each year the use (cut) of softwood for paper and other purposes is allowed to match available growth. Hardwood production for pulpwood is assumed to increase from 50 mcf/yr in 1980 to about 200 mcf/yr in 2030, due to the increasing cut of hardwoods anticipated in the longer term.

Use of wood for paper, as opposed to other uses, is anticipated to increase from 69 percent of the harvest to 75 percent by 2000 in response to the projections for stronger general economic conditions in Texas and other Southwestern states, well into the later years of the planning period. Product demand will be strong enough to allow full capacity use. Pulp and paper mill demand will be strong enough to allow full capacity use. Pulp and paper mill additions will include two new large-capacity mills in Jasper and Newton Counties. Other expansions will occur at existing mills. New plants are likely to operate more efficiently; expected water use per ton of pulp for bleached kraft varieties of paper is 19,000 gallons after the year 2000, compared with 20,000 gallons currently. Similar conservation factors were assumed for other product types. The use of recycled wastepaper is not assumed to increase over current levels at Texas mills in view of the types of future products which cannot use it in production processes and costs of supplying it to the mills.

The growth rates for industrial production from pulp and paper operations are substantially higher in the 1980-1990 decade than those for the longer term. Currently, the industry's production increases about four percent a year, yet industry spokesmen report plants running at less than full capacity, at an estimated 80 percent. Thus, the 20 year projections of growth in output are higher than depressed growth rates currently, because of both the anticipated rebound in consumer and industrial demand for paper products (especially in building and packaging) and the growth in output necessary to return to full capacity use. The projected compound rate of increase in paper production is about four percent a year from 1980 to 1990, slowing to two percent as 2000 approaches. Thereafter, industry output is affected by the resource and market competition restraints discussed earlier.

The paper and board industry will respond to export markets in addition to growing domestic markets. The product lines of Texas producers will follow national trends, toward more business papers and packaging materials. Substitutions of plastics for packaging has reached a near saturation of its potential, according to industry analysts. In the very long term (30 to 50 years), electronic telecommunications will surely pose a more serious threat to paper demand, nationwide. Texas productive capacity will be shifted away from printing papers towards more business forms, product packaging, and paper-based building materials.

Requirements for heavy capital spending for pollution controls, energy conservation and raw materials will accelerate industry efforts to employ alternative process technologies which use less water and energy. Water use conservation can be expected to improve appreciably in this industry. This, coupled with product output slowing to 0.9 percent growth annually, will reduce long-term water requirements in 2030 to only 6.5 percent more than the 2000 level, a small increase over the 30 years. However, by 2030 the paper producers then in operation will still require 30 percent more water a year than present use.

Projected Water Requirements

Projections of water use to 2030 show that the growth rate in production of pulp and paper products will increase at an annual rate of about two percent through the year 2000, then slow to 0.9 percent, a rate much slower than the overall Texas Gross State Product or rates for most other manufacturing industries. However, even with resource limitations the total capacity of the industry should double its 1980 level by 2030 (Table 9).

The Neches River basin requirements for water use in paper production from major mills are the largest and should also add the most capacity by 2030. The statewide additional water use in 2030 is 72 thousand acre-feet which is an increase of 38 percent over the 1980 base year total, a relatively slow increase of 38 percent over the 1980 base year total, a relatively slow increase compared to other recent years.

Table 9. Pulp and Paper Capacity and Water Use Projections (SIC 262 and 263), 1980 to 2020 by River Basin of Major Paper Mills

Production by River Basin	Year 1980	Year 2000	Year 2030
Capacity (tons per day)			
Sulfur	1,200	1,500	2,500
Sabine	1,200	2,850	3,700
Neches	4,130	6,400	9,100
San Jacinto	2,250	2,250	1,700
Total	8,780	13,000	17,000
Water Use (1000 acre-feet per year)			
Sulfur	34.0	40.0	55.0
Sabine	14.7	44.0	57.0
Neches	84.5	105.0	137.0
San Jacinto	55.8	56.0	22.0
Total	189.0	245.0	261.0

The effects of diminished timber resources, and an anticipated improvement in water conservation, from technological advances, results in the small future increases which would be substantially larger were it not for the anticipated declines in available timber supply.

In 1980, water use for all segments of SIC 26 totaled 193.8 thousand acre-feet, or approximately 13 percent of the State's total industrial water requirements. Annual water requirements are projected to increase by 57 thousand acre-feet by 2000, and 28.1 thousand acre-feet in 2030; a water-requirement growth rate of 0.4 percent per year over the 30 year period.

Water Requirements (SIC 26)
Pulp and Paper

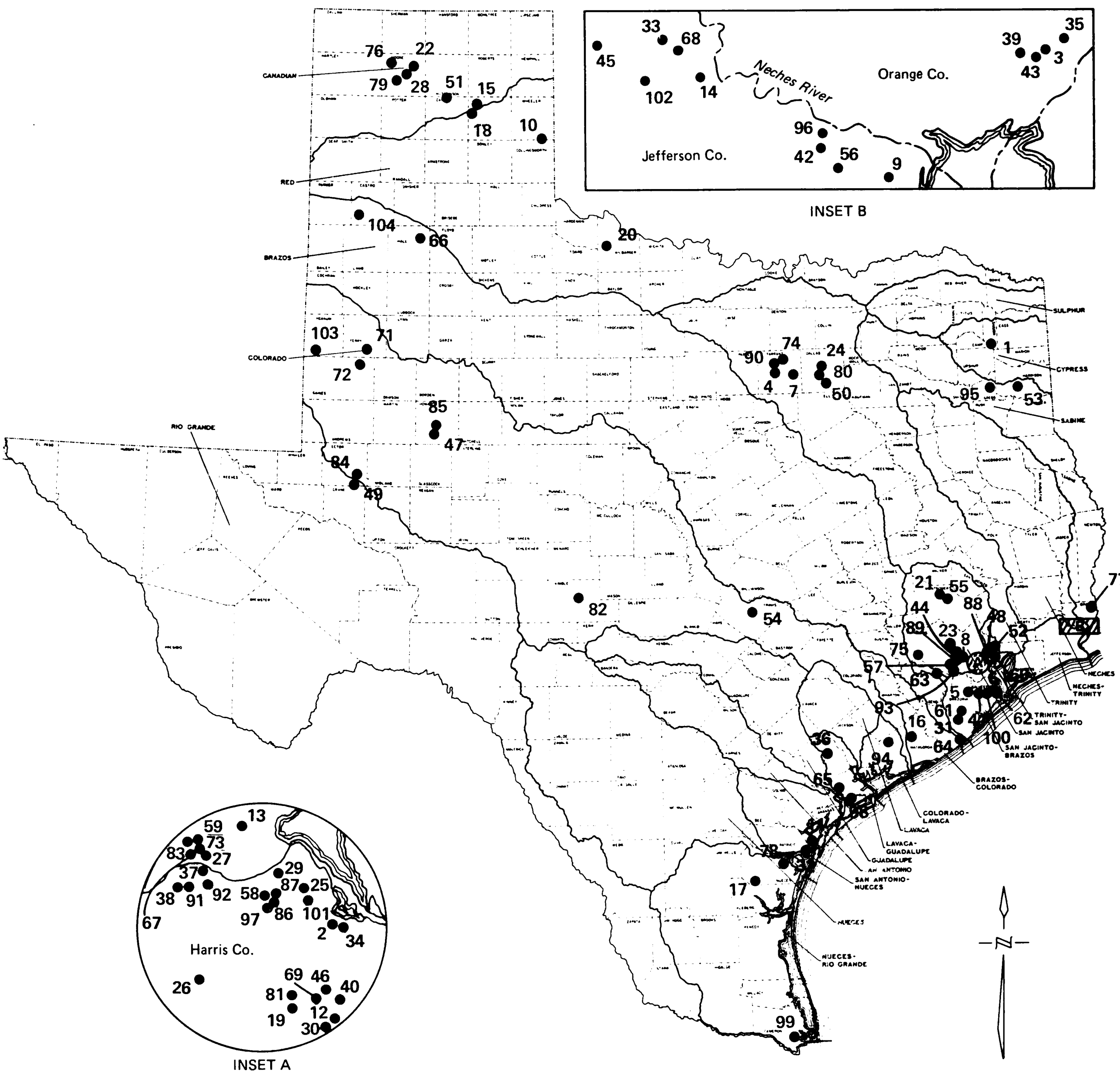
1980	1990	2000	2010	2020	2030
(thousand acre-feet)					
193.8	228.4	250.8	237.6	258.2	278.9

Chemicals (SIC 28)

There are 104 major chemical plants in Texas, mostly concentrated in large production complexes in Harris, Brazoria, Jefferson, Orange, and Galveston Counties. The industry employs over 80 thousand people. Other plants are located near natural gas and refinery feedstock suppliers in the High Plains area, the Coastal Bend and in North Texas (Figure 6). Thousands of different products are included in the SIC 28 classification. These are organized according to categories of chemical composition industrial organics, synthetic plastics, drugs, soaps, paints, inorganics, agricultural chemicals, and other miscellaneous chemicals. Texas' production of chemicals is

Figure 6

Major Chemical Industries in Texas as of January 1, 1980



0 4 8 MILES

0 8 KILOMETERS

SCALES FOR INSETS A AND B

EXPLANATION

• Chemical Industry

0 20 40 60 80 100 MILES

0 100 KILOMETERS

dominated by petroleum-based derivatives; the largest volumes are industrial organic chemicals (SIC 2869) and plastic materials (SIC 2821). These account for about 70 percent of the total value-added in SIC 28. Production of inorganic chemicals (chlorines, alkalies and industrial gases) is responsible for six percent and agricultural chemicals, four percent of the total industry value-added.

Water use is essential to the production processes in the chemical industry. Currently, and in recent years, the industry is the largest user of water, by total volume, of all industry classifications.

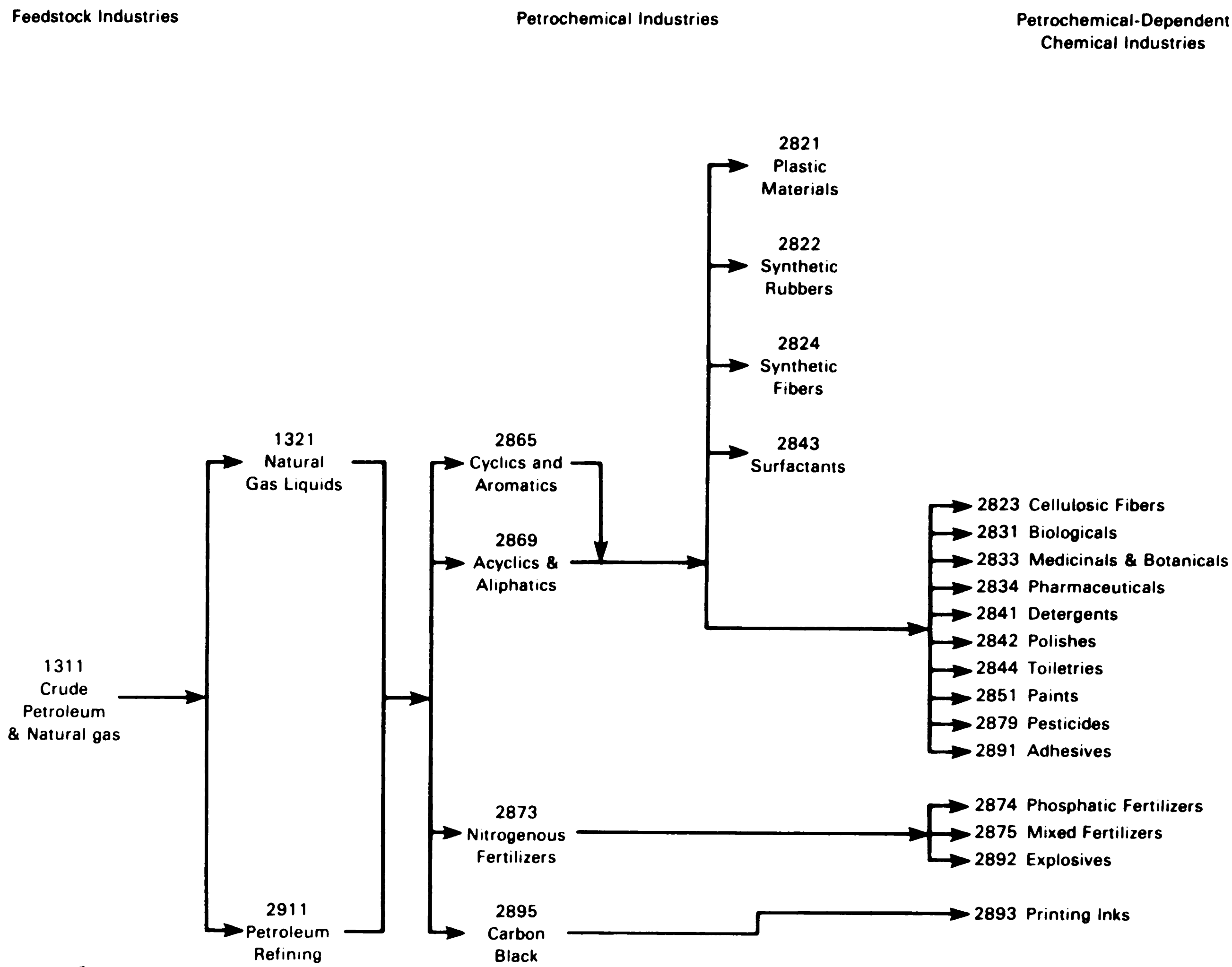
Industry Description

Petrochemicals, the dominant part of Texas' chemical industry, include primary (first-stage) materials, intermediates, and bulk materials for further fabrication that are petroleum derivatives. About 20 primary petrochemicals serve as the basic building blocks for hundreds of intermediates, which then serve as materials for the production of an almost unlimited variety of end products. Intermediate products include synthetic rubber, plastics, synthetic fibers, surface active agents and nitrogenous fertilizer materials. Fabrication by other industries produces tires, plastics, textiles, detergents, fertilizers and thousands of other derivative products.

