ESTABLISHMENT OF OPERATIONAL GUIDELINES FOR TEXAS COASTAL ZONE MANAGEMENT

Final Report on WATER NEEDS AND RESIDUALS MANAGEMENT

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This is one in a series of eight final reports describing progress on this research project for the period June 1, 1972, to May 31, 1974. The eight reports are:

- Summary
- Economics & Land Use
- Water Needs & Residuals Management
- Estuarine Modeling
- Resource Capability Units
- Biological Uses Criteria
- Example Application I. Implications of Alternative Public Policy Decisions Concerning Growth & Environment on Coastal Electric Utilities
- Example Application II. Evaluation of Hypothetical Management Policies for the Coastal Bend Region

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SUMMARY

The Water Needs and Residuals Management task force has developed a methodology for assessing, both quantitatively and qualitatively, water requirements and residual generation resulting from the activities of man in the Texas Coastal Zone. The results of the study enabled a linkage between the water use and residuals generation data and demographic and economic projections for the future resulting from alternative management policies. The area for which the methodology was tested was the thirteen county Coastal Bend Council of Governments region with particular emphasis on the Corpus Christi Bay area.

Development of the methodology involved collection of data on (1) water use patterns of municipalities, industries and agricultural concerns; (2) wastewater flows from municipal wastewater treatment plants, industrial return flows, and storm runoff; (3) solid waste generation from municipalities and industries; and (4) air emissions from automobiles and industries. These data were associated with population for municipalities and employment for industries to generate coefficients of water use and residual generation. The coefficients for industrial water use and wastewater generation were not used in the final test of the methodology because the water use and wastewater generation data did not correlate with employment. In lieu of the coefficients, a survey of major water uses and wastewater discharges was used.

An analysis of the data for 1970, the base year for the study, led to a few conclusions as to the general availability of fresh water supplies, the wastewater and solid waste disposal situation, and the air pollution potential of the area. These conclusions summarize areas of particular interest when considering future development in the area.

The Nueces River and the water impounded in Lake Corpus Christi are the major sources of municipal and industrial water supplies in the Coastal Bend Area. Use of the water resources of the Lake Corpus Christi impoundment was divided about equally between municipalities and industries in 1970. Since ground water supplies in the Coastal Bend are generally of poor quality they will not be a viable alternative source in the absence of adequate supply from the Lake Corpus Christi impoundment. Irrigation of crop lands in 1970 was supplemental in nature due partly to the fact that few counties in the Coastal Bend had water resources of sufficient quantity and quality for irrigation purposes. Expansion of irrigated acreage in the future will be limited by the availability of useable water resources.

During normal periods the significant wastewater discharges to the Corpus Christi Bay System are municipal wastewater treatment plant effluents, industrial discharges, and brine discharges resulting from the production of oil and gas. During significant rainfall periods storm runoff is the dominant waste input to the bay.

Solid waste disposal is a major problem in the Coastal Bend. The land is the major depository of solid waste in the region. Most site operators in the region projected, in 1968, that the capacities of the existing disposal sites would be exhausted by 1973. Both municipalities and industries are dependent on these sites for the disposal of solid wastes. The problem is expected to remain critical because of the lack of geologically and hydrologically suitable sites.

Meteorological conditions in the Coastal Bend are not conducive to severe air pollution episodes. Prevailing southerly winds tend to dispense and dilute pollutants generated in the industrial zone toward unpopulated areas. Estimated emission levels for industries and private automobiles suggested that pollutant levels are unlikely to reach harmful concentrations even with very stable weather conditions.

RECOMMENDATIONS

Development of a workable methodology for the Coastal Zone was, in a few instances, hampered by the lack of both analytical tools and data resources. The major inadequacies are outlined below.

1. A more detailed study of runoff quality and quantity is essential to accurately assess the role of urban and agricultural storm runoff in the determination of water quality in Corpus Christi Bay. The data should be collected in the Corpus Christi area as opposed to application of storm models calibrated for other areas.

2. There is a need for better reporting or collection of quantity and quality of wastewater flows and pollution abatement equipment, including capital and operating costs for industries in the Coastal Bend area.

3. A study of effluent toxicity, which should include all major industrial dischargers and some of the municipal treatment plants, should be conducted to assess acute and sublethal toxicity loads on the Corpus Christi Bay System. This study should involve direct bioassay analysis of the industrial and municipal effluents.

4. More accurate data on solid sites, both existing and planned, for the entire Coastal Zone is needed as well as information on potential locations for future sites.

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CHAPTER I
INTRODUCTION

The overall objective of the Texas Coastal Zone Management Project was the development of a methodology and criteria for evaluating the economic and environmental effects of proposed policies for the management of the Texas Coastal Zone. The primary objective of the Water Needs and Residuals Management Task Force was the quantitative and qualitative assessment of water requirements and residuals generation resulting from man's activities in the Texas Coastal Zone. The assessments were used to estimate future water requirements and residual loads resulting from predicted levels of economic activity and population resulting from three hypothetical coastal zone management policies.

Particular emphasis in all areas of study was made on development of objective methods of analysis. The usefulness of the study is recognized as dependent on the ease with which an agency, or combination of agencies, whether state or national, can use the methodology developed to conduct similar studies.

Scope

Water use data were collected and analyzed for municipal, industrial, and agricultural consumers. The study of generation of residuals was divided into wastewater, solid waste and air pollutants. The wastewater analysis included flows from municipal wastewater treatment plants, industrial wastewater flows, brine wastes resulting from the production of oil and gas, and storm runoff. Solid waste generation and disposal was divided into municipal and industrial contributions. The analysis of air pollution was based on industrial and automotive sources.

Many of the studies concerned with industries are organized by standard industrial classification numbers. A summary of these classifications and a brief description of the industries they represent can be found in Appendix A. Since the projections of industrial economic activity were oriented around the economic sectors associated with a regional input/output model provided by another project task force, industries are frequently summarized by the sector numbers. A summary of the economic sectors and the standard industrial classifications included in each can be found in Appendix B.

The data base for the project was the 37 county area of the Texas Coastal Zone. As the entire coastal zone is too complex to enable an intensive study, a sub-area with typical problems of resource management and economic activity was selected. The area decided on was the Corpus Christi Bay area, where pressures to expand the industrial base in the area often appear in direct conflict with attempts to preserve or maintain the estuarine ecosystem. In order to study this area it was necessary to include areas contiguous where economic and natural resources are interrelated with those of the central metropolitan statistical area, Corpus Christi. The area selected for this purpose was the thirteen county area known as the Coastal Bend Council of Governments Area (referred to in the report as the Coastal Bend). The thirteen counties of the Coastal Bend Council of Governments are listed below.

1. Aransas County
2. Bee County
3. Brooks County
4. Duval County
5. Jim Wells County
6. Karnes County
7. Kenedy County
8. Kleberg County
9. Live Oak County
10. McMullen County
11. Nueces County
12. Refugio County
13. San Patricio County

The Corpus Christi Bay System is defined to include Corpus Christi Bay, Nueces Bay, Redfish Bay and parts of both Laguna Madre and Aransas Bay. The analysis of wastewater flows is oriented exclusively around this bay system because of the significance of man's activities in the Corpus Christi metropolitan area in determining water quality in the Bay. The counties bordering the Corpus Christi Bay System are Nueces, San Patricio and Aransas Counties.

Chapters of this report are intended to establish conditions as they existed in 1970 and to explain the procedures used to make estimates for 1980 and 1990 as if three hypothetical coastal zone management policies were being implemented. The policies evaluated are: 1. no change in public environmental policies through 1990 with growth, both economic and demographic, proceeding as it has in the past; 2. no new construction within 1,500 feet of the mean high tide level after 1980; and 3. best available treatment of wastewaters economically achievable by 1980 and zero discharge of pollutants by 1990. The results of the evaluation of economic and environmental impacts of the three hypothetical management policies by the entire project staff is presented in a separate report entitled, "Example Application II. Evaluation of Hypothetical Management Policies for the Coastal Bend Region".

The basic constraint imposed upon the work of this task force was the limitation of data and analytical tools to those available to state agencies. This constraint was required because of the need to implement coastal zone management policies now, not some distant future when new research technology could be transferred to state agencies. A basic assumption used to enable predictions based on the data for 1970 was the assumption of constant technological coefficients, which is interpreted to mean water use patterns and waste generation patterns will remain the same through 1990; i.e. technological changes between 1970 and 1990 will not be estimated.

Methodology

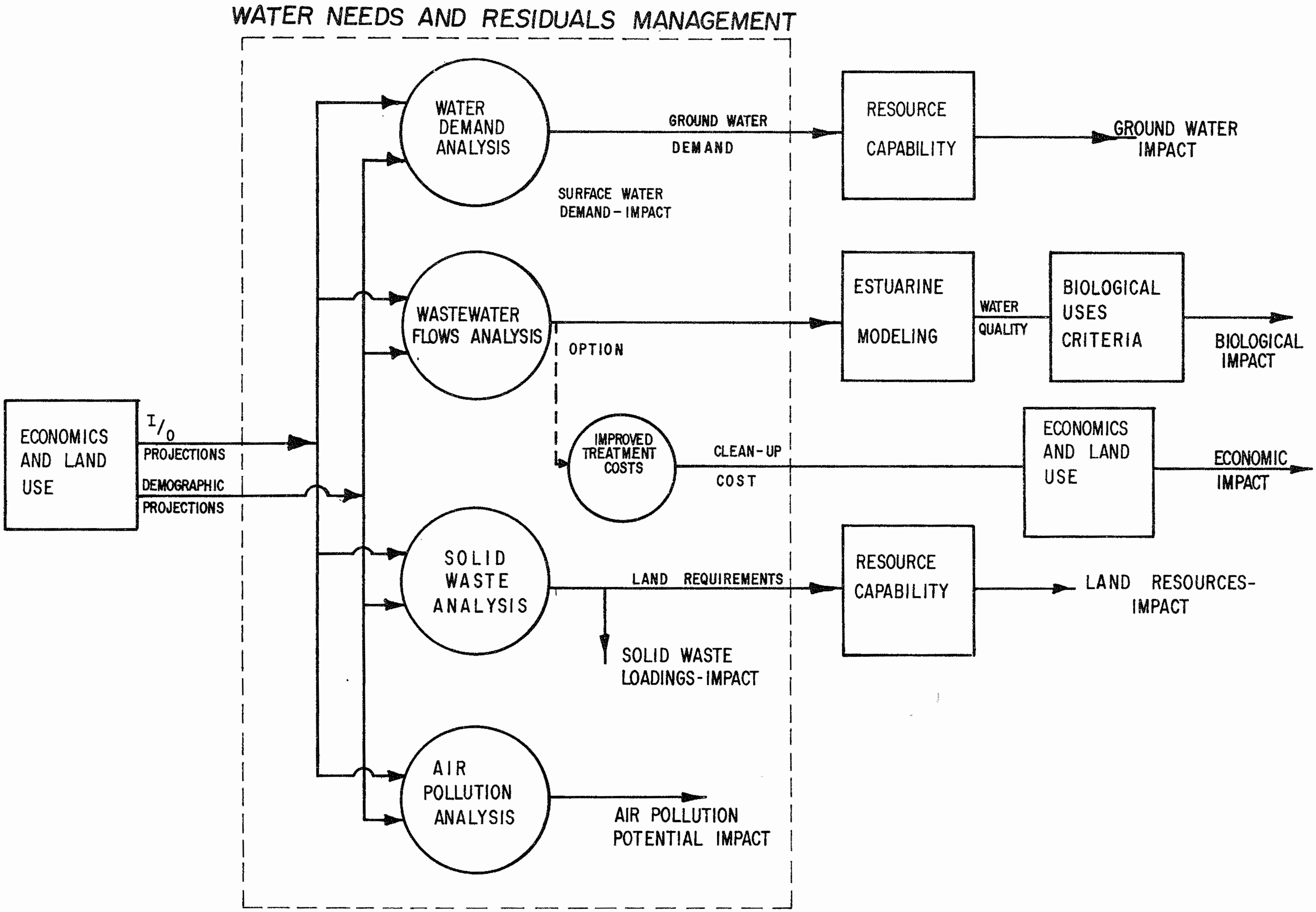
The objectives of the project included the development and evaluation of a methodology for effective management of the Texas Coastal Zone. The specific components of the methodology developed by the Water Needs and Residuals Management Task Force are presented in this section and the interrelationships of the duties performed by this group and other task forces are defined.

The first step in the development of the process was the definition of the analytical techniques and data required for the analyses. Each task force identified its data requirements and the data to be supplied to other task forces. The Water Needs and Residuals Management Task Force required input data from only one group, the Economics and Land Use Task Force. The resultant data generated on water requirements and residuals were used as input to three other task forces, namely Resource Capability, Estuarine Modeling, and Economics and Land Use. A diagrammatic interpretation of this data flow and duties performed specific to the Water Needs and Residuals Management Task Force is presented in Figure I-1. This diagram summarizes only the duties of this task force and does not represent all the interactions among the individual groups involved in the project as a whole.

The input data required by the Water Needs and Residuals Management Task Force to assess any management policy affecting resource utilization are the resultant economic and demographic projections provided by the Economics and Land Use Task Force. These data provided a basis for the assessment of water use and waste loadings. Final analysis of the impact of water demand on the available surface supplies, solid waste loadings on capacity of facilities, and air pollutant loadings on air quality were completed by this task force. Final projections of ground water demand, wastewater flows and quality, treatment costs, and land requirements for solid

FIGURE I-1

DATA FLOW BETWEEN WATER NEEDS & RESIDUALS MANAGEMENT & OTHER TASK FORCES



waste disposal were transmitted to other task forces who developed the impact analyses.

The details of the interactive process are illustrated by a discussion of the various linkages between the Water Needs & Residuals Management and other task forces. The example used will be the assessment of the municipal water demand component of the total water demand analysis. A diagrammatic breakdown of the water demand analysis depicted in Figure I-1 is presented in Figure I-2.

The input data are the county-wide population projections generated by the Economics and Land Use group and are summarized in Table I-1. These data are used in conjunction with the municipal water use coefficients (see Chapter II) which summarize the patterns of residential, commercial, and institutional water use in the county. The total water demand per county was divided into ground water and surface water demands based on the sources of water available in 1970. The surface water analysis including impact on available supplies was completed by this task force while the demand on ground water supplies, as tabulated in Table I-2, was transmitted to the Resource Capability group which related the demand to known ground water supplies in the counties.

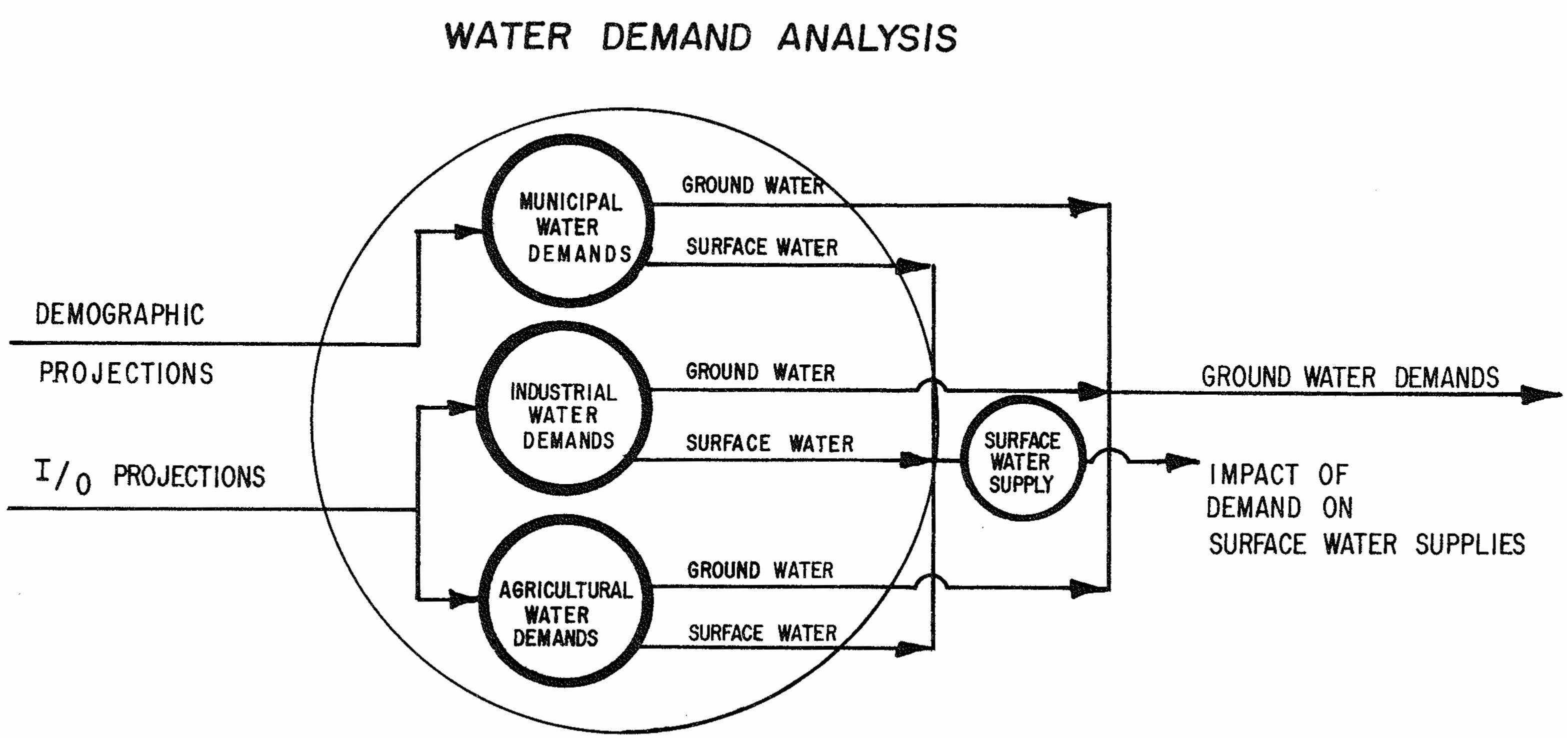


FIGURE I-2
DATA FLOW FOR THE ANALYSIS OF FRESH WATER DEMAND

TABLE I-1
COUNTY POPULATION PROJECTIONS

County	Population 1970[1]	1980[2]	1990[2]
Aransas	8,902	10,210	11,267
Bee	22,737	23,360	25,072
Brooks	8,005	7,587	7,344
Duval	11,722	11,074	11,227
Jim Wells	33,032	27,296	19,175
Karnes	13,462	12,875	12,997
Kenedy	678	612	612
Kleberg	33,166	37,395	42,618
Live Oak	6,697	6,054	5,720
McMullen	1,095	1,136	1,209
Nueces	237,544	248,246	299,483
Refugio	9,494	6,625	4,308
San Patricio	47,285	46,755	43,861

[1] 1970 Census

[2] Projected by the Economics and Land Use Task Force

TABLE I-2
AVERAGE DAILY MUNICIPAL WATER DEMAND ON
GROUND WATER SUPPLIES 1970, 1980, 1990

County	Millions of Gallons Per Day 1970[1]	1980	1990
Aransas	1.18	1.36	1.50
Bee	2.58	2.65	2.84
Brooks	1.00	0.95	0.92
Duval	0.92	0.87	0.89
Jim Wells	0.92	0.76	0.53
Karnes	1.26	1.20	1.22
Kenedy	0.07	0.07	0.07
Kleberg	6.60	7.44	8.47
Live Oak	0.31	0.28	0.27
McMullen	0.11	0.11	0.11
Refugio	0.63	0.44	0.28
San Patricio	0.96	0.95	0.89

[1] Texas State Department of Health data

CHAPTER II
DATA MANAGEMENT

The information needed to fulfill the objectives of the study were collected in the first year of the project. The data were contained in reports, on magnetic tapes, in files, on survey sheets and in various publications. In order to manipulate and analyze the vast quantity of data, a data management system was developed. The various state and federal agencies which contributed information to the data management system are listed in Table II-1. The data bank was oriented around water information, water use, wastewater flows, and stream quality, as these data constituted the majority of information needed in the investigation of three hypothetical coastal zone management policies.

Various forms and formats of data were encountered; therefore a data management system tailored to the needs of the project had to be designed and implemented. Objectives of the system included the following:

1. ability to retrieve data by county, river basin, standard industrial classification, and location (longitude and latitude boundaries);
2. ability to edit data files quickly and easily; and
3. ability to cross reference data originating from different sources.

These objectives were met by using the timesharing system at The University of Texas at Austin known as TAURUS. The TAURUS system ties into the CDC 6600 via telephone lines and involves the use of a teletype or cathode ray tube terminal. The first step in the development of the data management system involved transforming the various data formats into tape files which were easily accessible by TAURUS terminals. An inventory system was created and a procedure outlined to sequence data files according to a system of identification numbers developed by the Task Force. The data retrieval programs were written and the system was designed to enable expansion of retrieval to include any numerical identification in the data; i.e. river basin number, longitude-latitude, standard industrial classification number, etc.

The TAURUS interactive system, via cathode ray tube terminal provided an alternative to bulky computer cards. Data files stored on magnetic tapes were listed, altered, and merged with other files, faster and with more flexibility than was possible with other systems. When a retrieval program was run from TAURUS, instructions were listed and requests typed in over the terminal simplifying use of the system to enable personnel unfamiliar with programming techniques to assess the data needed.

The inventory files for water use data and the files for wastewater discharge data were organized and constructed in the same manner. The discharge inventory is described below as an example. Each outfall of each industrial or municipal site was assigned an identification number composed of a number between 1 and 37 to the left of the decimal point representing the county of the Coastal Zone; the next three digits, to the right of the decimal point, denote a specific industry or municipality (.001 to .699 denotes industrial discharge, .700 to .999 denotes municipal discharge); the last three digits specify the outfall. In addition to the identification number, each inventory listing consisted of additional descriptive information such as river basin, standard industrial classification, community, longitude and latitude, waterway, population if discharge is a community, or employment if it is an industry. In order to facilitate cross referencing and verification of data, the inventory also contained the Texas Water Quality Board permit number, the Texas State Department of Health identification number and indication of which data files contained information for the site inventoried.

When a new data file or an update of an old file was obtained, each inventory entry for which there already existed data was merged with the new data. If new sites were found in the data, the inventory was edited via a TAURUS terminal to include the new information. A program scans the cross reference section of each inventory entry to determine if the entry should be included on a temporary file, later to be merged with the data file. In this way, the data file which is used in the data retrieval system is built.

In present form, the retrieval program accepts input from the user, calling up the data file which needs to be listed. The system user must then determine whether the data is to be organized by identification number, county, river basin, standard industrial classification, or longitude and latitude boundaries. The resultant output includes both inventory information, including cross referencing information, and the requested data.

TABLE II-1
SOURCES OF DATA

TYPE OF DATA	AGENCY	FORM	REMARKS
Water Use			
Surface Water Use	Texas Water Rights Comm.	Tape	Check on diversions, surface water use
Agricultural Water Use	Texas Water Development Bd.	Report	Tabulation of county-wide waster use for irrigation
Municipal Water Use-surface & ground water	Texas Dept. of Health	Files	Study on water balance, use & return, for COG
Industrial Water Use	Environmental Protection Ag.	Reports (files)	Water use coefficients for industry
	Texas List of Manufacturers	Report (pub.)	Check on water use coefficients
Diversions from Lower Nueces	Lower Nueces River Authority	Data sheets	Diversions study on lower Nueces
Water Quality Data			
Industrial Waste Water	Army Corps of Engineers (EPA)	Reports	Waste water coefficients--industry
	Texas Water Quality Board	Tapes: (1) WCO; (2) Self Reporting	Waste water coefficients--industry
Industrial Waste Water (oil field brine)	Texas Railroad Commission	Files	Check on coefficients
Municipal Waste Flow	Texas State Dept. of Health	Tape	Municipal waste water coefficients
	Texas Water Quality Board	Tape: (1) WCO; (2) Self Reporting	Municipal waste water coefficients
Rivers & Creek Quality 1. Flow 2. Quality	U. S. Geological Survey	Reports, Tape	Quality & quantity of flow into estuaries for loadings study
Solid Wastes			
Municipal Solid Wastes	Texas State Dept. of Health	Reports	Municipal Solid waste coefficients
Industrial Solid Wastes	Texas Water Quality Board	Publications	Industrial solid waste coefficients
Air Emissions			
Industrial	Texas Air Control Board	Agency files; reports	Air emission coefficients--industrial
Employment	Texas Employment Commission	Computer runs	Employment for industrial coefficients
Population	U. S. Census Bureau	Report	Population for domestic waste coefficients

CHAPTER III
WATER REQUIREMENTS

The objective of the study of water requirements was to describe both quantitatively and qualitatively the uses of fresh water supplies and the sources available in the Coastal Bend Area and to develop a means of associating water use with economic and demographic projections which would be the result of alternative management policies for the area. The major users of fresh water supplies were identified as municipal, industrial, and agricultural concerns. The original plan for accomplishing the objectives of the study involved calculation of water use coefficients which were to be generated by dividing total gallons of water used in 1970 by (1) population for municipal coefficients, (2) employees for industrial coefficients, and (3) acres of irrigated crops for agricultural coefficients.