Eight four-digit SIC sectors are properly described as petrochemicals. Fourteen industries are dependent upon output from petrochemical manufacturing (See Figure 7).

The high degree of dependence upon petroleum refining and natural gas processing, as feedstock suppliers is evident from Figure 7. The chain of production, from crude oil to semi-finished products is shown, yet there are thousands of chemicals produced that can be classified in these sub-sectors.

Figure 7.—Petrochemical Inter-Industry Relationships



U. S. Department of Commerce
Bureau of Industrial Economics

These dependencies result in manufacturing establishment locations of supplier-user clusters, creating local areas of concentrated, large water demands, since both the feedstock producers and the chemical producers are largely water-intensive industries. The immense diversity of products renders summary analysis of the entire industry difficult, since production of one variety of product could influence the ability of its dependent, next-stage producer to operate.

Industrial organic chemicals (SIC 286), the largest part of the industry, provides the first-stage processed materials for an extended chain of processing. The producers of cyclic, acyclic and aromatic organic chemicals are constantly engaged in new product development because of the almost unlimited possibilities for chemical combinations and uses. As the basic materials for the vast array of end products, organic chemicals in substantial volume are usually necessary for economic operations in even indirectly related establishments.

The nature of the processing chain encourages vertical integration of business management within the broad category definition of the industry, from feedstock processing (SIC 286) to products such as explosives, detergents or medicinal materials. For instance, one Texas chemical company also operates a petroleum refinery as an assurance of feedstock supply for its chemical processing operations.

The inorganic chemicals products (SIC 281) consist of acids, chlorines, alkalies, caustic soda, industrial gases and other inorganic derivatives. The major markets for inorganic chemical production from Texas plants are in oil field drilling activities where secondary and tertiary recovery techniques make use of a wide range of products including caustic soda, nitrogen, and hydrochloric acid. Other examples of use are materials for fertilizer production, animal feed supplements, paper processing, electronics, aerospace industries, and primary metals production. Almost every industrial process uses some materials from inorganic chemical derivatives.

Plastic semi-processed materials (not finished products) are intermediate organic chemicals from which synthetic resins and other chemical products are manufactured. This part of the chemicals industry, SIC 282, depends upon petrochemicals. Products include polyethylene, polystyrene, polyesters, epoxy, acrylics, synthetic resins and other derivatives. End products which use these materials are very numerous, typically paints, adhesives, inks and especially plastic products which can be incorporated into almost unlimited varieties of manufactured goods.

Agricultural chemicals (SIC 287) include fertilizers and pesticides. The fertilizer industry produces nitrogenous, phosphatic and potash fertilizers. They are the primary plant nutrients. The basin nitrogen chemical is ammonia made from natural gas and nitrogen, potassium comes from potassium chloride and phosphorous is from phosphoric acid made from phosphate rock and sulfuric acid. Other segments of the chemical industry supply process chemicals necessary in fertilizer production. As an inorganic chemical derivative, the processes for making fertilizer require inputs of capital, labor, materials and water similar to the organic processes. Pesticides are generally produced as offshoots to other chemical processes. Their production is generally not confined to any one or several geographical areas, but is widespread. Ninety percent of production is divided equally between insecticides and herbicides, fungicides account for the remaining ten percent of pesticide outputs. Only a small part of production depends on mineral resources; most is based on multistep processing of synthetic organic material, largely based on petrochemical outputs. There are over 275 varieties of pesticides.

Economic Characteristics

The chemical industry is capital intensive, energy dependent and, considering the dollar value output, volumes of product and extent of raw materials required, is low in manpower needs for units of product compared to other industries. In general, the industry operates most efficiently at high levels of capacity use. It is well diversified in type of product, characterized by intensive research and development programs which serve to insulate against the sudden shifts in product demand, market competition, or feedstock supply difficulties. New product development is essential to future growth because rapid changes in consumer tastes can quickly curtail product demand. In the last decade expenditures for developing new products increased at a nine percent annual rate, totaling over $4 billion for 1980. The extensive product lines of the industry make it vulnerable to general economic conditions, yet parts of the industry can increase output while the total production of SIC 28 is decreasing. For example, plastics which are widely used in durable consumer goods have recently been in a declining demand market, while output of chemicals used in drilling has soared. In projecting growth rates of the industry it is necessary to determine which components are responsible for increases or decreases and to identify specific markets for those components.

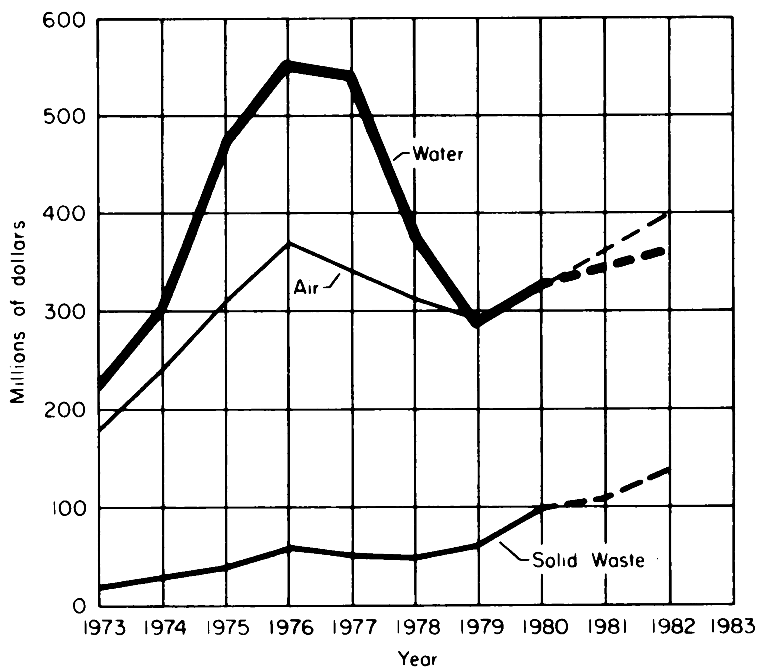
Chemical products are subject to extreme fluctuations in price due to shifting market demands, capital and variable cost changes and feedstock supply bottlenecks. Price changes in refined petroleum and natural gas liquids have a direct impact on the cost-price relationship of the industry. Of the refinery products, gasoline prices are the primary determinant of naptha feedstock prices, for example. Costs of refinery products and energy costs for processing are absorbed by chemical manufacturers to a degree that tends to adversely affect the industry's profitability, since product markets are competitive and subject frequently to sudden declines in demand. Stability in processed oil and gas prices is largely responsible for profitability in the industry.

Chemical and allied industries are heavily influenced by government environmental and trade regulatory agencies. Petrochemicals are directly influenced by 18 regulatory programs and indirectly by ten others. The major regulatory issues that impact output of the industry fall in five areas: hazardous waste disposal, technological developments, product testing, product liability, and pollution control. Hazardous waste disposal sites are rare. An estimated 90 percent of waste is estimated by the Environmental Protection Agency to be disposed of in unsound manners. Solving this problem will be important to the future potential of output. Disclosure of trade secrets can severely hurt the business interests of the companies in the industry and can inhibit product development. Required regulatory disclosure is an issue in toxic substances control efforts. If research developments are inhibited, the future ability of the industry to create new products, and thus, new markets could be impaired. Testing for regulatory purposes also slows the growth of the industry. Data on health, safety and effectiveness of chemical products is necessary for protecting public well-being. Yet, delays in government rulings on test results can impair profitability. The effects of chemical substances on large populations and on sensitive environments generally are not subject to liability laws. A national fund financed by excise taxes and general revenue has been created to aid in payment of ever-increasing chemical product liability settlements in these cases. The industry can be faced with other personal liabilities, however. This increases the costs of operations because contingency expenditures are necessary and legal costs must be covered. The Clean Air Act is an obstacle to the economic future growth of the industry, since potential restrictions in local areas where emissions may exceed regulatory limits may require curtailed operations, or possibly, canceled expansion plans. Pollution control, air and water, now accounts for about seven percent of total capital spending in the industry, a decrease from the record high of 12 percent in 1973. Highest total expenditures occurred in 1975 (Figure 8). In recent years, operating costs for the control equipment exceeded total capital expenditures by an average of 116 percent.

Compliance with environmental regulations is achieved by adding treatment facilities at the end of the production process. New plants are required to apply more stringent and effective methods of treatment than old plants. Consequently, decisions to expand capacity will likely be affected negatively by these rules.

Foreign markets for the industry are substantial. While domestic consumption accounts for 80 percent of the value of shipments, the 20 percent of shipments exported allow about a $14 billion balance of trade surplus for the industry. The value of U.S. petrochemical exports are over five percent of all merchandise exported from the nation. Trade in petrochemicals is now an important element of trade of all nations. It is influenced by the development of oil-rich and gas-rich nations which can establish their own manufacturing capabilities. Economic conditions in the world strongly affect volumes of output from Texas plants. Major competitive areas in Asia and western Europe, currently include nations which must import petrochemical feedstocks. Presently, two economic issues, the U.S. competitive advantage in production (because of lower feedstock costs than other nations) and government controls on U.S. export of petroleum products (limiting the foreign producer's access to low priced semi-processed feedstocks, such as naptha) are under

Figure 8.—Chemical Industry Pollution Control Capital Spending, U.S.



Source: Bureau of Economic Analysis

international dispute. The competitive advantages are precarious, however because foreign feedstock volumes are rising.

Reduced availability of refinery products and natural gas that provide feedstocks for petrochemical production make potential production increases vulnerable. Domestic feedstock supplies may be restricted because of strong competitive pressures for alternative uses. Growth projections must account for not only the general availability of feedstocks but also for the specific availabilities of particular hydrocarbon varieties which can be critical to particular chemical production processes. Overseas developments that recover waste natural gas that was previously discarded add to the susceptibility of the industry to foreign events. These recovered supplies, if made available, tend to negate the competitive cost-price advantage of U.S. producers because they can be obtained cheaper than present sources of foreign feedstock.

Alternative feedstocks, not now used extensively are also possible. Coal can be used on a more limited scale than current sources of feedstock hydrocarbons. Methanol from coal gasification can be processed into synthetic fibers and petrochemical intermediates. The alternative will also decrease the competitive advantage.

Fuels used for process heating account for about ten percent of the total cost of materials in petrochemical production. For the industry, fuel costs average about six percent of all expenditure for materials. Other manufacturing industries average about a two percent fuel cost proportion.

National Context of the Industry

Chemicals was the second largest industry group in Texas in terms of value of shipments in 1980. Recently, annual production has been valued at more than $27 billion. With coastal chemical manufacturing complexes among the largest in the world, the State ranks first in the nation in chemical output, led by inorganic petrochemicals. Output of all chemicals in Texas represents nearly 20 percent of the U.S. production, yet petrochemical capacity and production in Texas is over 61 percent of the national total. Including the neighboring Louisiana production, the Texas Upper Gulf coastal petrochemical industry represents an intense concentration of over 83 percent of national capacity in ethylene, propylene and benzene (the most important petrochemical products, by volume of output). The concentration of U.S. capacity share varies by type of product (Table 10).

Texas exports approximately 12 to 15 percent of its chemical production to foreign markets. Markets within the State (including other manufacturers in closely related industries which are not in SIC 26) account for an estimated 38 percent of the production. Manufacturing industries in the rest of the U.S., such as plastics, autos, apparel and ordnance, use the other 50 to 53 percent of Texas chemical production.

Recent Trends

In the decade of the 1970's the chemical industry experienced an extremely strong growth rate of over seven percent per year in Texas. New product development, relatively inexpensive feedstocks and strong market demand made the industry, especially the petrochemical component, the fastest growing manufacturing classification from 1972 to 1977. Real capital expenditures increased by three-fold, led by plastics materials, agricultural chemicals, and paints, as companies rapidly increased capacity, financed pollution controls and converted facilities to new product lines. Parts of the industry were relatively new and experienced the benefits of large returns on capital in short periods of time.

Table 10. Texas Chemical Production Capacity Relative to the National Total, 1980.

Chemical Product	U.S. Total Capacity by Volume	Texas Share (Percent of U.S. Total)
INORGANICS		
Sulfuric Acid	42,243 Kmt	9
Ammonia	18,771 Kmt	8
Chloride	14,331 Kt	31
Phosphoric Acid	10,477 Kmt	3
Alumina	7,930 Kt	34
ORGANICS		
Ethylene	37,086 mlb	68
Propylene	20,447 mlb	58
Benzene	2,263 mgal	51
Toluene	1,023 mgal	74
Methanol	1,380 mgd	70
Vinyl Chloride	8,245 mlb	33
Styrene	8,303 mlb	60
Phenol	3,563 mlb	41

Kmt - thousands of metric tons
Kt - thousands of tons
mlb - millions of pounds
mgal - millions of gallons

SOURCE: SRI International. 1980 Directory of Chemical Producers, Menlo Park, California, 1980.

However, during the eighties the industry has experienced sluggish growth. Its sensitivities to generally depressed economic conditions has been demonstrated by severe slackening of product demands both in domestic and also in foreign markets. Overcapacity is a concern of the industry. The downward trend started in 1979; by 1980, operating rates were from 60 to 82 percent of capacity, depending upon product type. The economically desirable rate is in the 80 to 90 percent range. Even during this period a buildup of world ethylene and other petrochemical product capacity was underway and presently continues. New plants are under construction in Canada, Mexico, Saudi Arabia, and Africa.

Some product lines, such as propylene and plastics materials have fared better. Overcapacity in these has not increased so sharply as has that for the major Texas petrochemical, ethylene. In 1980 propylene demand was up by 16 percent over 1979, because of price advantages over ethylene. Substitutions of new products for older products that have declining market demand have prevented drastic negative impacts for most individual producers, yet many companies have completely abandoned segments of the product streams which have become unmarketable. Price increases for the common Texas chemicals' feedstocks have trended 2.6 times higher than market price changes for petrochemicals since 1976.

High end-product prices and generally high interest rates, which curtail consumer spending, have been causes of slackening demand for petrochemical products such as plastics used in autos and synthetic fibers in clothing and construction materials. American chemical producers are faced with tight margins of profitability because of a relatively high cost structure in producing each unit of product. The trend is toward higher variable costs (energy, pollution abatement operating costs, etc.) relative to fixed costs. In the 1960's fixed costs (e.g., leases, depreciation, taxes) accounted for 75 percent of all costs, variable costs for 25 percent. In the period 1970 to 1975, energy price increases chiefly were responsible for increasing in the share of variable costs to 40 percent. The trend is toward higher shares for variable cost items. This trend emphasizes the importance of feedstock price changes to the future economic health of the industry. Locations of production facilities near available feedstock raw materials is becoming much more important of a factor in capacity expansion than in the past. Although substitutions among feedstock materials are resulting in lower costs for some producers, general price increases across the range of all feedstock types is limiting this cost saving approach. The largest recent (1976-1981) price changes have been for natural gas feedstocks.

In Texas, oil field chemicals account for an estimated 10 percent of the market for all chemicals. The growth of oil exploration is one positive influence upon future prospects of stable or increasing chemical outputs. Demand for chemicals used in secondary and tertiary recovery increased rapidly since 1979. Decontrol of crude oil production in early 1981 and the likelihood of natural gas deregulation both have contributed to market demand increases for specialty polymers, solvents and other organic compounds used in drilling operations. As much as 21 billion pounds of oil exploration related chemicals were produced in 1981, representing approximately four percent of U.S. chemical production.

Long-Term Outlook

Several forces point to slowing of the growth in production of the chemicals industry. Since the outlook for growth in the industry is now much less optimistic than it was in recent years, the Department anticipates decreases in the anticipated future volume of water use. Considering nationwide and state events which will likely place obstacles to the expansion possibilities of the industry, the rapid expansion of the industry in the mid-1970's cannot be maintained. Despite large projected decreases, the projections anticipate enough product-demand to allow continued growth for the industry until 2030, although at a decreasing rate.

Potential foreign competition strongly influences the projections for a slowdown in industry output over the long-term. Since domestic demand is forecasted to be slow to relatively flat over the long-term, the foreign markets are crucial to growth prospects. Yet, efficiencies and economies gained from producing chemicals near foreign sources of feedstocks will work to diminish the competitive advantage of existing U.S. establishments. Because of high growth rates in their domestic economies, the developing nations are anticipated to register faster growth in demand for all petrochemicals than the rates in the U.S. or other developed economies. Indigenous petrochemical production in developing countries is expected to grow at a higher rate than their own demand, however. New production facilities will compete with U.S. producers in U.S markets, and potential markets in developing countries will be lost to U.S. producers. Large complexes are planned in the Middle East, Mexico, and Canada. When compared with the U.S., location amenities are most favorable in Indonesia, Quatar, and Mexico.

The U.S. Department of Commerce expects present overcapacity in U.S. plants to last for at least a decade. After that, present producers will be faced with new competitive production centers overseas, which may cause domestic producers to necessarily shift into new chemical products to capture new markets.

The growth rate for ethylene, the major Texas chemical product, is projected by industry researchers to be about four percent annually during the present decade. However, industry studies have predicted the loss of roughly three world-scale ethylene complexes in the U.S. in the next two decades. Throughout the longer term period (30 to 50 years), growth rates will continue to decline because of bottlenecks in feedstock supply.

Pollution control costs should continue to rise over the next two decades. These expenditures and the annual operating costs for the equipment will discourage any major expansions in plants' capacity. Future price increases are anticipated for natural gas, affecting the potential for production derived from this feedstock to an indeterminant degree, but trending downward. The effect on agricultural chemicals, which are based on ammonia derived from gas, is expected to be negative; yet a stable market for pesticides and fertilizers is anticipated during the projection period.

New technology developments in processing chemicals, are anticipated, especially those related to cost-economizing. Evaluations of methods to use coal and lignite should lead to relief of long-term feedstock supply problems, yet economic feasibility of this use is well past 2000, by most industry opinion. Other potential breakthroughs which could lessen the expected downturn in output include developments in biotechnology (for example, biomass as feedstock) and synthesis of new materials from organic compounds. Numerous possibilities exist for research results which will change the fundamental structure of the industry economically and in terms of water use. On the product side, the ways that chemicals can be commercially applied are almost limitless. There is an optimistic prospect of increased production of methanol as a gasoline additive to improve performance of engines, for example. As a long-term prospect, methanol could be used to produce gasoline-like hydrocarbons that could replace fuels now produced from crude oil.

Overall, the future growth rate of Texas chemical production is higher than GNP by a healthy margin in the 1980-2000 period. The slowdown in growth after 2000 results in a rate which is then nearer to, or slightly below GNP. If Texas producers could develop new foreign markets or new varieties of chemicals, the growth rates would be slightly higher, but the cost pressures and market forces that have been identified will prevent large future increases.

Projection Data and Method

After conferring with industry representatives, analysts concluded that the long-term growth rates forecasted by the Bureau of Economic Analysis (BEA), also used for the low water-using sectors, were reasonable and adequately depict the future of the industry. Using the gross state product adjustment methodology (explained previously), projection methods resulted in the forecasted downturn of industrial output for SIC 28. The average annual rate of output drops from 4.94 percent in the 1980-1990 decade to 3.79 percent by 2000 and 2.61 percent by 2030. While appearing slow, these rates represent a continued increase in volumes of chemical output to the extent that unused capacity will likely come on line at some future time during the period, although very little new expansion is anticipated by industry reseachers.

Water use efficiencies are not anticipated to grow significantly over the period. An improvement of about three percent over present use per unit of product is predicted by the Department's engineering consultants.

Projected Water Requirements

Water requirements for the chemical industry accounted for more than one-third of the total State industrial water requirements in 1980. The dominance of this industry's water requirements relative to the State's total manufacturing demands is projected to continue over the 50 year planning period. Water requirements for the industry are projected to more than double by the year 2000, resulting in an increase of 692 thousand acre-feet of annual use. By the year 2030, the chemical industry's requirements are projected to account for approximately 59 percent of the total manufacturing requirements in the State.

Water Requirements (SIC 28)
Chemicals and Allied Products

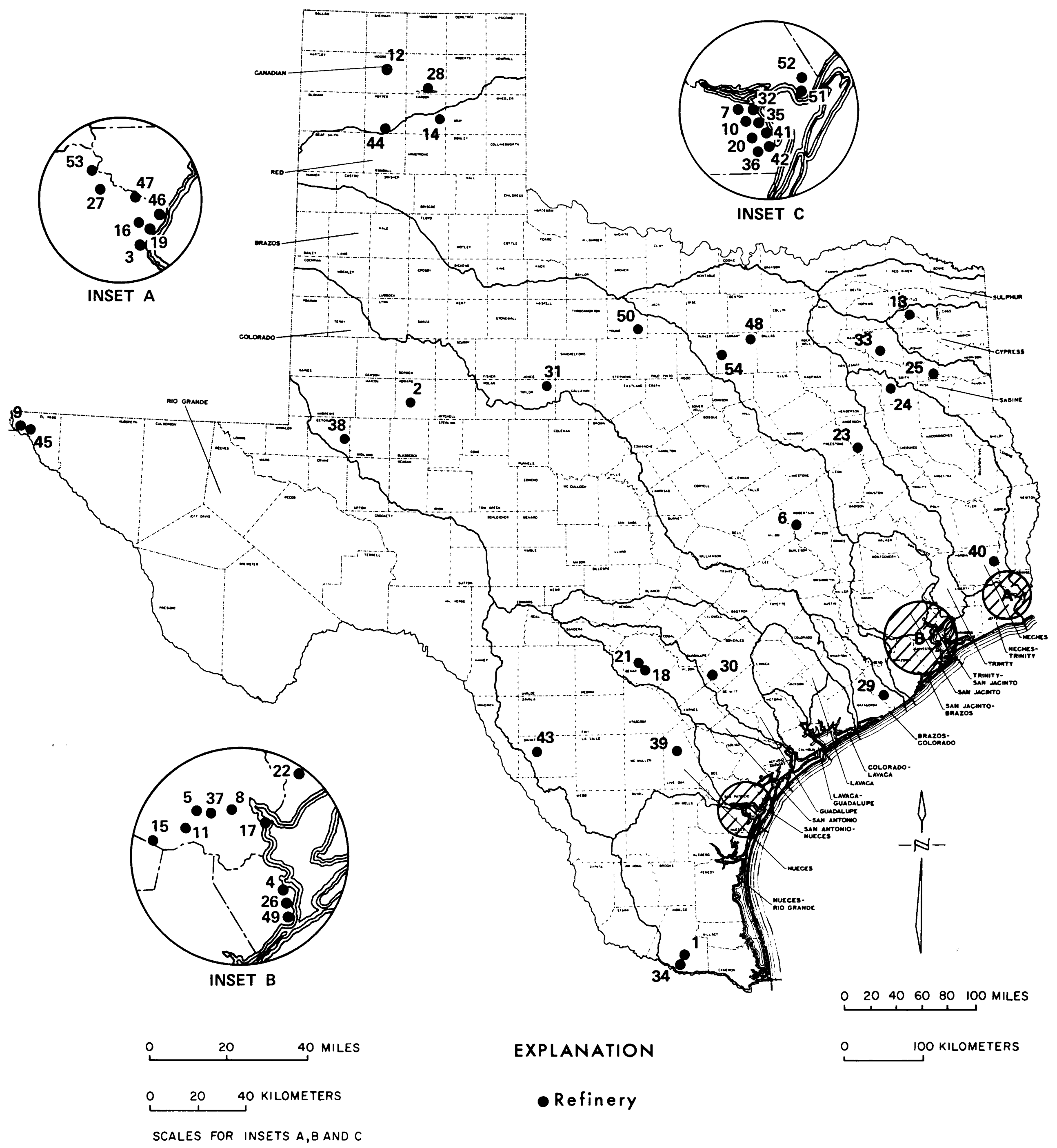
1980	1990	2000	2010	2020	2030
(thousands acre-feet)					
558.1	882.6	1205.5	1593.9	2054.7	2634.0

Petroleum Refining (SIC 29)

Some of the world's largest petroleum refining complexes are located on the upper Texas coast, other smaller refineries are spread over the State near areas of local crude oil production, especially in the Panhandle and in Northeast Texas (Figure 9). The processing of crude oil requires large amounts of energy, capital equipment and water. The industry is the second largest water user of the State's major manufacturing groups. Water is used mainly for cooling purposes, with boiler feed and process water (such as washing operations) as the other uses. The minimum water requirement to produce petroleum products is estimated at 20 gallons per barrel of product; however, under current water use practices about 60-65 gallons normally are required. Refineries generally are located near available water supplies, including saltwater, which also is used in cooling and washing operations.