The study was limited to a quantitative and qualitative description of water use patterns in 1970 which were assumed to remain constant and, therefore, no considerations were given to constraints associated with cost and availability of supply.

Municipal Water Use

General

Municipal water use is defined, for the purposes of this report, to include the following demands:

(1) residential;

(2) institutional (hospitals, schools, and churches);

(3) public departments and offices;

(4) parks; and

(5) commercial establishments.

Commercial establishments are included since this group provides the basic goods and services necessary to support the community and the commercial water requirements proportional to the population of the community. Industrial water users of municipal supplies will be treated separately in a later section of this chapter.

The purpose of analyzing water use patterns by the various components outlined above is the generation of water use coefficients that in turn will enable prediction of water needs in planning for the future. Such coefficients are calculated by dividing water use for some period (i.e., monthly, yearly, etc.) by the population of the community at that same time.

There are certain cautions which should be understood regarding the generation of water coefficients from basic data and the use of the coefficients for predictive purposes. The basic problem with developing one number to represent the water use patterns of a community is that the number is not static in time. The coefficients may be expected to vary by ±20% or more on a month to month basis depending primarily on climatic conditions. Climatic conditions and technological changes also tend to cause considerable variance in the coefficients on a year to year basis. The basic decision centers around what kind of conclusion is desired, i.e., conservative or average. If the purpose of a study is to examine the peak demand based on historical data the best data to use would be for the driest period on record. Perhaps a better way would be to calculate an average for the data on record, which will probably involve some estimates of population, and indicate the variance expected within some percentage to develop the range of demand to be anticipated.

Another major problem is associating some population, as water users, with the data for water used. The main source of population data is the U.S. Department of Commerce Census Bureau which collects data every 10 years. However, the population for intercensal or postcensal years must be estimated from other data such as number of school children or utility connections, etc. Some areas, such as the Coastal Bend of Texas, have a significant number of transient water users, or tourists, which are not included in census statistics. Therefore, the calculated coefficients were based on the permanent population and on the assumption that the ratio of permanent residents to tourists remains relatively constant. On the other hand if water demand as a function of tourism is necessary, then accurate historical data relating to tourists will be necessary.

The alternative to generating one number to represent water use under some stated condition is the development of a model or equation to describe the dependence of the coefficient on such factors as rainfall, climate, antecedent dry period, technology, permanent and transient population, and affluence of the population served. Such a study would require a great deal of reliable data collected for many years. In this study, a model was applied to the Corpus Christi area but the effort collapsed when difficulties were encountered in developing a good correlation with rainfall, which should have been the easiest correlation. Assuming such a project is feasible, perhaps for a wider area, it would be possible to incorporate values into the equation for climatic conditions, expected population, technological changes, etc., and calculate a water use coefficient tailored for the conditions of the study.

Municipal Water Use Coefficients for the Coastal Bend Area

The basic source of municipal water use data in the Coastal Bend was the Texas State Department of Health records for 1972. These files contained information on total water pumped from wells and surface water sources which were treated or used, all or in part, as municipal drinking water supplies. The data include pump capacities, estimates of population served, and average daily water usage. The ground water use data included the depths and locations of the wells. The data are filed yearly by the water utility districts and well owners.

The water use pattern was studied in greater depth, using the annual statistical report of the Water Division of the City of Corpus Christi. This document enabled a study of water use by the various subcategories (households, commercial establishments, etc.). The gross water use minus the industrial use for each of the years was related to rainfall for those years in an attempt to develop a correlation based on climatic factors. A reasonable correlation did not exist, probably because the total water use for any year is dependent on the pattern of rainfall, i.e., antecedent dry period. The rainfall intensity and frequency are more significant than the total rainfall for the year. However the coefficient was based on the actual data reported for 1970, which reflect the climatic conditions and other factors of that year for Corpus Christi. This approach is consistent with the assumption of constant technological coefficients.

About 60 per cent of the total municipal water supplies in the Coastal Bend are provided by the facilities of the Corpus Christi Water Division, and specific breakdowns into user categories for other cities were not attempted.

A summary of the Texas State Department of Health data is presented in Tables III-1 and III-2. The total average daily water use in millions of gallons per day, listed in the tables, includes the water sold to industries in some counties. These data, along with the information on industrial water purchases obtained from the Corpus Christi Water Division, were used to calculate the municipal water use coefficients presented in Table III-3. The estimates of population served from Tables III-1 and III-2 were generally lower than the 1970 census population for the same areas. The population base for the coefficients in Table III-3 was the 1970 census and not the estimated population served (except for Aransas County and the A&I University estimate for Kleberg County). The unusually high coefficient for Kleberg probably is the result of industrial water sales. The relatively low coefficients calculated for Refugio and San Patricio Counties are difficult to explain but might be caused by the use of facilities not covered by the Health Department survey in 1972.

Estimates of municipal water needs in 1980 and 1990, for the evaluation

TABLE III-1

GROUND WATER USAGE - PUBLIC

County	Facility/Supplier	Water Connections	Population Served	Daily use MGD	Gal/cap-day
Aransas	Baumgart WSC	245	850	0.005	5.88
	Copano Cove WC	120	350	0.02	57.14
	Key Allegro WC	190	500	0.05	100.00
	Lamar Waterworks	149	530	0.06	113.21
	Oak WSC (Sold to Baumgart)		340	0.025	73.53
	Palm Harbor Subdivision	68	240	0.0096	40.00
	Peninsula Oaks	45	170	0.015	88.24
	City of Rockport	2,657	6,000	1.0	166.67
Bee	City of Beeville	4,480	17,000	2.5	147.06
	Pawnee Independent School District	9	275	0.01	36.36
	Pettus MUD	228	600	0.07	116.67
Brooks	City of Falfurias Utility Board	2,134	7,100	1.0	140.85
Duval	Duval County (San Diego)	1,100	4,490	0.325	72.38
	Duval County (Realtos)	96	400	unknown	
	Freer WCID	979	2,200	0.3	136.36
	Duval County (Conception)	47	200	unknown	
	Duval County (Benavides)	680	1,900	0.3	157.89
Jim Wells	City of Orange Grove	420	1,100	0.118	107.27
	Premont	937	3,282	0.8	243.75
Karnes	Falls City	173	460	0.06	130.43
	City of Karnes	950	3,146	0.25	79.47
	City of Kenedy	1,350	4,100	0.85	207.32
	City of Runge	422	1,150	0.1	86.96
Kleberg	City of Kingsville	6,995	30,000	6.8	226.67
	Ricardo Water Supply Corporation	102	350	0.027	77.14
	Riviera Water Supply	170	700	0.06	85.71
	Texas A & I University	51	8,000	1.1	137.50

TABLE III-1
(contd.)

County	Facility/Supplier	Water Connections	Population Served	Daily use MGD	Gal/cap-day
Live Oak	City of George West	620	2,100	0.16	76.19
	Lake Vista Utilities Company	180	1,000	0.15	150.00
McMullen	McMullen County WCID #2 (Calliham)	52	150		
	McMullen County WCID #2 (Tilden)	135	500		
Nueces	City of Agua Dulce	275	850	0.042	49.41
	City of Bishop	1,140	4,000	0.395	98.75
	City of Driscoll	185	669	0.03	44.84
	Nueces County WCID #5	185	620	0.023	37.10
Refugio	Refugio County WCID #1 (Tivoli)	242	700	0.016	22.86
	City of Austwell	102	300	0.015	50.00
	Bayside Water Systems, Inc.	60	250	0.008	32.00
	City of Refugio	1,465	4,300	0.5	116.28
	Woodsboro	678	2,100	0.09	42.86
San Patricio	City of Mathis	1,358	5,300	0.45	84.91
	St. Paul WSC	68	210	0.013	61.90
	City of Sinton	1,870	5,563	0.5	89.88

SOURCE: Texas State Department of Health

TABLE III-2

SURFACE WATER USAGE - PUBLIC

County	Facility/Supplier	Water Connections	Population Served	Daily use MGD	Gal/cap-day
Jim Wells	City of Alice (Lake Corpus Christi)	6,229	28,000	3.0	107.14
Live Oak	City of Three Rivers (Nueces River)	670	1,767	0.4	226.37
Nueces	City of Corpus Christi (Same)	54,057	204,000	56.3	
	Violet Water Supply (City of Corpus Christi)	127	450	0.026	57.78
	Nueces County FWSD #1 Clarkwood (City of Corpus Christi)	325	2,000	0.07	
	Nueces County WCID #3 Robstown	4,195	20,000	1.75	87.50
	River Acres WSC (Nueces County WCID #3)	232	1,400	1.0	
	Nueces County WCID #4 Port Aransas	837	2,500	0.5	
San Patricio	City of Aransas Pass (San Patricio MWD)	2,200	7,500	1.0	133.33
	City of Gregory (San Patricio MWD)	560	2,270	0.015	
	City of Ingleside (San Patricio MWD)	1,500	4,500	0.35	
	City of Odem (San Patricio MWD)	694	2,130	0.2	

SOURCE: Texas State Department of Health

TABLE III-3
SUMMARY OF MUNICIPAL WATER USE COEFFICIENTS
FOR COUNTIES IN THE COASTAL BEND

County	Water Use Coefficient gal/capita/day	Source(s) Ground per cent	Surface (Nueces River) per cent
Aransas	131.92	100	0
Bee	113.47	100	0
Brooks	124.92	100	0
Duval	78.9	100	0
Jim Wells	118.61	23.4	76.6
Karnes	93.6	100	0
Kenedy	No Data		
Kleberg	198.85	100	0
Live Oak	106.02	43.7	56.3
McMullen	No Data		
Nueces	124.42	0	100
Refugio	66.25	100	0
San Patricio	53.46	38.1	61.9

SOURCE: Texas State Department of Health

TABLE III-4
COMPONENTS OF THE MUNICIPAL WATER USE
COEFFICIENT FOR CORPUS CHRISTI
(1970)

	Non-Industrial Users per cent	All Users per cent
Residential	64.16	33.30
Hospitals, Schools & Churches	4.7	2.44
City	1.05	.55
Parks	2.06	1.07
Commercial	28.03	14.55
Industrial	___	48.09
TOTAL	100	100

of hypothetical policies, were made by using the county water use coefficients in conjunction with the demographic projections generated by the Economics and Land Use Task Force.

The components of the municipal water use coefficient for the City of Corpus Christi are illustrated in Table III-4. The far right-hand column represents the percentages of water purchased by all users. These data reflect the dependence of industry on municipal water supplies.

The water quality requirements of importance for municipal supplies can be summarized into a few criteria, the raw water supply must be free of toxic materials, taste and odor problems, and have a dissolved solids concentration less than 500 mg/l (Texas State Department of Health, 1970). The range of concentration of dissolved solids in municipal water supplies in the Coastal Bend range from 300 to 2300 mg/l and average around 1000 mg/l (Texas State Department of Health, 1970). It is evident that good quality water supplies are scarce in the area. The Corpus Christi area suffers from a lack of ground water resources of suitable dissolved solids concentration to be a viable alternative in the event of supply problems from the Nueces River. The protection of water quality in the Nueces watershed is essential to insure a sufficient water supply for public consumption.

Industrial Water Use

General

Industrial water use includes water from both fresh and saline sources in the Texas Gulf Coast. For all practical purposes saline waters are used only for cooling purposes.

In general, in those areas where fresh water is scarce most of the water for cooling is saline. A high percentage of saline water intake therefore is a good index of problems of supply of fresh water such as high cost of purchased water, lack of good ground water supplies or just non-availability of fresh water sources. Capital costs of equipment and operation and maintenance costs for once through cooling processes using saline waters are slightly higher than those for fresh water sources, creating economic incentives to develop fresh water supplies where possible. Salt water supplies are generally unsuitable for anything but cooling.