Figure 9

Refineries in Texas as of January 1, 1980



Industry Description

The dominant products of SIC 29 are gasoline, jet fuels, fuel oil and petrochemical feedstocks, manufactured by the distillation and fractionization of crude oil. Other products under the classification include asphalt, minor petroleum-based materials, and lubricating oils, all accounting for only three percent of total value of refined petroleum products. Coal products are also in SIC 29, but Texas has insignificant production of these.

The number of refineries fluctuates yearly because of the response to legal regulations, markets, and tax rulings affecting the numerous very small operators. There have been at least 50 refineries operational since 1977, but the size of individual plants varies widely. The largest single establishments are located in the Houston-Texas City-Beaumont areas, with some complexes capable of producing as much as 400 thousand barrels per day.

Refining of petroleum products from raw crude oil requires the distillation and fractionization of the feedstock. Redistillation and cracking produce many varieties of derivative. High heat, chemical treatments, water for cooling and washing are required in the process. Ready access to crude oil throughput facilities and supplies are essential for economical operation.

Economic Characteristics

Petroleum refining is the largest industry in terms of value of shipments, and second largest (after chemicals) in terms of value-added in Texas. Current annual shipments total over $57 billion. Texas refiners produce over 29 percent of the nation's refined petroleum product.

The markets for the industry extend throughout the nation through extensive pipeline networks. The midwestern and southwestern states exert the strongest influence on market demand for Texas products. Only four percent of product is exported to foreign buyers.

Crude supplies arrive at the refineries by pipeline from Texas oil fields and by ship tankers from foreign suppliers. In 1981, refineries were importing 33 percent of their crude oil raw materials. The user of heavier, "sour" crude oil from foreign supplies requires extensive retooling of refinery equipment which has historically been geared to the lighter qualities of domestic oil. This conversion, spurred by increased demand for petroleum-based products, and dwindling domestic supplies, has caused capital expenditures for the industry to rise rapidly from the 1972 total of $187.4 million to $1 billion a year by 1977, when foreign imports were increasing to more than 42 percent of total crude oil throughput (Table 11).

Output from refineries is highly sensitive to fluctuations in the prices of finished product and the costs of production such as fuels, crude oil, labor and transportation. There is also a seasonal characteristic to type of products produced, such as the conversion from gasoline to heating fuel oil for use in winter months, requiring summer stockpiling of gasoline. Accordingly, the output volume of any one type of product is cyclical and occasionally, as in 1977, the difficulty of matching product demand with adequate supplies causes either bottlenecks or surpluses and thus severe upward (or downward) price changes. Price fluctuations strongly influence decisions about future production volumes.

Fuels are used by every industrial sector in the economy and by consumers, with transportation consuming the largest volumes, more than 9.7 million barrels a day, or 52 percent of the total of about 18 million barrels

Table 11. Foreign Imports of Crude Oil to Texas Refineries.

Year	Total Inputs	Domestic	Foreign	Foreign as a % of Total
1972	1,113	1,089	23	2.11
1973	1,171	1,043	128	10.94
1974	1,188	963	225	18.65
1975	1,210	905	305	25.10
1976	1,308	852	456	34.88
1977	1,427	836	592	41.45
1978	1,460	812	648	44.39
1979	1,436	767	669	46.61
1980	1,316	792	524	39.82
1981	1,203	803	400	33.25

SOURCE: U.S. Department of Energy.

in 1980. Industrial users consume 3.6 billion barrels a day, or almost 20 percent of the total. Given the extent and magnitude of the market for refined products, even small changes in per-unit efficiencies (such as fuel use per-mile in transportation) in energy consumption can impact the demand for refined fuels to a major degree. Price-induced reductions in volumes of fuel used, result from the inability of consumers to transfer the cost burden to other items in their budgets. The effect is that market demand decreases to the extent that oversupply can result from small miscalculations of energy conservation trends. The Bureau of Industrial Economics estimates that a ten percent increase in the price of fuels results in a two percent decrease in consumption. Since exports are only 4.4 percent of total value of shipments, there is no effective foreign market for U.S. petroleum products. The industry is extremely sensitive to supply interruptions, as shown by the effects of the 1973 embargo and the results of refiners' difficulties in obtaining economical throughputs in 1979. World events could trigger price rises at any time; although, unlike previous perturbations of the market, stockpiles of crude oil and refined products could now be used to prevent immediate responses to crises. If supplies were again tightened there would be further price-induced conservation, resulting in stimulation to develop water conservation technologies, thus further limiting the demand for refined products in the long term.

Recent Trends

The historical position of petroleum refining as the premier industry in the State's economic base is being challenged. The Arab oil embargo of 1973-74, during which prices of crude petroleum more than doubled, fundamentally changed the structure and production potential of the industry.

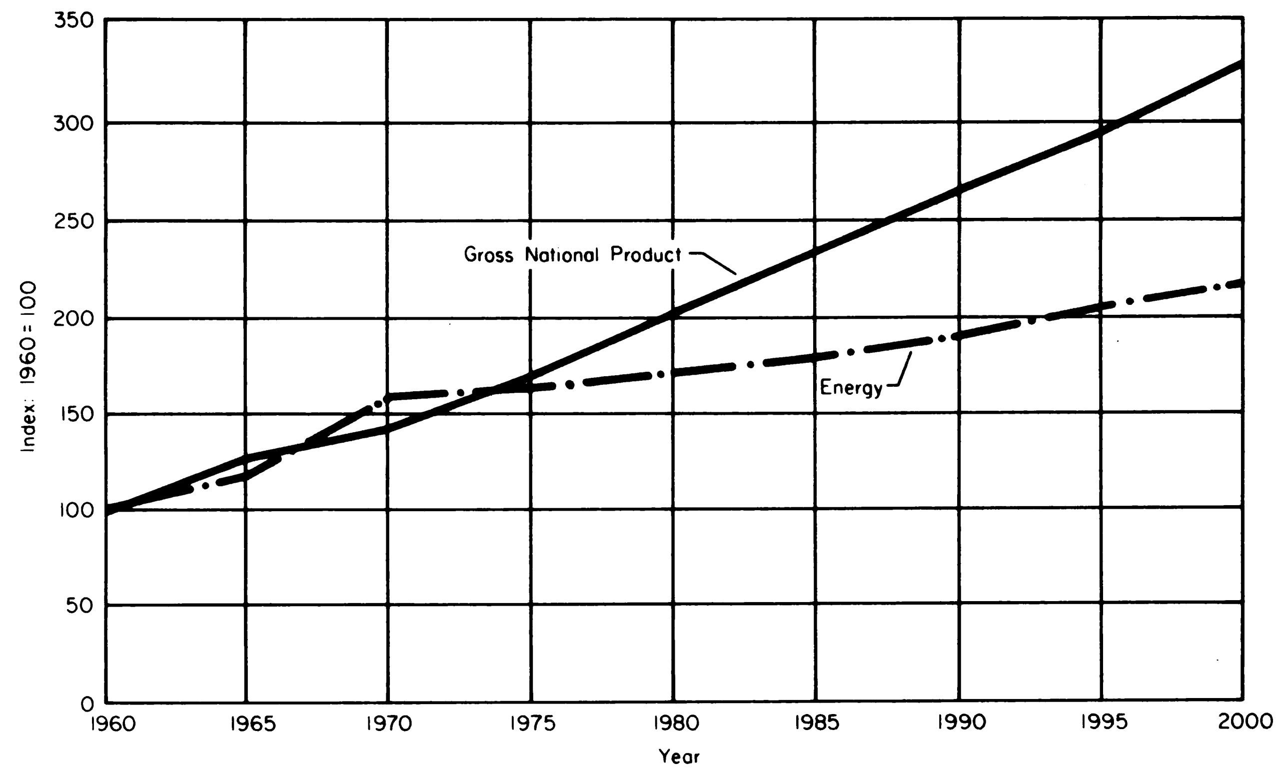
Higher prices for product, caused by increases in foreign and domestic crude oil costs, recently have decreased the world's demand for petroleum by large amounts, especially in the U.S. Likewise, search for more supply has intensified. Traditional energy price and growth relationships among the segments of the industry have been altered, triggering an unprecedented increase in drilling and exploration for oil and gas during the past several years. Until 1975, the demand for energy generally followed the changes in GNP. Since then, energy demand in relation to economic growth has dropped off, with the trend for a further widening gap between growth in GNP and energy demand clearly in evidence (Figure 10). However, there still exists an economic growth component in the demand structure for fuels, although its importance has diminished.

Texas refinery imports of foreign crude oil reached a peak of 48 percent of total receipts in 1979. The recent trend of foreign imports has been a significant decline to about 27 percent of the total, reflecting increased domestic production of crude oil, the current oversupply of refined products, and changes in market-price relationships between domestic and foreign sources of supply.

Texas refineries have been operating at far below their throughput capacity since 1977 (Table 12). In 1980 only about 73 percent of capacity for processing crude oil was being used. This came at a time when substantial capital expenditures were still being made. However, the expenditures do not indicate additional product capacity but largely have been made for retooling to process different qualities of crude oil than have been refined in the past.

The main goal of energy policy in the nation has been to decrease U.S. dependence on foreign oil and to increase incentives for domestic production.

Figure 10.—U.S. Real GNP and Energy Demand



Source: Oil & Gas Journal, Nov. 9, 1981

Table 12. Post-1973 Historical Refinery Capacity Utilization, Texas.

Year	THROUGHPUT CAPACITY USE*
	(percent of total capacity)
1973	89.8
1974	85.5
1975	83.0
1976	89.2
1977	91.0
1978	85.0
1979	78.8
1980	72.6

* Measured by crude oil throughput capacity divided into total crude throughput each year.

SOURCE: Texas Energy and Natural Resources Advisory Council. Texas Energy History 1979 Update Report No. 8008, Austin, August 1980, and other TENRAC reports.

Phased decontrol of domestic crude oil prices has enhanced exploration in old and new fields, onshore and offshore, and has improved the feasibility of enhanced oil recovery techniques. Price increases in crude oil have also spurred the development for alternative sources of energy, yet their production has not been an important cause recently, for the overall reduction in product demand for refined petroleum.

Environmental regulations for control of pollutants and requirements for vehicle emissions are tending to increase refinery and consumer transport operating costs. The mandated increase in production of unleaded gasoline necessitates new processing units even when there is excess capacity for other products. Relaxation of lead emission rules tends to alleviate operating costs for refineries and may improve output levels to a small degree.

The key trend for an indication of the direction of production volumes in the industry is the previously unanticipated decreases in level of demand caused by rising product prices. After 1973-74, world oil price hikes cut the growth rate of domestic demand (formerly 4.1 percent annually) to only 1.8 percent between 1973 and 1978. As the efficiency of auto gasoline consumption has rapidly improved, further declines in energy use per unit of measure have occurred since then. Demand for gasoline has been on a downward trend since 1978. Use of refined fuel for industrial production and generating electricity has increased as a proportion of the end-use market. Regardless, these uses are relatively minor when compared to the use of fuels in transportation and are not large enough to offset declines in all forms of energy used in vehicular movements.

Substitute fuels have begun to replace refined products to a noticeable extent. Electricity, coal and natural gas have increased production outputs from 3.5 to 7 percent in recent years, while refined petroleum has declined.

The late 1970's and early 1980's are the beginnings of growth in alternate fuel use by industry, electric utilities and residential-commercial markets which need long periods of time to economically convert equipment to adapt to the conversions. Again, the influence of high refined petroleum fuel prices is crucial to the length of the time required for substitution.

Long-Term Outlook

Most projections of refinery output made prior to 1979 have now become invalid because of basic changes in the industry. U.S. oil consumption may have reached its peak in 1978. In forecasting the industry's future, the effects of price rises on demand are far more important than previously thought.

Petroleum refining output now faces a declining future, completely the opposite outlook from that of 1977, when long-term output was widely forecasted to rise significantly. In the next two decades (1980-2000) prospects are for a continuing erosion in domestic demand for refined products, especially gasoline used in personal transportation. Total vehicle miles are projected by industry experts to be lower -- by 1990 the fuel economy of new cars will be about 15 percent greater than in 1980 -- and the stock of older, less efficient vehicles will be replaced. Production volumes of fuels will eventually level off to a more or less constant output as other market factors, such as a declining national population growth rate, tend to stabilize potential demand. In the residential sector, fuel substitution in electricity generation (coal and natural gas) will continue. The BIE projects the 1985 consumption of refined products in electricty generation to decline by 16 percent of the 1978 volume. The price of electricity is projected to increase more slowly than the price of oil; in addition, more fuel efficient heating and cooling equipment will be put in place.

In response to legislative mandates, utilities will continue converting from fuel oil to alternative sources of energy. For example, BIE projects consumption of coal by the electric power industry to increase by almost 44 percent by 1985.

The concensus of industry analysts is for stable, or increasing world oil prices at a slightly higher rate than inflation, on average, with fluctuations upward and downward until 2000. U.S. total energy demand will increase but the share met by refined products will decrease from about 50 percent in 1980 to less than 30 percent in 2000. The demand for oil in the U.S. will average about 14 to 15 million barrels per day (or b/d) in 1990, compared with about 17 million b/d in 1980. The ranges of demand by 2000 are from 13 million b/d to 16 million b/d, resulting in a long-term flattening of the output demand curve.

Stability or a decline in the real price of finished refinery products could quickly change the demand outlook since the sensitivity to price changes is acute. If real prices of oil had been declining in 1975 to 1980 at a rate similar to that from 1959 to the early 1970's, industry analysts estimate that world petroleum consumption would have been almost 80 million b/d instead of 49 million b/d in 1980. Forecasts of prices vary widely, but almost all of them anticipate some long-term increases. The possibility exists, however of stable or even declining prices of refinery products during periods of oversupply of crude oil. In these times refineries likely would experience increases in demand that would encourage use of idle production capacity, but not new capital expenditures for plant expansions.

Few analysts are forecasting the long-term future of the industry past the year 2000. There are complete uncertainties for fuel alternatives, potential new sources of energy, and changes in the technology of transportation in that period. Refined products likely will continue to be produced so long as there is an available supply of crude petroleum. Sharp declines in refining will tend to prolong the period of time in which petroleum-based fuels can be marketed economically. Alternative uses for the extensive capital holdings of refiners can be expected to be researched. Shifts in product mix toward intermediate distillates such as kerosene, naptha, diesel fuel, and unleaded gasoline can be expected. Increased petrochemical feedstock production will be necessary because of growth (though not rapid) in petrochemicals output, yet feedstock volumes are small when compared to the amount of production for gasoline or other fuels. Post-2000 annual changes in output will likely remain constant or decline; no increases in growth rates are foreseen.

Water Use Efficiencies in Refinery Operations

Future improvements in water use efficiency are projected for SIC 29. Currently, a barrel of crude oil, when processed, requires an average 64.7 gallons of freshwater intake, the minimum requirement is about 20 gallons. Since water quality is not crucial to cooling reuse, most water used by this industry is recirculated. Recycling of cooling water over heat exchangers is a common reuse practice. Other potential conservation practices include air cooling of barometric condensers, reusing boiler feedstock water, and recirculating the large volumes of water used in coking operations.

The future increased production of intermediate products from refineries will require increased volumes of water per barrel of crude oil since their production processes are more water intensive than those for the present mix of products. This expected shift will tend to offset water conservation through reuse, yet not so much that water use per barrel would increase by year 2000. The future rates of efficiency in water use per unit of product, projected by the Department's engineering consultants, are 11 percent gain (lower per unit use than at present) in 2000 and 14 percent gain in 2030.

Projection Data and Method

No further production capacity additions are foreseen in SIC 29. Industry representatives and analysts have concluded that overcapacity is likely to remain into the long-term future. Therefore, the potential for water use volume above that necessary to operate at current capacity is not projected. Coupled with a decline in demand and future substitutions of alternative fuels, prospects for growth rates in annual output are projected to be zero by 2000; consequently, volumes of output are projected to remain relatively constant from year to year in the long-term period, 2000-2030.

Between 1980 and 2000 growth was assumed to continue at slow rates, averaging 1.26 percent annually for 1980 to 1990 and 0.42 percent for 1990 to 2000. These rates resulted from a decision to allow refining output, especially in the near term, to recover its highest capacity use after 1973, which occurred in 1977 (see Table 12). A growth curve was fitted from 1980 to 2000 that would show capacity use increasing from 77 percent (Table 13) to 91 percent. After 2000, no increases in output were projected.

The reasoning behind this approach involves some insoluble uncertainties about the nature of this volatile industry. Oversupply of crude oil for refining could result in rapid price decreases which could, in any given year, require demand-induced increases in output. It was judged reasonable to allow

Table 13. Capacity Utilization by Texas Refineries, Monthly, 1980.

Month	Utilization Rate	
	Texas Inland	Texas Gulf
January	80.8	78.6
February	73.2	82.0
March	72.0	75.9
April	74.7	72.8
May	75.8	73.8
June	78.4	70.8
July	79.5	67.3
August	79.7	65.2
September	76.9	71.1
October	75.5	67.9
November	77.6	68.0
December	79.1	66.0
Annual Average	76.9	71.6

SOURCE: U.S. Dept. of Energy. Energy Data Reports. Monthly Petroleum Statements, DOE/EIA-0109.

the industry to recover idle capacity in order to meet this possible event. Over the 20 year period there will be large deviations from the assumed capacity/recovery growth curve. But this approach allows for unforeseen increases in product demand. The influence of this industry on the rest of the Texas economy will remain strong throughout the projection period because the products are essential to other economic sectors. It is thus necessary to maintain potentially available supplies of water for this industry until the full effect of eventual reductions of refined product volumes is known for certain.

In any event, during the next two decades sufficient water for the production of alternate products (intermediate distillates) will be necessary. Moreover, increased supplies of petrochemical feedstocks will be needed.

There is little information upon which to base projections for production, for years after 2000. Technological improvements in transportation that will result in less fuel use and developments of new petroleum-base products or markets are likely. Projected growth rates in output caused by economic conditions were held constant, resulting in a decline in total SIC 29 water use volumes owing to the gains in water use efficiency projected for refinery processing.

Projected Water Requirements

In 1980, the petroleum refining industry required nearly 293 thousand acre-feet of water for its various production processes. This volume of water accounted for an estimated 19 percent of the State's industrial water use. Water use in the industry is projected to grow only slightly by the year 2000, resulting in 15.2 thousand acre-feet more use than that in 1980. The slow growth is caused by declines in demand for refinery products (particularly motor fuels) and declines in domestic crude oil production. By the year 2030, annual water requirements for the petroleum refining industry are projected to account for only six percent of the State's total industrial water requirements, a significant decrease from the current 19 percent share.

Water Requirements (SIC 28)
Petroleum Refining

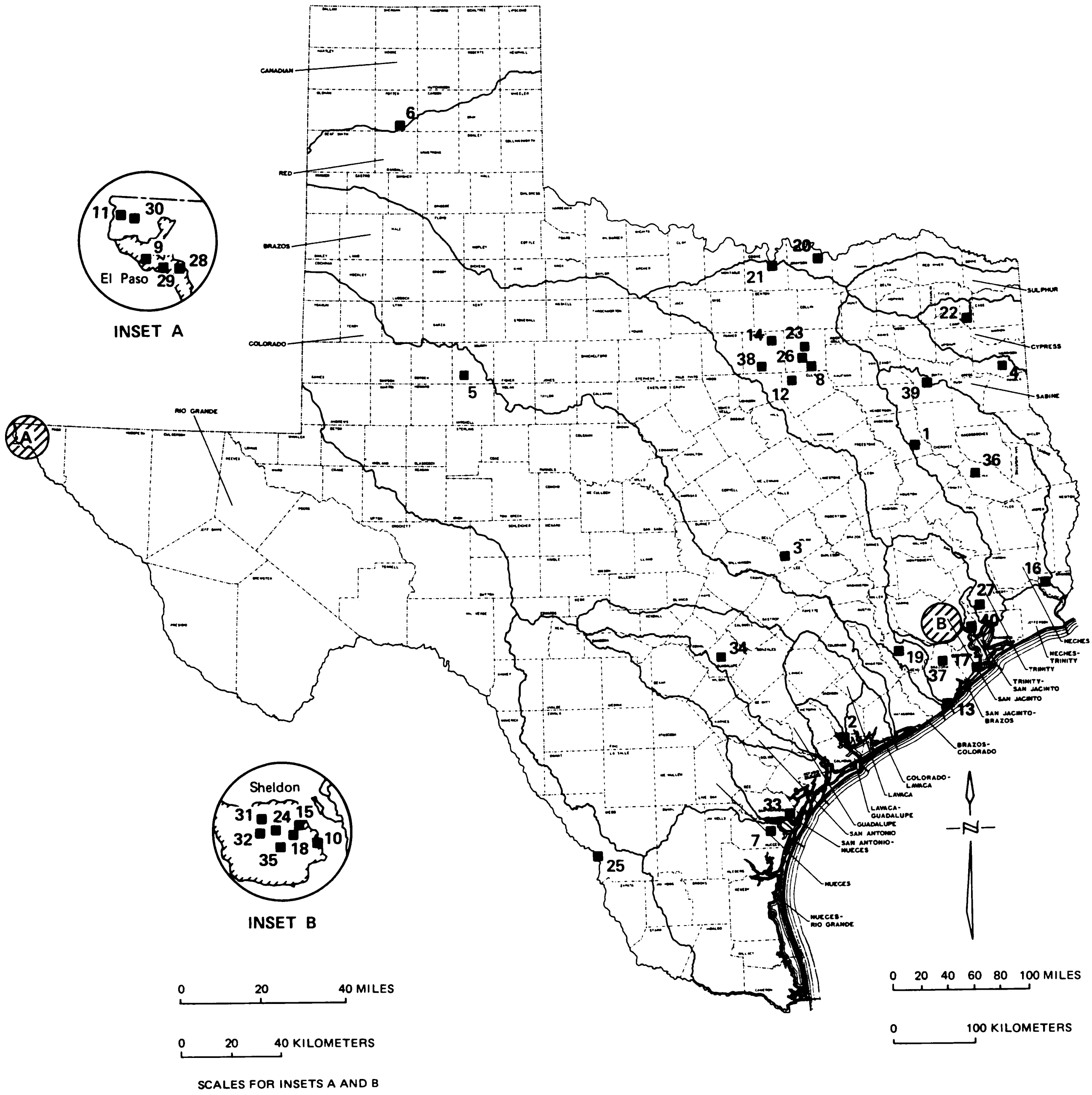
1980	1990	2000	2010	2020	2030
(thousands acre-feet)					
292.8	292.9	308.0	280.3	280.3	280.3

Primary Metals (SIC 33)

Concentrations of plants in the primary metals industry are located in the coastal and eastern sections and in the El Paso area of Texas (Figure 11). There are 45 thousand workers in metals production. In Texas, SIC 33 consists of mostly aluminum and basic steel production. Copper smelting in El Paso and Potter Counties accounts for about eight percent of total value added for SIC 33, and there are five establishments which produce relatively small volumes of lead, zinc, antimony and other metals. The classification also includes blast furnaces, steel pipe, foundaries, nonferrous rolling and drawing, and other primary metals products which are in the initial stage of manufacture. The industry does not include fabricated metal from forgings, metal containers, formed metal and other similar products.

Figure 11

Primary Metal Industries in Texas as of January 1, 1980



EXPLANATION

■ Primary Metal Industry

In Texas, aluminum ingot and first-stage extruded product account for slightly more value-added than does steel and steel products. Primary metals manufacturing accounts for only four percent of total industrial value of shipments in the State.

Water use in primary metal processing industry is for cooling, processing and pollution control. In steelmaking and foundaries water is used as a cooling agent, precipitator of ores, and transportor for air and water pollution controls. Aluminum production requires large volumes of water for extracting alumina from bauxite in the production process. Direct-contact cooling of processed aluminum, washing required in air pollution scrubbers, and water pollutant control require significant volumes of water flow-through. All types of processing in the industry are suitable for recycling much of the water, especially non-contact cooling processes.