The overall industrial water requirements are illustrated in Figure III-1. Industries in the Coastal Zone, using saline water for cooling, would have the option of a separate system combining with fresh water flow only at the discharge. For simplicity, only a single source of intake water is shown

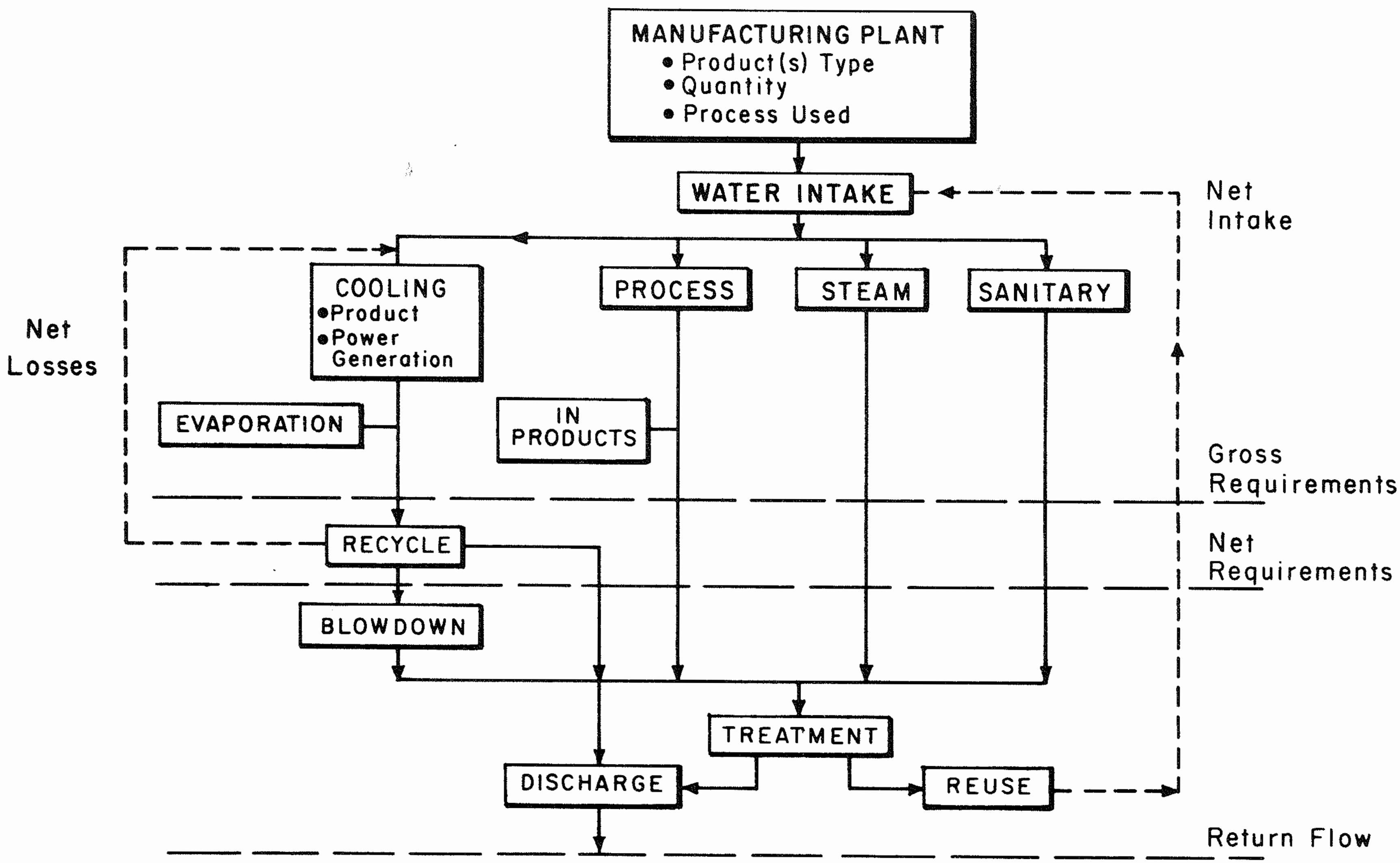


FIGURE III-1 GENERAL PROCEDURE FOR ESTIMATING WATER REQUIREMENTS while in practice water quality requirements, and sometimes sources, vary for each of the four illustrated uses of water. An example of water quality requirements for cooling, process, and steam generation are presented in Table III-5. The requirements for sanitary purposes are essentially those of drinking water, and other personnel uses. An industry could purchase water from a municipal supply to satisfy sanitary and boiler feed requirements, and could treat ground water for process feed. In addition, saline water could be pumped from a bay or estuary for cooling purposes. This multiplicity of sources must be taken into account when examining industial water use patterns and options for the future.

A major problem with collecting water use data from an industrial plant is that many plants produce a variety of intermediate products and slightly fewer final products at the same location, and water use data are not broken down into the specific processes where the water is actually used.

Water Use Coefficients

A definite need exists for some means of predicting the water requirements of industries. Water resource analysis on the national, state, or local level requires some means of processing industrial water requirements into coefficients that can be used readily for predictive purposes. The desired end result is a coefficient which is determined by dividing the total water used by plants in an industry, i.e., plants producing the same or similar products, by the production or employment data for the industry. A coefficient might be based on any number of individual plants for which data are available, but the extent to which the coefficient is useful is the extent to which a correlation may be drawn between water use and production or employment for each of the data points. A plot of water use in some appropriate units versus production or employment can be used to evaluate the correlation.

The independent variables most commonly used are production and/or employment. The latter is easily accessible. If production data are available and accurate, they are preferable. Employment may be used based on the assumption that employment is directly proportional to production which, in turn, is directly proportional to water use. The correlation of water use with production data suggests that deviations in the data are caused primarily by technological differences, i.e., advanced technology processes require less water than old technology processes in refineries. The end effect of correlating water use with employment is to add one more assumption to the chain of dependencies.

There is a basic, difficult to circumvent, problem with obtaining, interpreting and using employment data. That problem is in separating the number

TABLE III-5

WATER QUALITY REQUIREMENTS OF INDUSTRIAL WATER USES[1]

(SIC 28 & 29)

CHARACTERISTICS (mg/l)	COOLING WATER[2] FRESH	COOLING WATER[2] BRACKISH	PROCESS WATER[3]	BOILER FEED (STEAM GENERATION) 0-150 psig	BOILER FEED (STEAM GENERATION) 1500-2000 psig
Dissolved Solids (TDS)	1000	35000	970	700-5000	0.5 -750
Suspended Solids (SS)	5000	2500	10	10- 600	0.05- 60
Chemical Oxygen Demand (COD)	75	75		5	0.0
Dissolved Oxygen (DO)				0.015- 2.5	.007
pH (units)	5.0-8.3	6.0-8.3	6.5-8.0	7-10.0	8.8 -10.8
Temperature (F)					
Hardness	850	6250	250	0- 350	0
Alkalinity	500	115	125	140	150
Acidity				0	0
Color (Co units)			20		
Hydrogen Sulfide (H_2S)					
Chloride (Cl^-)	600	19000	300		
Sulfate (SO_4^-)	680	2700	100		
Calcium (Ca)	200	420	68		.01
Nitrate (NO_3^-)			5		
Phosphate (PO_4^-)				40- 80	20- 40
Silica (SiO_2)	50	25	50	30- 133	0.8-1.1
Magnesium (Mn)			.1	0.3	0.01
Iron (Fe)			.1	1	0.01

[1] At Point of Use
[2] Once Through Cooling
[3] Maximum Requirements

of employees involved in the operation of the plant from the total number of employees of the company. If employment data are expected to correlate with water use data the employment must be based only on those individuals directly related to the production processes of the plant. The advantage to using employment data is ready availability while production data are difficult to obtain.

The data should be selected from areas of similar water availability and cost constraints since these factors play a major role in water use or conservation. The correlation of water use with some independent variable, such as production or employment, may be maximized under the following conditions:

(1) the basic unit of analysis should be single product plants, i.e., same basic products rather than aggregations of similar products;
(2) plants should have the same constraints of water cost and availability; and
(3) the independent variable should be production, however if employment data only are available, the employees involved in production only should be included.

It is highly unlikely that all the above criteria can be met for any industry. Any aggregations of data from the one product, one plant level will obviously diminish the correlation.

Industrial Water Use Coefficients for The Coastal Zone

The specific area under study does not have an industrial base large enough to study industrial water use coefficients. The entire Texas Coastal Zone, however, is sufficiently large and was used as a data base for a study into industrial water use coefficients.

The study was based on two digit (highly aggregated data) and four digit (specific products) Standard Industrial Classifications. Water use was correlated with employment in all cases and in one case production data also were used.

Two sources of water intake data were used: the U. S. Army Corps of Engineers' permits to discharge into navigable waters and the industrial water use survey of 1970 conducted by the Texas Water Development Board.

A good correlation between employment and water use was observed in only two of the seven industrial groups based on two digit Standard Industrial Classifications. Insufficient data were available for two of the seven industries and the other three did not correlate well. One of the highly aggregated groups, SIC 26, was broken down into six four-digit groups. One category showed an excellent correlation (coefficient of correlation $\geq .99$), two categories showed good correlation (coefficient of correlation $> .9$), and two categories were fair (coefficient of correlation $> .8$). An example of a typical excellent and a poor correlation is illustrated in Figures III-2 and III-3, respectively. All the graphs of water use versus employment can be found in Appendix C.

The statistical analysis of employment and water use data was applied to the Coastal Bend. In order to evaluate the water use coefficients in the Coastal Bend, an independent source of employment had to be used. The employment source used was the Texas Employment Commission data for counties in the Coastal Bend area. However, the water use coefficients were based on employment in operations while the Texas Employment Commission lists gross employment. In order to make some estimation the number of employees in operations for various firms, the Texas Water Development Board data were compared to the Texas Employment Commission total employment data for each firm. It was assumed that this ratio of employees in operations to total employees was the same for all firms in the industrial classification. The predicted water use for 1970 was 100 per cent larger than the amount actually used based on this approach of allocation of employment by a fixed ration. The accuracy required was much greater; therefore, the method of water use coefficients for predicting quantitative use patterns in the Coastal Bend was abandoned. An illustration of the differences in data base and water use coefficients for the Coastal Bend and the Coastal Zone for four-digit classifications is presented in Table III-6. It is apparent from the table that insufficient data were available for most of the four-digit classifications. It is doubtful that generalized industrial water use coefficients can be useful in analyzing use of water resources in any area, except as a rapid, order of magnitude approximation. These estimates can be useful in predicting possible water demands by new industries planning to move into an area such as the Coastal Zone.

The method used to predict water use involved an inventory of water users. The Texas Water Development Board survey data for the Coastal Bend was tabulated into surface and ground water use for the industries. The surface water use data indicate that although the industries covered by the Texas Water Development Board survey numbered only 14 and the City of Corpus Christi reported 61 industrial purchasers of surface water supplies, the 14 industries accounted for 85 per cent of the total amount of water sold in 1970. Compared to the method of using industrial water use coefficients based on data from the whole Coastal Zone, the tabulation method was preferred. Table III-7 is a tabulation of the major uses and sources of water.