Industry Description

Metals production is the first processing stage after the mining of minerals. It also includes some formed products and the processing of bulk (unformed) metal from recycled scrap. Other industry classifications such as machinery (SIC 35) and fabricated metals (SIC 34) use the output of SIC 33 in a second stage of processing.

Steel production in Texas (SIC 3312) is oriented heavily to oil field supplies and equipment, such as steel tubing, casing and other drilling pipe. Other important steel products include steel plate for shipbuilding, steel reinforcing bars for construction and gray iron castings used as construction and railroad equipment.

Aluminum and copper production in Texas consists of both primary ore processing and first-stage extruded products. The production of basic aluminum ingots from bauxite ore at the larger plants in Calhoun, Anderson, and Milam

Counties require the largest volumes of water in their operations. Rolling, drawing, and castings do not require large volumes of water as do the primary processors. Aluminum is used mainly by the fabricated metals industries. Copper smelting produces anode and refined copper for various uses, chiefly in electronics. Secondary smelting, using scrap materials, is widespread over the State in small plants. Major aluminum products classified in SIC 33 include communication cable, seismic cables used in geologic exploration, sheet aluminum for construction material, tubing, and specialty castings.

Economic Characteristics

Many metal and mineral resources provide raw materials for this industry. The United States is largely dependent upon imports for raw materials -- ores and concentrate. Bauxite for aluminum is imported from Australia, Jamaica and Guinea. Only 10 percent of industry raw materials are produced domestically. Since world prices of ores are raising input costs for metals production, the industry is encouraging recycling. Substitution of aluminum for steel or any metal for another type is common because product prices have fluctuated enough to cause market demands to shift. Improvements in the technology of processing or marketing of products in one sector of the industry can cause either a positive or negative economic impact on another, such as the negative effect of increased use of aluminum on steelmaking. Substituting plastics for metals, a general trend in the past several years also has a negative impact on the industry's level of production.

These metal industries are energy-intensive manufacturers. Texas' relatively cheap energy costs historically have attracted the industry to locate new plants here. Recently, gains in energy use efficiency have improved the operating costs of existing plants to a measurable degree, especially in aluminum production. The industry is committed to a 10 percent reduction in energy use per pound of product by 1985.

Nationally, metals output responds quickly to the worldwide demand for durable goods and capital expenditures by industries. Since fluctuations in the economies of trading nations influence the volumes of domestic output for steel, aluminum and copper, competition from foreign suppliers also influences the industry. The nation has recently become a small net importer of aluminum and an exporter of steel. Foreign governments are actively involved in metals production from ore mining to first-stage processing, resulting in the current acute sensitivity of domestic producers to international product competition.

National Context of the Industry

As a part of national production in SIC 33 Texas 1980 output accounted for 5.5 percent of the total value of shipments. Foreign exports of primary metal output from Texas were estimated at 27.6 percent of shipments, compared with a total of 23.7 percent exported nationally. This industry is the most dependent on foreign markets of any other in the State.

Oil field machinery and equipment markets heavily influence Texas steel production; for the most part, electronics, technology-oriented markets and construction, influence copper and aluminum production in Texas. Annual growth rates in gross products originating have historically been above the national average for the State's metals industry -- from 1969 to 1979, Texas' rate of annual increase was 3.29 percent above the national average (1.67 percent for the nation, 4.39 percent for Texas in SIC 33 growth). One-third of the aluminum industry is located in the Pacific Northwest, near relatively inexpensive hydroelectric power sources and a high market for the product in aircraft manufacturing.

The raw material for production of metals at Texas plants is almost totally imported; some scrap metal from recycling is also used. Scrap steel is recycled mostly in Houston-area furnaces, and some domestic ore and scrap recycling is used in East Texas steel operations. Historically, relatively cheap energy costs have allowed the aluminum and steel plants to operate profitably. Texas has had a competitive advantage in abundant, inexpensive natural gas and electricity used in foundry, blast furnance and smelting operations, an important part of past corporate relocation decisions. Presently, however, the rising energy costs and distance from both raw material and scrap supplies is eroding the advantage.

Recent Trends

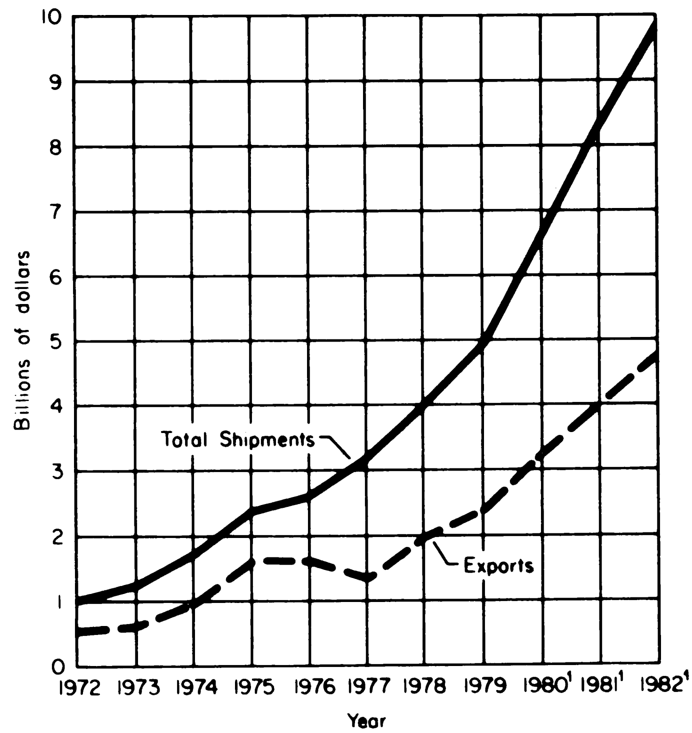
The Texas steel industry does not follow national trends closely because the marketed products are largely not comparable. Yet, some events in the national economy tend to influence the level of output, especially of steel used in durable industrial capital equipment that is not related to the oil industry. Since 1977, oil and gas exploration activities have created record markets for steel tubular products, with a growing demand for exported finished goods (Figure 12). However, the recent strengthening, diversification and rapid growth in industrial output in the Southwest also has allowed steel production to maintain growth. Oil exploration activities continue to make the production response erratic.

The industry is investing heavily and rapidly in capital equipment in response to the stimulus of tax liberalization for modernization purposes. Aged methods and equipment are being phased out in favor of newer processes such as the continuous casting process already employed by Asian and European steelmakers, major competitors to U.S. producers. According to the Department of Commerce, imports of Asian tubular steel used in oil exploration are increasing due to the inability of domestic producers to manufacture enough high quality pipe necessary for deeper drilling for crude oil, especially on offshore sites.

Copper production has been slow recently. Substitution of other metals and a slack in demand in the wide variety of products using copper are depressing this part of the metals industry. Given sufficient raw material, imported from other states and foreign sources, Texas producers should generally follow the growth in overall national economic output in the next two decades.

Aluminum production also responds to general economic conditions but Texas producers have been outpacing the national average in growth of output. Nationally about 23 percent of aluminum goes to containers, 18 percent to building and construction, 16 percent to transportation, nine percent to electrical goods, 11 percent to consumer goods and other uses, six percent of machinery and equipment and the rest (17 percent) is exported. The upsurge in geophysical work in oil and gas exploration and the general health of the industrial output in the Southwest and in foreign markets served by Texas producers has maintained a strong demand for Texas-produced aluminum. Capital expenditures for aluminum production equipment are not keeping pace with the growth in product demand, however. The ratio of capital spending to value of output was lower in 1972. Employment in primary aluminum smelting (SICs 333 and 335) has increased by 21 percent since 1977 indicating significant production step-up and increased use of the imported bauxite ore. Since 1977, however, production of domestic ore has suffered sharp declines. Secondary smelting operations are increasing the use of scrap. Aluminum recovered from scrap accounts for about 26 percent of the total U.S. supply of unformed aluminum. The use of recycled aluminum in the production process is growing

Figure 12.—Oil Field Machinery Shipments and Exports



[1]Estimated by Bureau of Industrial Economics

Source: U.S. Department of Commerce, Bureau of Census, and Bureau of Industrial Economics each year, since the energy cost savings are very substantial, at only five percent of the energy required in bauxite processing. Water-use savings, although not precisely measured, are similarly large when processing recycled material.

Long-Term Outlook

The U.S. primary metals industry has long been a key economic sector in the base of the economy. In Texas, metals are an important industry in some local areas, yet overall their influence is not critical to the continued growth in the State's economy. Suppliers of basic metals, located in other parts of the nation and especially in foreign countries, will continue to offer stiff competition. The use of extruded metals in oil field machinery and equipment is expected to increase throughout the next 20 to 25 years, as exploration in old domestic and new foreign fields (onshore and offshore) continues. However, these will likely be periods of erratic products demand as the price for crude oil fluctuates. Countries which are presently net importers of oil and gas also are intensifying their exploration efforts to find new reserves. Offshore drilling will increase because as much as one-half of the world's total undiscovered reserves of oil and gas are believed to lie in those areas. Texas machinery producers (SIC 34), the largest customers of the State's primary metal output, should continue to produce at capacity and will have expanded outputs for the earlier part of the projection period (1980 to 2000). However, the ability of primary metals production to match local demands for heavy machinery is questionable owing to anticipated bottlenecks in raw materials (ore) and scrap metal supply. Also, U.S. oil field machinery manufacturers are expected to eventually establish foreign subsidiary manufacturing plants or to license foreign production. The net effect of these events will be limited to long-term expansion of primary metals output. After 2000, new markets for metals production will be necessary for the industry to maintain growth or even to remain at a constant level of output.

Aluminum producers are undergoing major changes in their production and market orientations. Wtih relatively little bauxite ore, the U.S. is at a disadvantage in world trade of aluminum since transport costs of the ore are rising. Domestic primary aluminum output is not expected to grow as fast as demand for products. Foreign subsidiaries and wholly-owned foreign facilities will increase their share of the market. A large effort at energy savings will be made by U.S. producers, resulting in growth of scrap as a raw material, decreasing process water requirements. However, there are serious limits to the amount of scrap aluminum potentially available to meet the anticipated steady increases in demand.

Texas plants likely will suffer the effects of these growing disadvantages in the near term, paring their operations to meet a shifting product demand. Primary aluminum is becoming uneconomical to produce in the State because of dwindling, uneconomical ore supplies and high energy cost requirements in the production processes. Existing operations cannot expand profitably unless recycled aluminum use grows quite substantially.

Projection Data and Method

The future for primary metals output is one of slowing growth due to the market orientation of the industry. Steel output should slowly grow (even though erratically) in the near term, then level off to a constant or declining output. Aluminum production from ore (alumina) is not anticipated to grow, and possibly could decline.

Meetings with industry representatives revealed a strong conclusion that there will be no capacity expansions in aluminum production after 2000 and there is a likelihood of output slackening. A major producer of alumina has ceased operations recently, showing the immediacy of the disadvantaged competitive position of plants in Texas. Remaining plants will continue a steady increase output in response to strong market demand in the next decade, however. By 2000, no additional capacity for increased output is foreseen. Increased use of scrap material, shifts in product mix and regional industrial demand should allow aluminum (mainly recycled products) and steel to maintain output over the 2000 to 2023 period.

Thus, the compound annual growth rate for SIC 33 was set to zero after 2000, based on industry representatives' judgements as to future capacity limits and upon the disadvantaged future position of this industry, as indicated by recent trends and obvious limits in international market shares for raw materials.

The method of calculation (exponentially declining the growth rate to zero at 2000) allows most of the increase in output to occur in the 1980-1990 decade, conforming to the information available about expected short-term increases in the industrial output of SIC 33. From a production growth rate of three percent in 1980, the industry's annual rate of increase in output declines to only 0.5 percent in 1990; by 2000 it is zero and remains constant thereafter.

There is much potential for water use conservation through both technological improvements in processing and through use of recycled scrap material, the processing of which does not require large volumes of water when compared with ore processing. The projections of water use efficiency (RxT parameters) showed improvements resulting in per-unit use of 38 percent of the 1980 level by the year 2000.

Projected Water Requirements

Considering the declining growth rate and substantial improvements expected in the efficiency of water use per unit of output (conservation) and the negative output impact of foreign competition, future decreases in water requirements for primary metals are projected -- reversing past trends. Declines in the economic position of the industry slows the output of the industry to an assumed constant (no annual increase) from 2000 to 2030. Still, the projected annual water use volumes may be significant in local areas or river basin zones.

The primary metals industry required more than 228.0 thousand acre-feet in 1980, the third largest water use industry in Texas. Declines in average annual use by 26 thousand acre-feet are projected by the year 2000.