Prediction of water requirements for 1980 and 1990 will be accomplished

FIGURE III-2
SIC 2819, DATA FROM 1970 TWDB WATER SUMMARY

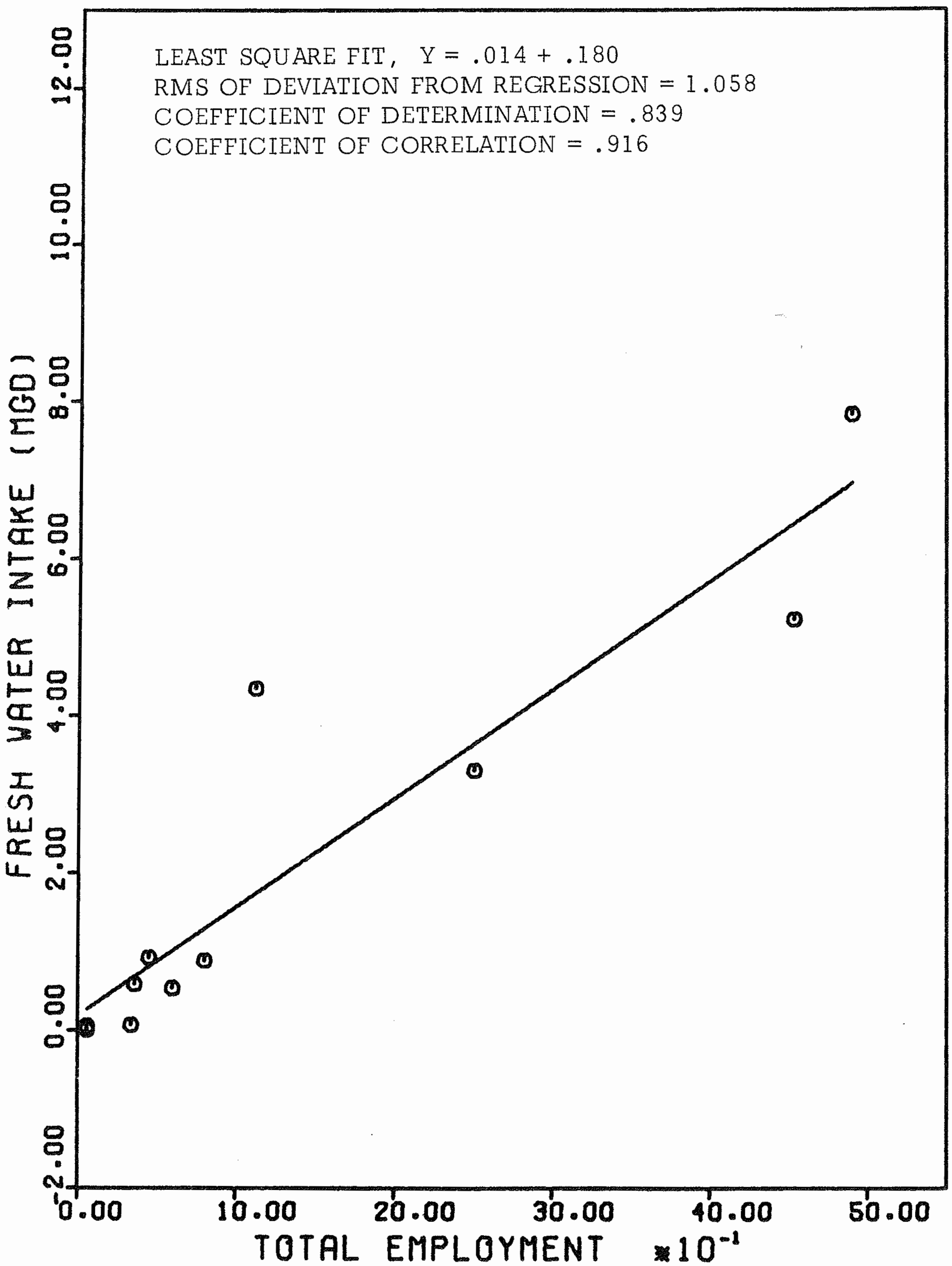


FIGURE III-3
SIC 32, DATA FROM 1970 TWDB WATER SUMMARY

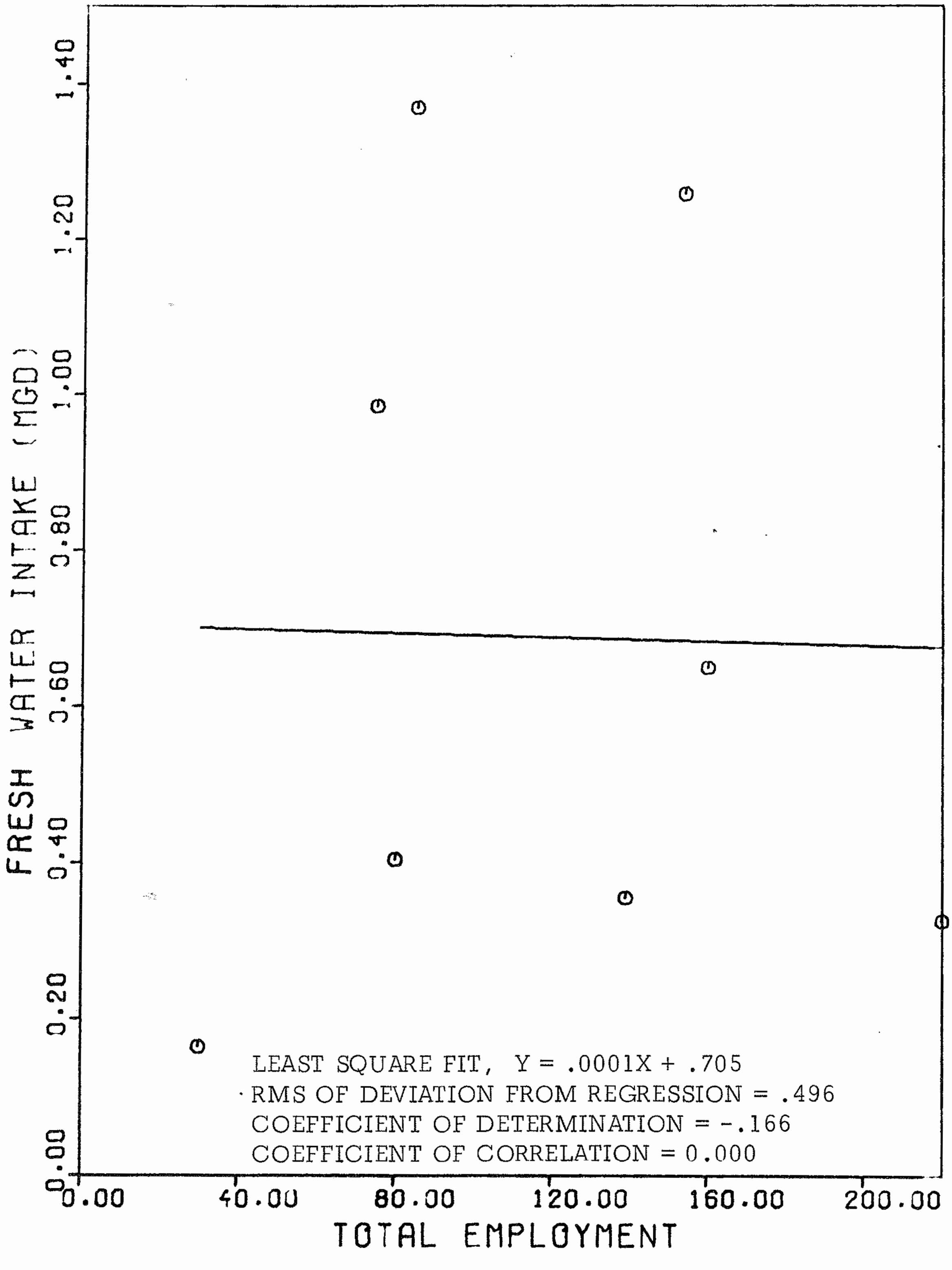


TABLE III-6
COMPARISON OF INDUSTRIAL WATER USE COEFFICIENTS
COASTAL BEND AND COASTAL ZONE

Standard Industrial Classification	Gallons/Year/Employee - (No. of Industries)	
	Coastal Bend	Coastal Zone
1321	4.5014×10^6 - (16)	4.9570×10^6 - (28)
1389	4.100×10^6 - (1)	4.1000×10^6 - (1)
2024		0.049×10^6 - (1)
2037		0.121×10^6 - (1)
2046	2.0946×10^6 - (1)	2.0946×10^6 - (1)
2511		$.002 \times 10^6$ - (1)
2812	2.0663×10^6 - (1)	2.0663×10^6 - (1)
2813		
2814		7.749×10^6 - (2)
2818	10.3025×10^6 - (1)	6.2273×10^6 - (9)
2819		21.2495×10^6 - (2)
2821		5.9176×10^6 - (3)
2895		1.5867×10^6 - (2)
2911	5.0419×10^6 - (4)	3.7165×10^6 - (9)
3069		7.198×10^6 - (1)
3241	1.2611×10^6 - (1)	1.7241×10^6 - (2)
3295		5.539×10^6 - (1)
3339	1.0306×10^6 - (1)	1.0306×10^6 - (1)
3441		0.055×10^6 - (1)
3553		0.281×10^6 - (1)
3731		11.8029×10^6 - (3)
4911	11.5224×10^6 - (2)	67.7455×10^6 - (8)
4922	1.2632×10^6 - (2)	$.9783 \times 10^6$ - (5)

SOURCE: Texas Water Development Board - Industrial Water Survey 1970

TABLE III-7
COASTAL BEND INDUSTRIAL WATER USE
SUMMARY - 1970

County	Standard Industrial Classification	Gallons in 1970	SOURCE(S) Ground percent	Surface* (Nueces River) percent
Aransas	2895	144.203×10^6	100	
Bee	1321	198.0×10^6	100	
Brooks	1321	135.1×10^6	100	
Duval	1321	851.4×10^6	100	
Jim Wells	1321	29.0×10^6	100	
Jim Wells	1321	232.24×10^6	100	
Karnes	1321	44.939×10^6	100	
Kleberg	1389	27.2×10^6	100	
Kleberg	1389	20.5×10^6	100	
Kleberg	1321	1269.1×10^6	100	
Live Oak	1321	91.66×10^6	100	
Live Oak	1321	50.40×10^6	100	
McMullen	1321	90.99×10^6	100	
Nueces	1321	39.40×10^6	100	
Nueces	1321	106.22×10^6	100	
Nueces	1321	57.0×10^6	100	
Nueces	1321	33.5×10^6		100
Nueces	1321	38.0×10^6	100	
Nueces	2046	576.0×10^6		100
Nueces	2812	1215.0×10^6	39	61
Nueces	2818	2575.617×10^6	8	92
Nueces	2911	1189.349×10^6		100
Nueces	2911	557.956×10^6		100
Nueces	2911	455.8×10^6		100
Nueces	2911	1164.896×10^6		100
Nueces	3241	129.888×10^6		100
Nueces	3333	668.868×10^6		100
Nueces	4911	1298.394×10^6		100
Nueces	4911	15.166×10^6		100
Refugio	1321	11.563×10^6	100	
Refugio	1321	93.0×10^6	100	
Refugio	4922	26.0×10^6	100	
Refugio	4922	28.32×10^6	100	
San Patricio	1321	54.605×10^6	100	
San Patricio	1321	24.812×10^6	100	
San Patricio	3334	2175.407×10^6		100

SOURCE: Texas Water Development Board - Industrial Water Survey 1970
*Purchased from the City of Corpus Christi

by increasing the water used by each user by the predicted increase in the economic sector of which they are a part.

Agricultural Water Use

Primary Data Sources

Assessment of irrigation water demand was based on historical data for acreage of irrigated crops and water applied. Readily available data for irrigation practices in Texas include Texas Water Development Board Report 127 (Inventories of Irrigation in Texas 1958, 1964, and 1969) and Texas County Statistics compiled by the Texas Crop and Livestock Reporting Service of the Texas Department of Agriculture.

Theoretical Water Use Coefficients for Irrigation

Comprehensive methods for calculating water use coefficients take into account theoretical water demand by crop, i.e., so many inches of irrigation water to grow corn to maturity under optimum conditions, effective precipitation, irrigation efficiency, and delivery system efficiency. The water use coefficient may be defined as

$$\text{Water Use Coefficient} = \frac{\text{Theoretical Crop Requirement} - \text{Precipitation}}{(\text{Irrigation Efficiency})(\text{Delivery System Efficiency})}$$

in which

Theoretical Crop Requirement - amount of water applied to crop under optimum conditions (in inches)

Precipitation - effective rainfall (in inches)

Irrigation Efficiency - fraction of water which is actually applied to the crops from the farm headgates

Delivery System Efficiency - fraction of water which makes it to the farm headgates from the water source

Theoretical crop water requirements depend on the rooting characteristics of the crop, the soil characteristics including surface texture, soil depth, permeability, and moisture retention characteristics, and the growing time including yield potential of the crop. The theoretical crop requirements are geographic (regional) in nature.

The theoretical crop requirement in inches of water can be associated with any yearly or multi-yearly precipitation data to determine the amount of water actually needed to grow the crop under optimum conditions. If precipitation data are available over many years, five or more, a reasonable figure for average water requirement can be calculated. The Texas Water Development Board has a computer program which can provide such an analysis given any rainfall pattern for any area in Texas.

If data are available, irrigation system efficiencies reflecting water losses from the farm headgates to the crops and delivery efficiencies reflecting losses from the water source to the farm headgates can be calculated to enable estimation of the actual water required by a crop from the primary water source. It should be remembered that this figure represents the requirement under optimum conditions. In practice optimum conditions are rarely achieved where costs of building irrigation systems or water costs are very high and the economics of the farming operations are marginal. If water is not available in sufficient quantity, optimum conditions cannot be achieved. If water is plentiful and the economics are favorable, the reverse situation may occur, excess water may be used resulting in large return flows which in turn may cause water quality problems in impoundments, rivers, and estuaries.

Agricultural Water Use Coefficients for the Coastal Bend

The Coastal Bend Region suffers in general from lack of water and the available water is of poor quality for irrigation purposes. In most areas in the Coastal Bend irrigation is supplemental in nature and for this reason use of optimum water requirements would provide unrealistic results.

The water use coefficients calculated for the Coastal Bend counties are actual, and represent supplemental rather than optimum irrigation practices. The data presented in Table III-8 in inches per acre per crop are from the 1969 Inventory of Irrigation data and represent the water requirement at the farm headgate and do not reflect losses in transporting the water to the headgate. A comparision of the theoretical water requirements at the farm headgate per crop for average precipitation conditions calculated by the Texas Water Development Board (assuming irrigation 78% efficient) and the actual amounts of water applied in 1969 is presented in Table III-9.

The actual irrigation data for the Coastal Bend were used to estimate the irrigation requirements predicted by the input/output model. The basic assumption used in the evaluation of the hypothetical policies was that of constant technological coefficients. Therefore in this case, that assumption is interpreted to mean static:

1) crop densities;
2) planting practices;

TABLE III-8
IRRIGATION WATER USE COEFFICIENTS*
BY COUNTY (ACRE-INCHES) WITH
SOURCES

County	Irrigated Cotton - Source	Irr. Grains - Source	Veg. Citris, Other - Source
Aransas	1	1	1
Bee	6"-Ground	5.5"-Ground	6"-Ground
Brooks	1	4"-Ground	5"-Ground
Duval	6"-Ground	6"-Ground	12"-Ground
Jim Wells	6"-Ground	5"-Ground	5"-Ground
Karnes	2	10"-Ground	2"-Surface
Kenedy	1	1	1
Kleberg	2	4"-Surface/Ground	8"-Surface/Ground
Live Oak	6"-Ground	4"-Ground	4"-Ground
McMullen	1	1	1
Nueces	6"-Surface	6"-Surface	12"-Ground
Refugio	2	2	2
San Patricio	6"-Ground	4"-Ground	8"-Surface/Ground

* 1969 Irrigation Data
[1] No irrigated crops
[2] No irrigation in 1969 although in other years irrigated crops were grown

TABLE III-9
COMPARISON OF IRRIGATION FACTORS IN INCHES/ACRE

	Cotton	Rice, Etc.	Citrus	Climatic Conditions
Crop Irrigation Requirements[1]	16.5	19.5	16.65	Average year
1969 Data (Average for Coastal Bend)	6.0	5.4	10.5	Wet year

[1] Texas Water Development Board

3) cost of irrigation systems and water;
4) water use coefficients; and
5) laws concerning use of water for irrigation and subsequent return flows.

Without this basic assumption some changes would need to be made which might dramatically alter the entire irrigation analysis.

The step by step procedure for estimating the irrigation water demand in 1980 and 1990 is listed below.

1. The acreage of crops that was irrigated in 1970 was tabulated by crop and county;
2. The amount of water used per crop (inches per acre) in 1969 was used to determine the amount of water needed per acre per crop, and to calculate the average County water use coefficients;
3. Economic projections were used as percent increases in crops (i.e., bales of cotton, bushels of wheat in Coastal Bend, etc.). Assuming 1970 technology the increase must be caused by more acres planted. The number of acres for 1970 was known and the projected increases were used to estimate acreages in 1980 and 1990. The percent of each crop grown in each county was averaged for a four-year period (1968-1971) and the average was assumed to remain constant. The data are presented in Table III-10. Irrigation water sources were also assumed to remain the same as in 1969.
4. The total acreage per crop per county was combined with the water use coefficients to provide an estimation of water requirements in 1980 and 1990.
5. The data were tabulated by county and source of water.
6. The prediction of water requirements was analyzed in light of known resources and general suitability of the county for irrigation as summarized in Table III-11.

The economic model predicts economic output associated with three irrigated crops, 1) cotton, 2) grains, and 3) vegetable, citrus, other. For this reason, all data presented also are based on these three classifications.

Summary

Evaluation of the water use data for the Coastal Bend indicate a general scarcity of fresh water supplies in the area and a dependence on the water resources of the Nueces River for supplying the municipal and

TABLE III-10
AVERAGE IRRIGATED ACRES OF CROPS IN THE COASTAL BEND
GROWN IN EACH COUNTY (1968-1971)
(percent of Total)

County	Irrigated Cotton	Irr. Grains	Veg., Citrus, Other
Aransas	0	0	0
Bee	1.4	5.7	1.8
Brooks	0	0.1	16.9
Duval	.2	3.2	27.5
Jim Wells	5.3	14.6	22.5
Karnes	1.5	1.1	1.1
Kenedy	0	0	0
Kleberg	1.3	2.6	9.1
Live Oak	2.1	7.3	9.1
McMullen	0	1.1	0
Nueces	26.3	21.7	0.6
Refugio	1.3	7.1	0
San Patricio	60.5	36.4	11.3

SOURCE: Agricultural Statistics Data Sheets 1968-1971

TABLE III-11
SUITABILITY OF WATER RESOURCES IN COG
FOR IRRIGATION, BY COUNTY

County	IRRIGATION WATER RESOURCES COMMENTS
Aransas	Water not suitable for irrigation, ground or surface
Bee	Favorable quantity and quality
Brooks	Only water available is ground water and is in limited supply, supplemental irrigation only
Duval	Water fairly saline
Jim Wells	Only suitable water is Nueces River which is in extreme Northeast portion of county
Karnes	Lack of good ground water limits irrigation
Kenedy	Insufficient data on ground water due to lack of wells but unlikely to be good quality water
Kleberg	Ground water not suitable for irrigation; some surface water supply
Live Oak	Northern portion of county does not have good water supply, strictly supplemental
McMullen	Wells in county are showing severe drop in water table
Nueces	Good water is plentiful
Refugio	Good water both surface and ground
San Patricio	Ground water limitations quality and quantity - irrigation mostly supplemental

SOURCE: Work Sheets for 1969 Texas Water Development Board Survey industrial needs of the City of Corpus Christi. A diagrammatic summary of municipal and industrial water demand on the surface water supplies managed by the City of Corpus Christi is presented in Figure III-4.

Industrial water use coefficients based on data from the Texas Coastal Zone proved to be inadequate as a method of describing industrial water use in the Coastal Bend.

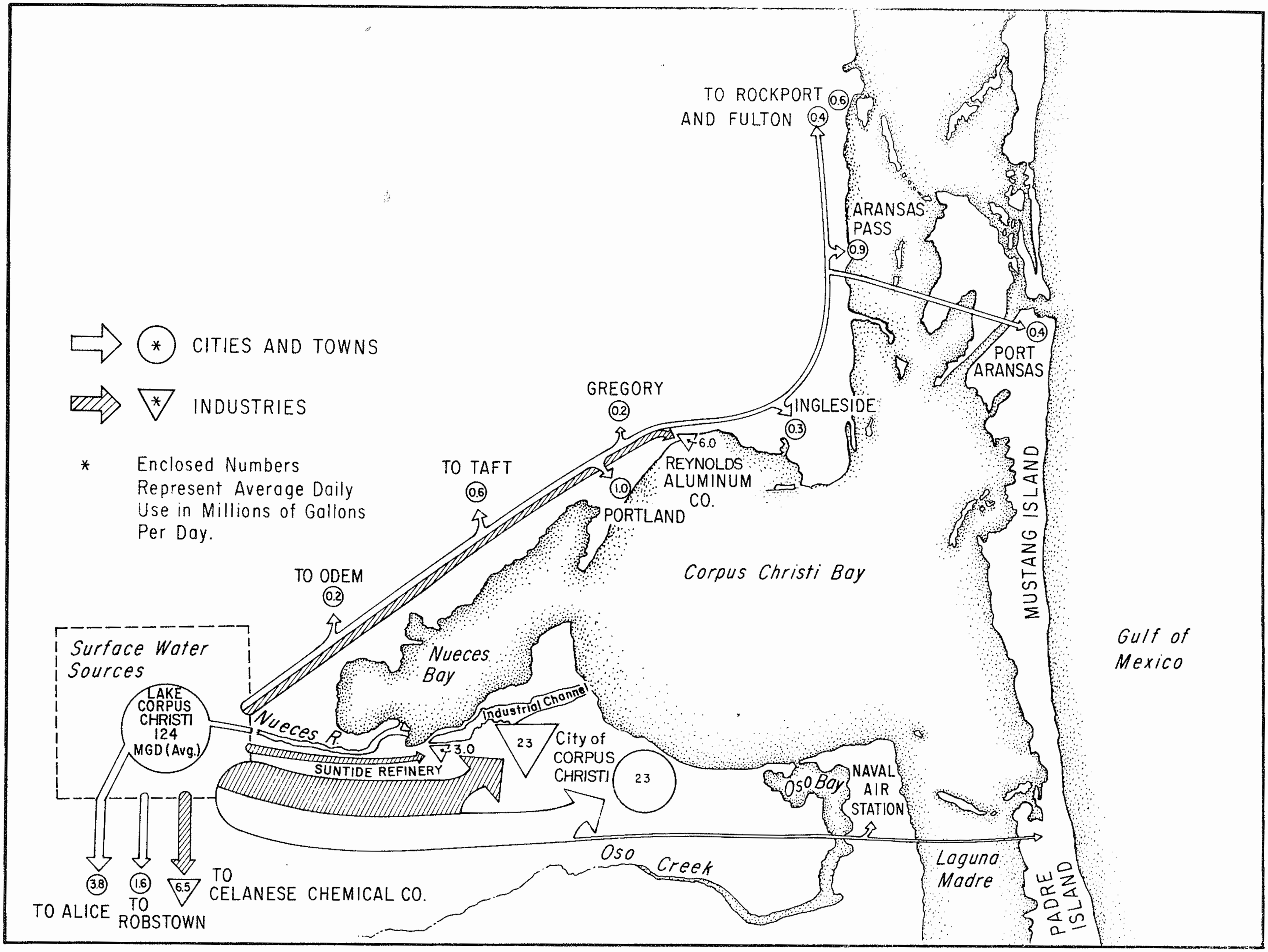


FIGURE III-4
MUNICIPAL & INDUSTRIAL DEMAND ON THE SURFACE WATER RESOURCES OF THE LOWER NUECES RIVER 1970

CHAPTER IV
WASTEWATER FLOWS

The basic objective of the Wastewater Flow Study was to establish the quantity and quality characteristics of wastewater inputs, associated with the activities of man, into the Corpus Christi Bay System and to link those inputs with economic and demographic projections resulting from the evaluation of alternative management policies for the area. The following potential sources of pollutants were analyzed as to their significance as waste inputs to the Corpus Christi Bay System:

(1) flows from municipal wastewater treatment plants;
(2) wastewater flows from industries;
(3) brine waste flows associated with the production of oil and gas;
(4) storm runoff, primarily urban;
(5) agricultural return flows; and
(6) insecticide and herbicide loads in rivers and creeks flowing into the system.

Municipal Wastewater Flows

Return flows or effluents of municipal wastewater treatment plants may be composed of wastewater from residences, commercial establishments, institutions, industries, or any combination of the above. However, municipal wastewater usually contains only residential, commercial, and institutional components. These components contribute flows in proportion to the size of the community; therefore, the total flow usually is divided by the population to yield waste generation coefficients. These coefficients are useful in predicting design capacities for treatment plants when population estimates are available. However, breakdown of the flow into components is difficult. These factors introduce some errors into calculation of municipal wastewater coefficients.

Generalized municipal wastewater generation coefficients, expressed in gallons per capita per day, are tabulated for the thirteen counties of the Coastal Bend in Table IV-1. These flows were derived from average return flows of the plants and the estimated population served based on Texas Department of Health records. Municipal plants which discharge effluents into the system are tabulated in Table IV-2 and the approximate locations of the plants in the Corpus Christi Bay System are illustrated in Figure IV-1. The effluent quality data reported in Table IV-2 include only two parameters actually reported by the plant operators, flow and B.O.D. The nutrient and dissolved solids concentrations were estimated based on

TABLE IV-1
MUNICIPAL WASTEWATER FLOW IN THE COASTAL BEND

County	Actual Pop. 1970	Population Served	Plant Design Capacities Gallons	Average Design Capacity gallons/capita/day	Actual Flow Gallons	Average Flow gallons/capita/day
Aransas	8,902	10,800	1,300,000	120	1,190,000	110
Bee	22,737	17,600	1,210,000	68	1,000,000	56
Brooks	8,005	5,600	525,000	93	400,000	70
Duval	11,722	5,700	750,000	132	495,000	87
Jim Wells	33,032	17,300	4,805,000	278	1,940,000	112
Karnes	13,462	7,300	655,000	90	1,038,000	142
Kleberg	33,166	21,400	---------	---	810,000	38
Live Oak	6,697	3,400	535,800	158	236,000	69
McMullen	------	------	---------	---	----------	---
Nueces		230,800	32,198,000	139	22,902,000	99
Refugio	9,490	9,700	1,280,000	131	604,000	62
San Patricio		25,900	3,086,500	119	2,602,900	100
Average for the Area				132.8		94.5