Water Requirements (SIC 33)
Primary Metals

1980	1990	2000	2010	2020	2030
		(thousands acre-feet)			
228.0	248.6	201.1	201.1	201.1	201.1

CONCLUSION -- PROJECTED MANUFACTURING WATER REQUIREMENTS

In 1980 Texas manufacturing industries required 1.51 million acre-feet of the State's water resources for various production processes. Of this total, manufacturers in five broad categories accounted for 1.37 million acre-feet, or 91 percent of the State's total industrial water requirements. These industries were: (1) chemicals and allied products (37 percent); (2) petroleum refining (19 percent); (3) primary metals (15 percent); (4) pulp and paper (13 percent); and, (5) food and kindred products (7 percent). The largest water-using industries by volume were included in 17 three-digit SIC categories, led by industrial organic chemicals and petroleum refining (Table 14). Projected industrial water requirements indicate a continued dominance of industrial water demand by the five industries over the 50 year planning period (Table 15). However, increased water use efficiencies and anticipated slowing of the growth rates for some of the more mature industries such as petroleum refining, primary metals, and pulp-and-paper products results in declining aggregate demands by the major water-using industries on industrial water supplies to 87 percent of the current level by the year 2000 and to 85 percent by 2030.

Of the five largest industrial water-using industries, only chemicals and food-and-kindred products show increases in water requirements over the 50 year planning period (Table 16). Future water requirements for the chemical industry are projected to double by the year 2000, with smaller increases through 2030. Projected growth of the manufacturing sectors in Texas is well above national averages throughout the planning period (Table 17). As the State's economy matures, a slowing of growth in manufacturing production can be expected to approach the national average rate of change. As shown by Figure 13, the total volume of water necessary to support industrial output in

Texas will continue to increase, despite slowdowns in water use by the water intensive industries.

Table 14. Leading Water-Using Industries in Texas by Volume of Annual Freshwater Use, 1980.

SIC	Industry Description, Rank	Number of Large Establishments*
Over 200 thousand acre-feet: b/		
286	Industrial Organic Chemicals	28
291	Petroleum Refining	28
75 to 200 thousand acre-feet:		
263	Paperboard Mills	3
262	Paper Mills	3
25 to 75 thousand acre-feet:		
281	Industrial Inorganic Chemicals	5
331	Basic Steel Products	10
372	Aircraft and Parts	13
282	Plastic Materials and Synthetics	17
201	Meat Products	25
333	Primary Nonferrous Metals	9
5 to 25 thousand acre-feet		
287	Agricultural Chemicals	3
329	Miscellaneous Mineral Products	10
203	Preserved Fruits and Vegetables	1
324	Cement, Hydraulic	2
289	Miscellaneous Chemicals	2
208	Beverages	14
353	Construction and Oilfield Machinery	78

* Employee size of over 250 in County Business Patterns 1979, Texas, Report No. CBP-79-45. Data include administrative offices which cannot be separated. Establishments of this size, however, are likely to be the physical production facilities.

Table 15. Projected Manufacturing Water Requirements, Texas.

Industry	Decade 1980	1990	2000	2010	2020	2030
	(thousand acre-feet)					
Food & kindred prdts.	110.2	138.4	175.5	216.6	267.5	328.2
Pulp & paper	193.8	228.4	250.8	237.6	258.2	278.9
Chemicals	558.1	882.6	1205.5	1593.9	2054.7	2633.9
Petroleum refining	292.8	298.6	308.0	280.4	280.4	280.4
Primary metals	228.0	248.6	201.2	201.2	201.2	201.2
TOTAL	1382.9	1796.6	2141.0	2529.7	3062.0	3722.6
Other manufacturing*	135.0	215.1	310.1	414.8	535.7	685.3
STATE TOTAL	1517.9	2011.7	2451.1	2944.5	3597.7	4407.9

* Includes remaining manufacturing industries.

Table 16. Projections of Manufacturing Water Requirements by Industry, Texas, 1980-2030.

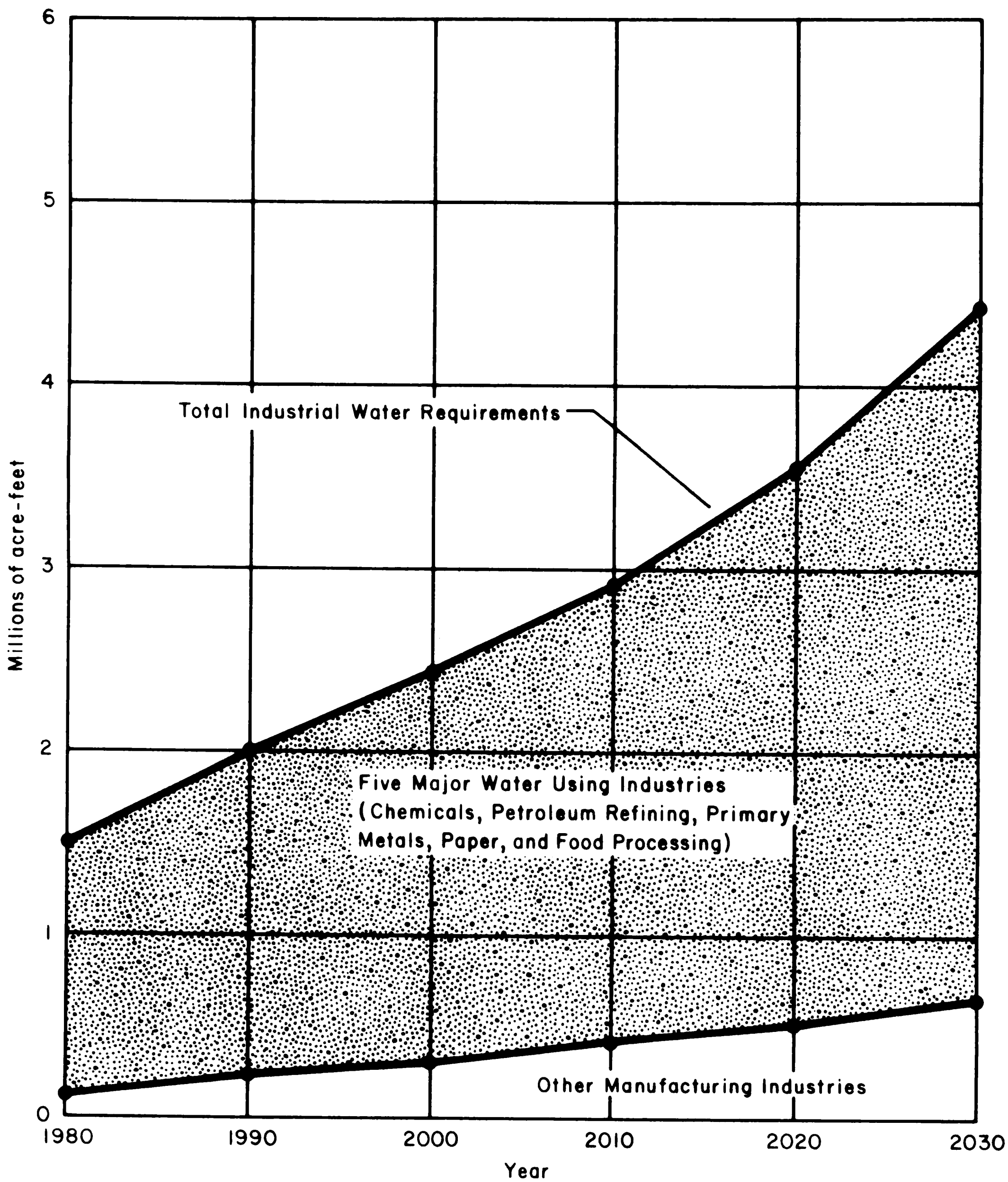
Industry	Decade 1980	1990	2000	2010	2020	2030
	(thousand acre-feet)					
Food & kindred prdts.	110.2	138.4	175.5	216.6	267.5	328.2
Textiles	5.7	6.2	7.4	8.8	10.9	13.4
Apparel	1.4	2.2	3.0	3.8	4.8	6.1
Wood	4.5	6.5	7.9	8.6	9.4	10.3
Furniture	0.4	0.5	0.8	1.0	1.3	1.7
Paper	193.8	228.4	250.8	237.6	258.2	278.9
Printing	0.5	0.7	1.0	1.3	1.7	2.1
Chemicals	558.1	882.6	1205.5	1593.9	2054.7	2634.0
Petroleum refining	292.8	298.6	308.0	280.3	280.3	280.3
Plastics	4.0	7.0	10.6	14.5	19.1	24.5
Leather	0.2	0.3	0.3	0.3	0.4	0.4
Glass/Stone	33.2	48.6	66.8	86.5	110.2	139.2
Primary metals	228.0	248.6	201.1	201.1	201.1	201.1
Fabricated metals	10.6	19.6	31.1	44.0	59.5	77.7
Non-elec. machinery	11.2	22.5	35.3	51.5	66.8	87.8
Elec. machinery	18.6	38.0	59.3	83.3	110.1	143.6
Transportation equip.	42.4	59.2	80.6	102.8	130.2	163.6
Instruments	1.8	3.1	4.9	6.9	9.3	12.2
Miscellaneous	0.5	0.8	1.2	1.7	2.2	2.8
TOTAL	1517.9	2011.8	2451.1	2944.5	3597.7	4407.9

Table 17. Projected Growth Rates of Texas Manufacturing.

SIC	Industry	Decades 1980-1990 Percent	1990-2000 Percent	2000-2010 Percent	2010-2020 Percent	2020-2030 Percent
20	Food & kindred prdts.	2.38	2.64	2.17	2.17	2.10
22	Textiles	0.83	1.83	1.66	2.18	2.11
23	Apparel	4.20	3.31	2.57	2.44	2.31
24	Wood	4.01	2.00	0.90	0.90	0.90
25	Furniture	3.84	3.71	2.86	2.64	2.50
26	Paper	4.01	2.00	0.90	0.90	0.90
27	Printing	4.36	3.60	2.85	2.62	2.47
28	Chemicals	4.94	3.79	3.01	2.74	2.61
29	Petroleum	1.26	0.42	0.00	0.00	0.00
30	Plastics	6.00	4.11	3.21	2.86	2.68
31	Leather	0.94	1.44	1.10	1.34	1.25
32	Glass/Stone	4.75	3.86	3.02	2.75	2.59
33	Primary Metals	3.00	0.50	0.00	0.00	0.00
34	Fabricated Metals	6.37	4.79	3.52	3.04	2.76
35	Non Electrical Machinery	7.13	4.59	3.46	3.00	2.77
36	Electrical Machinery	7.62	4.63	3.41	2.96	2.71
37	Transportation Equipment	3.12	2.93	2.35	2.31	2.25
38	Instruments	5.66	4.81	3.49	3.01	2.76
39	Miscellaneous Products	5.19	4.11	2.99	2.68	2.46

SOURCE: Texas Department of Water Resources, Planning & Development Division; Economics, Water Requirements & Uses Section; June 1982.

Figure 13.—Projected Industrial Water Requirements



SELECTED REFERENCES

Chase Econometrics, Incorporated. Long-Term Regional Forecasts: State and Metropolitan Areas. Vol. 3, The West. Bala Cynwyd, Pa.: Chase Econometrics, Inc., 1981.

Data Resources, Incorporated. U.S. Long-Term Review: Winter 1981-82. Lexington, Mass.: McGraw-Hill, Inc., 1981.

Engineering-Science, Incorporated. "Manufacturing Water Demand and Return Flow Projections." Prepared for the Texas Water Development Board. Austin, Texas. 1976.

_______. "Updated Projections on Future Changes in Manufacturing Water Use in Texas." Austin, Texas. 1982.

International Petroleum Encyclopedia: 1981. Tulsa, Okla.: Penwell Publishing Co., 1981.

"OGJ Report: Petrochemical Report." Oil and Gas Journal 80 (March 1982): 81-124.

Pace Company Consultants and Engineers, Incorporated. "Pace Petrochemical Service." March 1982.

Plaut, Thomas R. A Supply Side Model of the Texas Economy and Economic and Population Forecasts to the Year 2000. Bureau of Business Research BP-82-2. Austin: The University of Texas at Austin, n.d.

"Pulp and Paper Mills Tabulation." Lockwood's Directory of the Paper and Allied Trades 1980-81. New York: Vance Publishing Corporation, 1981.

Texas Department of Water Resources. Municipal and Industrial Water Conservation in Texas. Publication Series LP-17. Austin, Texas. May 1977.

_______. Planning and Development Division. Water Use, Projected Water Requirements, and Related Data and Information for the Standard Metropolitan Statistical Areas in Texas. Publication Series LP-141. Austin, Texas. March 1981.