SOURCE: Texas State Department of Health

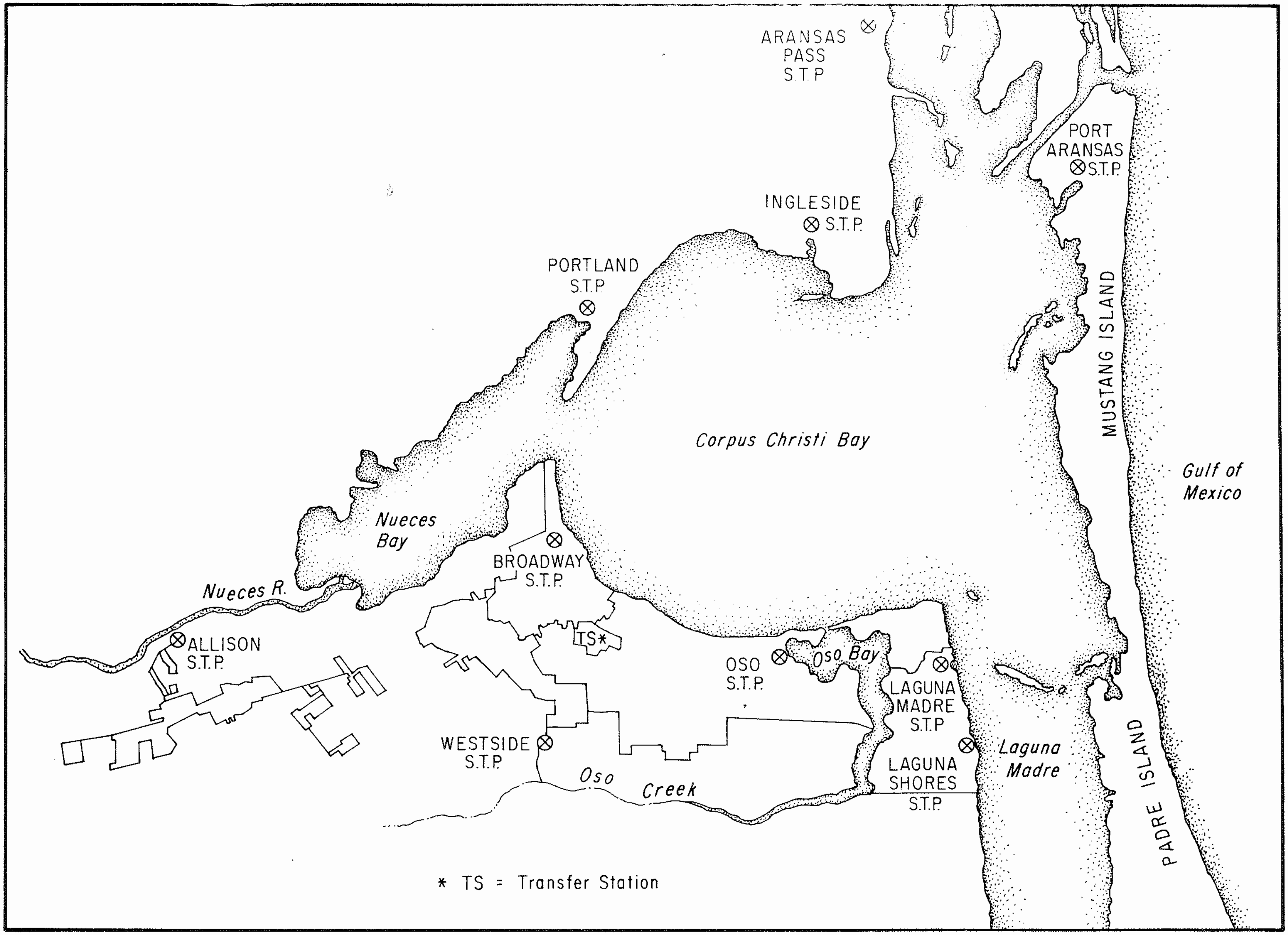


FIGURE IV-1
LOCATION OF MUNICIPAL SEWAGE TREATMENT PLANTS WHICH DISCHARGE INTO THE CORPUS CHRISTI BAY SYSTEM

TABLE IV-2

QUANTITY AND QUALITY CHARACTERISTICS OF MUNICIPAL WASTEWATERS 1970

QUALITY CONSTITUENTS

TREATMENT PLANT	FLOW*	BOD* mg/l	ORGANIC** NITROGEN mg/l	AMMONIA** NITROGEN mg/l	PHOS.-T** mg/l	TDS** mg/l
C. C. Broadway	10.0	15	15	15	8.0	900
C. C. Oso	8.6	4	15	15	8.0	900
C. C. Allison	1.89	12	15	15	8.0	900
C. C. Westside	01.8	45	15	15	8.0	900
C. C. Flour Bluff (Laguna Madre)	0.2	4	15	15	8.0	900
C. C. Laguna Shores	0.03	10	15	15	8.0	900
Port Aransas (Nueces Co. ,WCID)	0.86	25	15	15	8.0	900
Gregory	0.21	100	15	15	8.0	900
Ingleside	0.18	20	15	15	8.0	900
Portland	0.44	4	15	15	8.0	900
Aransas Pass	0.69	70	15	15	8.0	900
Rockport	0.5	7	15	15	8.0	900
	25.4 mgd Total					

* Texas State Department of Health

** Engineering Judgement

engineering judgement because of incomplete records from the Coastal Bend. The values for organic nitrogen and ammonia nitrogen, 15 mg/l for each, are within the ranges for untreated municipal wastewater reported by several studies (Culp, 1967) (Merrel, 1967) (Oswald, 1961). The estimated phosphorus concentration of 8 mg/l also is within the ranges reported in the above references. It was assumed that the secondary treatment processes were successful in removing only a small fraction of the nutrients in the influent wastewater. The estimate of the total dissolved solids concentration was derived by adding a use increment of 450 mg/l to the 450 mg/l average concentration of dissolved solids in the treated water supply for the City of Corpus Christi. The concentration of dissolved solids in the Corpus Christi water supply was reported in the Annual Statistical Report of the Water Division of the City of Corpus Christi (1972) while the use increment was within the range of 128 to 541 mg/l reported in the literature (Neal, 1964).

In order to correlate increases in population around the bay into increased return flows a methodology was developed utilizing maps of the areas served by the municipal wastewater treatment plants and the census tracts in the same areas. The demographic projections for the area were based on census tracts. Each census tract, or portion thereof, was associated with a wastewater treatment plant and the predicted loads of each were calculated. The method involved the following two assumptions:

(1) homogenous distribution of population in each tract, i.e., if 1/3 of a tract lies in the area served by plant A, 1/3 of the projected population of the census tract is assumed to be served by Plant A; and
(2) areas served by treatment plants will remain the same.

The areas served by the respective municipal wastewater treatment plants are illustrated in Figure IV-1 and the census tracts in the same area are delineated in Figure IV-2. The census tracts serviced by each plant were tabulated by overlaying the two figures.

The wastewater services division of the city of Corpus Christi was contacted to determine the planned construction of new plants or expansion of existing facilities. At the present time only the Laguna Madre plant is to be enlarged, and this expanded facility was taken into account when the impacts of the policies were evaluated.

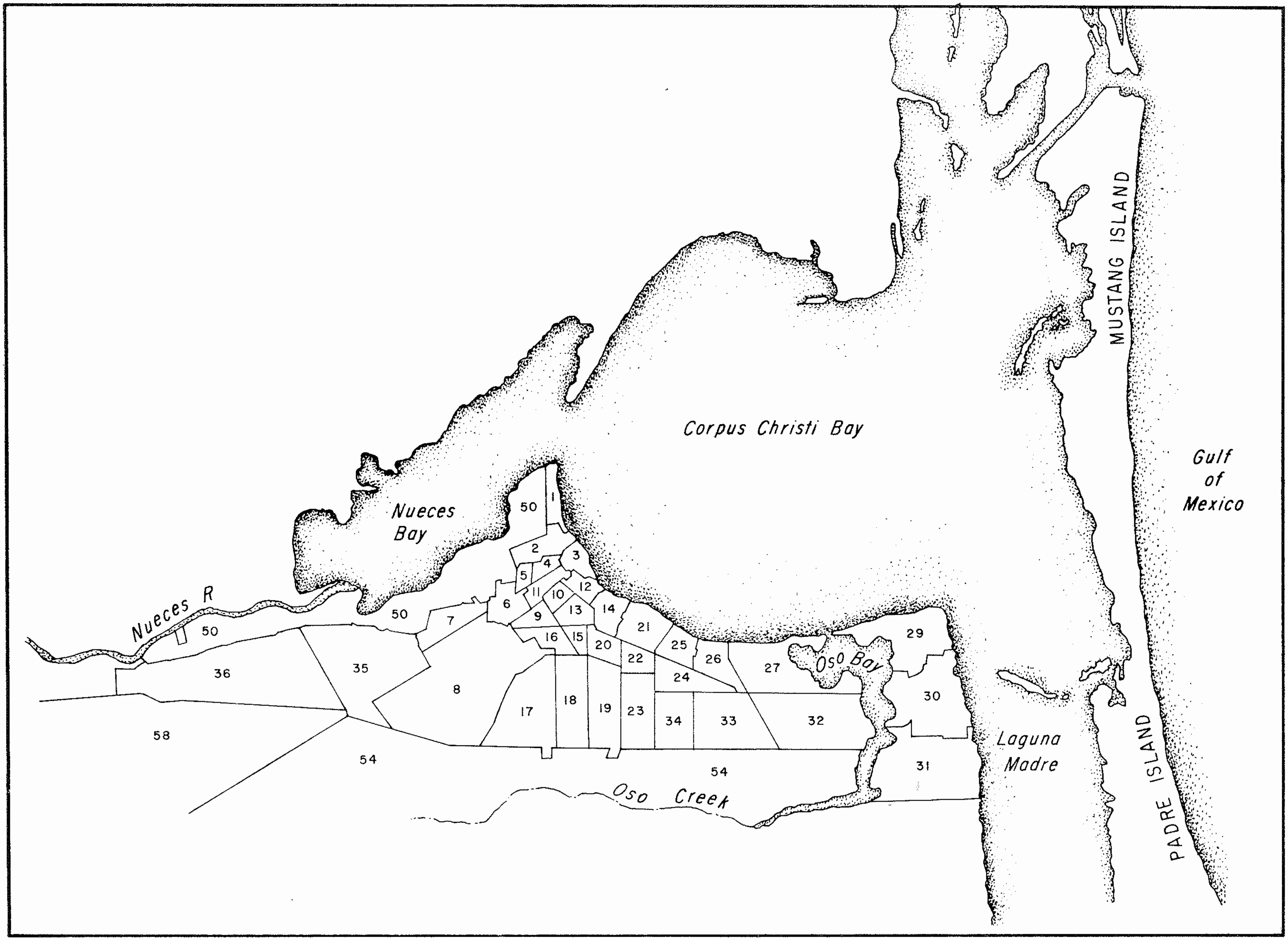


FIGURE IV-2
CENSUS TRACTS OF THE CITY OF CORPUS CHRISTI

Industrial Wastewater Flows

The study of industrial wastewater flows included discharges from industrial manufacturing plants and brine discharges associated with the production of oil and gas. Industrial return flows were assumed to be proportional in quantity to production while brine discharges were assumed to be dependent on the age of the oil field. In both cases, average figures for daily discharges (quantity and quality) were used based on data sources from the two-year period 1970 to 1971.

Industrial Manufacturing

The concept of "average" figures, used to describe dynamic, non-steady state systems deserves some comment. Industrial discharges are very complex and unpredictable compared to discharges from municipal wastewater treatment plants. For example, within a large integrated refinery or petrochemical plant many processes are involved and at any given time one or more operations may be in some upset, or unstable, condition. All processes are periodically shut down for maintenance of equipment. When they are started up again waste materials enter the waste stream in quantities considerably larger than under normal operating conditions. The various waste streams from the different processes vary in both quantity and quality with time and may or may not be combined into one outfall.

With these facts in mind, the water quality engineer is faced with the basic decision of whether to attempt to model the waste inputs separately, estimate possible worst conditions, or rely on average loads for calculations. The complexities associated with modeling individual waste outfalls from industries are extensive; therefore, this option was eliminated from consideration. Such a study would be impossible because of the lack of specific process information relating to effluent characteristics. If there is a need to study the worst possible condition, then quantity and quality data for such conditions could be obtained, but with a great deal of effort and questionable accuracy. One caution would certainly involve adequately defining the duration of the worst condition to be expected. The last option of using average discharge conditions was selected for this study.

Regardless of the method used to describe the plant discharge, information limitations hindered the overall analysis. In most cases the data only pertained to the final outfall and individual components were not broken out of the composite waste stream. A more important deficit was the lack of information relating to the wastewater treatment facilities in use or planned for the industry. In most cases it was unknown whether the quality of the return flow was the result of a treated or untreated waste stream.