_______. Planning and Development Division. Economics, Water Requirements and Uses Section. "Survey of Ground and Surface Water Use for the Calendar Year Ending December 31, 1980." Annual survey of municipal and industrial water use. Unpublished data. Various years.

Texas Energy and Natural Resources Advisory Council. Texas Energy Outlook: 1980-2000. January 1980.

Texas Forest Service. Harvest Trends 1979. Publication 122. College Station: Texas A&M University System, 1980.

_______. Harvest Trends 1980. Publication 125. College Station: Texas A&M University System, 1981.

"The U.S. Energy Outlook for the Year 2000." Chemical Engineering Progress 77 (September 1981): 9-15.

Tipee, Robert T., ed. "The Oil Surplus: A Fleeting Phenomenon?" Oil and Gas Journal 79 (November 1981): 141-219.

United Nations. Industrial Development Organization. Second World-Wide Study on the Petrochemical Industry: Process of Restructuring. (ID/WG.366/3) Second Consultation Meeting on the Petrochemical Industry. Istanbul, Turkey. 22-26 June 1981.

U.S. Department of Agriculture. Forest Service. An Analysis of the Timber Situation in the United States: 1952-2030. 1980.

U.S. Department of Commerce. Bureau of Economic Analysis. "1980 OBERS BEA Regional Economic Projections: Methodology, Concepts, and State Data" [Machine-readable data file]. 1981.

_______. Bureau of Industrial Economics. 1982 U.S. Industrial Outlook for 200 Industries With Projections to 1986.

_______. Bureau of the Census. 1977 Census of Manufacturers: Texas Geographic Area Series. Vol. MC77-A-44. 1981.

_______. Bureau of the Census. 1980 Annual Survey of Manufacturers: Origin of Exports of Manufactured Products. Subject series M80(AS)-6.

Wilkerson, Robert M., ed. 1981 Worldwide Petrochemical Directory. Tulsa, Okla.: Penwell Publishing Co., 1980.

APPENDIX

Water Using Industries Referenced by Maps in Text

Pulp and Paper Industries

1. Champion International Corp.
2. Container Service Corp.
3. Equitable Bay Co. Inc.
4. Houston Corrugated Box Co.
5. International Paper Co.
6. Minnesota Mining and Manufacturing Co.
7. Owens-Illinois, Inc.
8. Southland Paper Co. (Houston Mill)
9. Southland Paper Co. (Lufkin Mill)
10. Temple-Eastex Incorporated (Devall Plant)
11. Temple-Eastex Incorporated (Evadale Mill)
12. United State Gypsum Co.

Chemical Industries

1. Air Products and Chemicals Inc.
   Lone Star Plant

2. Air Products and Chemicals Inc.
   La Porte Texas Facility

3. Allied Chemicals Corp.

4. American Cyanamid Co.

5. Amoco Chemical Corp.
   Chocolate Bayou Plant

6. Amoco Chemical Corp.
   Texas City Plant

7. Arbrook Inc. and Ortho Diagnostics

8. Arco - Polymers Inc.
   Monmument Resin Plant

9. Arco - Polymers Inc.
   Port Arthur Plant

10. Ashland Chemical Co.
    Shamrock Plant

11. Ashland Chemical Co.
    Aransas Pass Plant

12. Big Three Industries Inc.
    Bayport Plant

13. Big Three Industries Inc.
    Channelview Plant

14. Big Three Industries Inc.
    Beaumont Plant

15. Cabot Carbon Co.
    Pampa Plant

16. Celanese Chemical Co.
    Bay City Plant

17. Celanese Chemical Co.
    Bishop Plant

18. Celanese Chemical Co.
    Pampa Plant

19. Celanese Chemical Co.
    Clear Lake Plant

20. Celanese Chemical Co.
    Vernon Plant

21. Cities Service Oil Co., Columbian Division

22. Continental Carbon Co.
    Sunray Plant

23. Cook Paint and Varnish Co.

24. Diamond Shamrock Corp.
    Dallas Plant

25. Diamond Shamrock Corp.
    Battleground Plant

26. Diamond Shamrock Corp.
    Pasadena Plant

27. Diamond Shamrock Corp.
    Greens Bayou Plant

28. Diamond Shamrock Corp.
    McKee Plant

29. Diamond Shamrock Corp.
    Deer Park Works

30. Dixie Chemical Co.
    Bayport Plant

31. Dow Chemical Co.

32. E.I. Dupont De Nemours Co. Inc.
    Corpus Christi Plant

33. E.I. Dupont De Nemours Co. Inc.
    Beaumont Plant

34. E.I. Dupont De Nemours Co. Inc.
    Houston Plant

35. E.I. Dupont De Nemours Co. Inc.
    Sabine River Works

36. E.I. Dupont De Nemours Co. Inc.
    Victoria Plant

37. Ethyl Corporation

38. Fertilizer Co. of Texas

39. Firestone Tire - Rubber Co.
Orange Plant

40. F.M.C. Corp., Industrial Chemical Div.
Bayport Plant

41. G.A.F. Corporation, Chemical Group

42. B.F. Goodrich Chemical Co.
Port Neches Plant

43. B.F. Goodrich Chemical Co.
Orange Plant

44. Goodyear Tire - Rubber Co.
Houston Chemical Plant

45. Goodyear Tire - Rubber Co.
Beaumont Chemical Plant

46. Goodyear Tire - Rubber Co.
Bayport Chemical Plant

47. W.R. Grace & Co., Agricultural Chemical Group

48. Gulf Oil Chemical Co.
Cedar Bayou Olefin Plant

49. General Tire and Rubber Co., Chemical-Plastics Div.

50. Hooker Chemical and Plastics Corp.

51. J.M. Huber Corp. Carbon Division
Borger Plant

52. J.M. Huber Corp. Carbon Division
Baytown Plant

53. I.C.I. United States
Marshall Plant

54. Jefferson Chemical Co. Inc.
Research Laboratories

55. Jefferson Chemical Co. Inc.
Conroe Plant

56. Jefferson Chemical Co. Inc.
    Port Neches Plant

57. Kocide Chemical Corp.

58. Lubrizol Corp.

59. Merichem Co.

60. Mobay Chemical Co.
    Baytown Plant

61. Monsanto Chemical Co.
    Chocolate Bayou Plant

62. Monsanto Chemical Co.
    Texas City Plant

63. Nalco Chemical Co.
    Sugarland Plant

64. Nalco Chemical Co.
    Freeport Plant

65. National Starch and Chemical Corp.

66. Occidental Chemical Co.

67. Olin Corp., Agricultural Products Division
    Pasadena Plant

68. Olin Corp., Industrial Products Division
    Beaumont Plant

69. Oxirane Chemical Co.
    Pasadent Plant

70. Oxirane Chemical Co.
    Channelview Plant

71. Ozark Mahoning Co.
    Brownfield Plant

72. Ozark Mahoning Co.
    Cedar Lake Plant

73. Pennwalt Corp., Organic Chemicals Div.

74. Petrochemicals Co. Inc.
    Division Chatlem Drugs and Chemicals

75. Phillips Petroleum Co.
Adams Terminal

76. Phillips Petroleum Co.
Cactus Fertilizer Plant

77. Phillips Petroleum Co.
Echo Philback Plant

78. P.P.G. Industries Inc., Industrial Chemicals Div.

79. Potash Company of America

80. Procter and Gamble Mfg Co.
Dallas Plant

81. Quaker Oats Co., Chemical Division

82. The Paks Company

83. Reichhold Chemicals Inc., Southwest Division

84. Roxene Polyolefins Co.

85. Sid Richardson Carbon Co.

86. Shell Oil Co., Deer Park Manufacturing Complex

87. Soltex Polymer Corp.

88. Stauffer Chemical Company - Baytown Plant

89. Stauffer Chemical Company
Houston Plant

90. Stauffer Chemical Company
Fort Worth Plant

91. Stauffer Chemical Company
Pasadena Plant

92. Tenneco Chemicals Inc., Intermediate Div.

93. Texas Brine Corp.
Pierce Junction Plant

94. Texas Brine Corp.
Matagorda County Plant

95. Texas Eastman Company

96. Texas - U.S. Chemical Co.

97. Union Carbide Corp.
Deer Park Plant

98. Union Carbide Corp.
Seadrift Plant

99. Union Carbide Corp.
Brownsville Plant

100. Union Carbide Corp.
Texas City Plant

101. U.S. Industrial Chemicals Co.
Houston Plant

102. Velsical Chemical Corp.
Beaumont Plant

103. Vulcan Materials Co., Chemical Div.

104. Western Ammonia Corp., Subdivision of Goodpasture Inc.

Refineries

1. Adobe Refining Co.
2. American Petrofina, Big Spring (Cosden Oil & Chemical Co.)
3. American Petrofina, Port Arthur
4. Amoco Oil Co.
5. Atlantic Richfield Co.
6. Carbonite Refinery Inc (Mid-Tex Refining)
7. Champlin Petroleum Co.
8. Charter International Oil Co.
9. Chevron U.S.A. Inc.
10. Coastal States Petrochemical Co.
11. Crown Central Petroleum Co.
12. Diamond Shamrock Corp.
13. Dorchester Refining Co., Mount Pleasant (American Petrofina)
14. Dorchester Refining Co., White Deer
15. Eddy Refining Co.
16. Erickson Refining Co.
17. Exxon Co. U.S.A.
18. Flint Chemical Co.
19. Gulf Oil Co.
20. Gulf States Oil and Refining Co.
21. Howell Hydrocarbons
22. Independent Refining Co.
23. J and W Refining Co. (Sector Refining Co.)
24. La Gloria Oil and Gas Co.
25. Longview Refining Co. (Crystal Oil Co.)
26. Marathon Oil Co.
27. Mobil Oil Corp.
28. Phillips Petroleum Co., Borger
29. Phillips Petroleum Co., Sweeny
30. Pioneer Refining Co. Ltd.
31. Pride Refining Co. Inc.
32. Quintana-Howell Joint Venture
33. Quitman Refining Co. (Gulf States Oil and Refining Co.)
34. Rancho Refining Co. of Texas
35. Saber Refining Co.
36. Sentry Refining Inc.
37. Shell Oil Co., Deer Park
38. Shell Oil Co., Odessa
39. Sigmor Refining Co.
40. South Hampton Refining Co.
41. Southwestern Refining Co. Inc.
42. Sun Oil Co.
43. Tesoro Petroleum Corp.
44. Texaco Inc., Amarillo
45. Texaco Inc., El Paso
46. Texaco Inc., Port Arthur
47. Texaco Inc., Port Neches
48. Texas Asphalt and Refining Co.
49. Texas City Refining Co. Inc.
50. Thriftway Inc.
51. Tipperary Corp.
52. Uni Refinery Co.
53. Union Oil Company of California
54. Winston Refining Co.

Primary Metals Industry

1. Aluminum Company of America
   Anderson County Works

2. Aluminum Company of America
   Point Comfort Plant

3. Aluminum Company of America
   Rockdale Smelting Works

4. Aluminum Conductor Products Co.
   Scottsdale Plant, Marshall Works

5. American Magnesium Co.
   Snyder Plant

6. American Smelting and Refining Co.
   Amarillo Copper Refinery

7. American Smelting and Refining Co.
   Corpus Christi Plant

8. American Smelting and Refining Co.
   Dallas Plant

9. American Smelting and Refining Co.
   El Paso Smelting Works and Antimony Plant

10. Armco, Steel Corp.

11. Border Steel Mills

12. Chaparral Steel Company

13. Dow Chemical Co. U.S.A. Texas Div.

14. Falcon Steel Co.

15. Federated Metals

16. Georgetown Texas Steel Corp.

17. Gulf Chemical Metallurgical Co.

18. Gulf Reduction Corp.

19. Gulf States Tube Div.
    Quanex Corp.

20. Hitchcock Industries, Tex. Div.

21. Jones and Laughlin Steel Corp.

22. Lone Star Steel Co.
E.B. Germany Works

23. Murph Metals Inc.

24. N.L. Atlas Bradford

25. N.L. Industries Inc.
Antimony Division

26. N.L. Industries Inc.
Metal Div. Dallas Plant

27. National Pipe and Tube Co.

28. Phelps Dodge Refining Corp.

29. Phelps Dodge Copper Products Co.

30. Proler International
Vinton Plant

31. Proler International
Metal Chemical Division
Liberty Road Plant

32. Proler International
Wallisville Road Plant

33. Reynolds Metals Co.
Sherman Reduction Plant

34. Structural Metals Inc.

35. Texas Electric Steel Casting Co.

36. Texas Foundaries Inc.

37. Texas Reduction Corp.

38. Texas Steel Co.

39. Tyler Pipe Industries Inc.

40. United States Steel Corp.