An evaluation of the use of wastewater generation coefficients based on employment was undertaken as in the case of industrial water use. The results were less reliable than those obtained for the industrial water use coefficients because of the added complexity of wastewater treatment for which no data were obtained. The study relied upon a discharge inventory as opposed to discharge coefficients, which were only used in special cases.

Only the discharges to the Corpus Christi Bay System were used. The study involved the collection of data for industrial wastes discharged by location. Once an inventory, complete in the sense of available data, was compiled for the bay system, the problem of associating the discharge load with the economic predictions of the input/output model was undertaken. Each facility was expanded according to the projected increases for that industrial classification; i.e., the predicted increases were prorated to the industries based on the 1970 discharges. However specific knowledge of the in-house water uses and treatment would have enabled fewer assumptions and thereby possibly a greater degree of accuracy.

Two types of discharges were inventoried. The return flows associated with various fresh water consumption of manufacturing industries and brine discharges resulting from the production of oil and gas. The locations of the various discharges, excluding the brine discharges, within the bay system are illustrated in Figure IV-3. The numbers on the map are associated with industries in Table IV-3 with standard industrial classification number and quantity and quality parameters. The brine discharges were not included on the map as there were some 71 widely scattered points of discharge. (The analysis of the brine discharges can be found later in this chapter.)

The industrial wastewater discharge study was based on three data sources, all of which were not exclusively independent. The main data source was the U.S. Army Corps of Engineers permits to discharge to navigable waters (ACE), which contained flow data and many quality parameters. The ACE permits covered both industrial and brine discharges but were reported only once. Of lesser value was the Texas Water Quality Board (TWQB) self-reporting discharge data. The self-reported discharge information is submitted to the TWQB monthly by the industry but only a few quality parameters, namely BOD and SS are included. Therefore the data were of limited value.

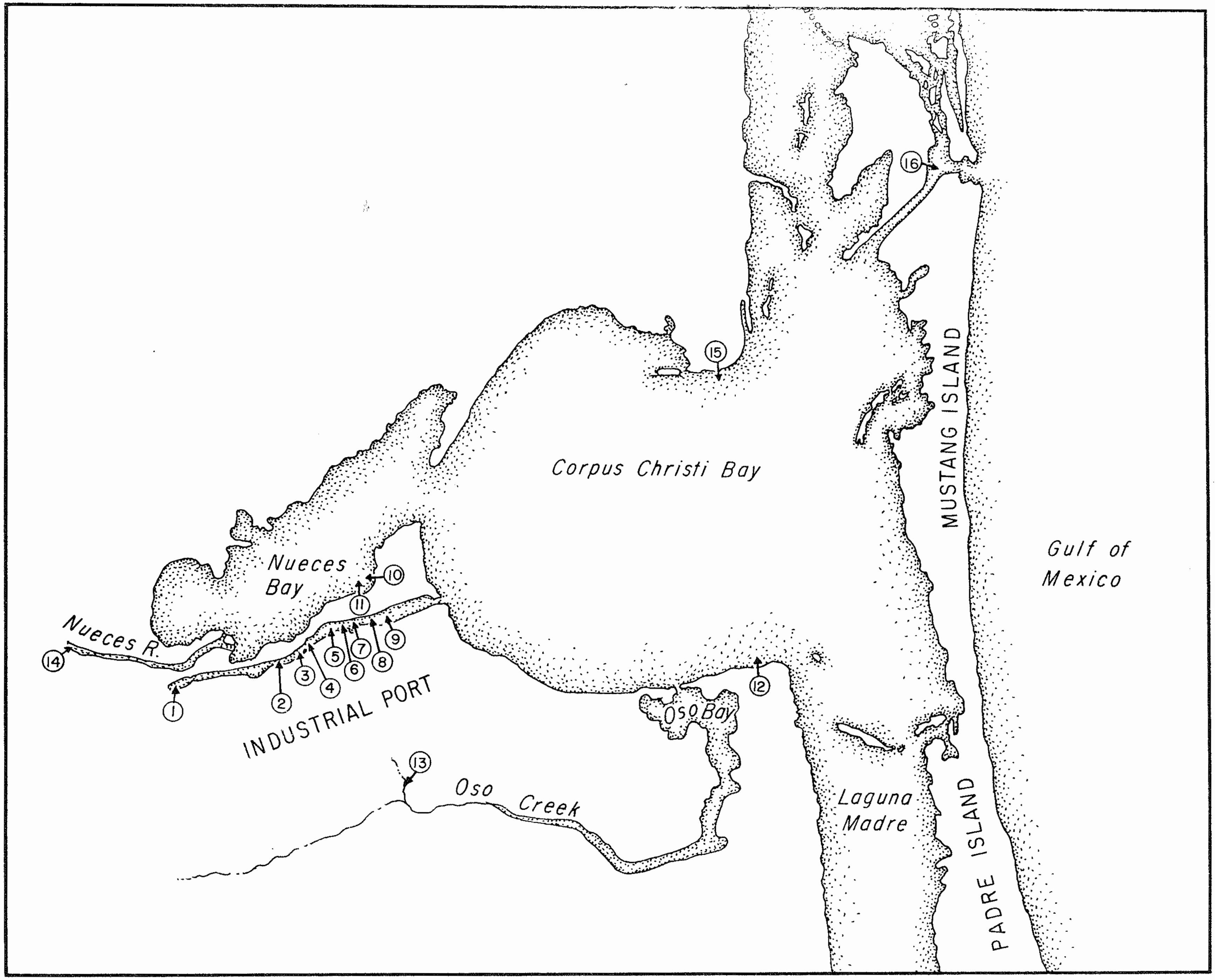


FIGURE IV-3. LOCATION OF INDUSTRIES WHICH DISCHARGE WASTEWATERS INTO THE CORPUS CHRISTI BAY SYSTEM

TABLE IV-3
IDENTIFICATION OF INDUSTRIAL CLASSIFICATION, FLOW, AND QUALITY OF INDUSTRIAL DISCHARGES INTO THE CORPUS CHRISTI BAY SYSTEM, 1970 (NOT INCLUDING BRINE)

Discharge Number (Fig. IV-3)	SIC	Flow (MGD)	BOD	Organic Nitrogen	Ammonia Nitrogen	NO_2 Nitrogen	NO_3 Nitrogen	Total Phosphorus	Total Dissolved Solids
1	2911	0.82	30	17	5	.004	0.4	5.0	2,220
2	2046	2.2	800	0.0	4.0	0.0	0.0	15.0	39,400
3	3333	1.0	86	38.6	5.5	0.0	0.5	4.5	2,944
4	2911	0.1+	31*	8.7*	15.5*	0.0*	0.25*	2.6*	2,560*
5	2911	1.13	34	8.7*	15.5*	0.0*	0.25*	2.6*	2,454
6	2911	0.26+	31*	8.7*	15.5*	0.0*	0.25*	2.6*	2,560*
7	2812	75.92	3	0.5	0.5	0.0	0.02	0.17	30,000
8	2911	0.47	34	0.4	26.0	0.0	0.1	0.14	3,130
9	2911	0.35	23	8.7*	15.5*	0.0*	0.25*	2.6*	2,418
10	3241	1.4	30	.28	0.46	---	0.22	0.28	33,900
11	4911	608.0			TULE CHANNEL WATER				
12	9176	0.13	38.4	15.0	15.0	0.01	0.1	2.0	800
13	4953	0.03	25	0.0	2.0	0.0	25.0	3.0	2,975
14	4911	1.1	10	NUECES RIVER WATER				5.0	2,561
15	4463	0.24	30	0.0	0.0	0.0	0.0	0.01	1,000
16	4463	0.84	30	0.0	0.0	0.0	0.0	0.0	900

+ Flow Estimated
* Average Concentration for Refineries in the Coastal Bend

SOURCE: U. S. Army Corps of Engineers Discharge Permits

Brine Wastewater Flows

Brine discharge information was secured from both the Texas Railroad Commission (TRC) and the U.S. Army Corps of Engineers. The oil and gas production companies sent essentially the same information to both agencies with the more extensive quality data going to the U.S. Army Corps of Engineers.

There are seventy-one individual points of discharge reported resulting from oil and gas operations located in the bay. In order to reduce the complexity associated with the multiple discharges in the bay transport model, these sources were consolidated into 12 discharge points around the bay. In lieu of a lengthy tabulation, a general summary of the data is provided in Table IV-4. In general, the individual brine discharges are small, with an average of about 30,000 gallons per day and total of approximately 2.2 million gallons per day for the entire bay system. The total brine flow is relatively small compared to the 11 million gallons per day of industrial discharges excluding cooling water.

Brine generation from oil and gas wells in general is a function of the age of the well. Oil and gas are located at the "top" of the reservoir with the more dense brine located underneath. As the oil and gas are depleted, increased amounts of brine are produced and the ration of brine produced to oil and gas increases until the well is either shut in or reworked. Brine generation is therefore not analogous to wastewater discharges from industrial plants which result directly from planned production levels. It is obvious that economic projections, as they were used in predicting wastewater from other industrial sectors, are not a viable tool in predicting future brine releases.

In order to account for the brine discharges it was necessary to make the following few assumptions:

(1) the discharges will increase in volume in the future (economic projections predict increased oil and gas production);
(2) the location of future discharges will be the same as in 1970; and
(3) the increase will be uniform over the period studied.

Barring some major technological breakthrough in oil discovery or recovery it is a safe assumption that the major oil reserves in the Corpus Christi Bay system have been discovered and the prospects for future discovery are minimal at best. Since the economic model projects increased production it was necessary to set some reasonable figure representing increased brine production which realistically should be very small. An increase of 15 percent was set as a reasonable "upper limit" of brine production for the periods 1970-1980 and 1980-1990 regardless of the policy evaluated. Brine discharges to the Corpus Christi Bay System are therefore assumed to be essentially independent of economic growth in the area.

TABLE IV-4
SUMMARY OF BRINE DISCHARGE DATA FOR
CORPUS CHRISTI BAY SYSTEM*

QUANTITY		
Number of Discharge Points	-	71
Total Flow	-	2.216 MGD
Average Discharge per Source	-	0.03 MGD
QUALITY		
Average BOD_5	-	230 mg/l
Average Total Dissolved Solids	-	40,000 mg/l
Average Total Phosphorus	-	0.18 mg/l
Average Organic Nitrogen	-	2.86 mg/l
Average Ammonia Nitrogen	-	16.0 mg/l
Average NO_2-N (Nitrite)	-	.05 mg/l
Average NO_3-N (Nitrate)	-	.71 mg/l

* SOURCE: U.S. Army Corps of Engineers Permits to Discharge to Navigable Waters

Toxicity

Primary Data Sources

Complete assessment of the effects on marine organisms of wastewater return flows required some estimate of toxic materials in addition to the BOD, suspended solids, dissolved solids, and nutrient inputs into the bay system from municipal, industrial and non-point sources. A two phase study was undertaken to fullfill this need. The first part of the study involved tabulation of potentially toxic materials based on biological use criteria supplied by the Biological Uses Task Force. The constituents considered are listed in Tables IV-5 and IV-6. The only waste input data source with concentrations of toxic constituents were the U.S. Army Corps of Engineers Permits to Discharge to Navigable Waters which were used to tabulate the concentrations for the industrial discharges of oil field brines, and return flows from other industries.

Eleven industries were identified as potential dischargers of toxic materials. No U.S. Army Corps of Engineers permit information was available for two of these non-brine discharging industries. Four industries indicated no toxic materials in their respective wastestreams. A single industry indicated that fourteen toxic materials were included in the wastewater discharge but no quantitative data was provided. Another plant report provided incomplete data. Therefore, only three industries discharging toxic materials into the bay system were covered by the data. A summary of the data available is presented in Table IV-7. The most important discharge, potentially, is the one for Standard Industrial Classification 3333. The main products of this facility are zinc and cadmium, which are toxic to fish and other marine life and are known to exist in the industry's waste stream. It is interesting to note that a recent publication (Holmes, W.H., et al, 1974) has pointed out significant concentrations of those metals in the bay, with the highest concentrations found near the mouth of the harbor. The report concludes that the source of the zinc and cadmium is industrial discharges along the harbor. However, in the absence of specific data on the concentrations of those materials in the wastestreams, it was impossible to undertake any analysis on toxic loadings of zinc and cadmium.

Considerable data were available on brine discharges with flow and concentrations of toxic materials reported for 71 discharges. An average concentration of the constituents of the 71 discharges was calculated to determine which constituents were present in potentially harmful quantities in brines. These averages are presented in Table IV-8. These data indicate that the constituents present in potentially harmful quantities include sulfates, copper, lead, nickel, manganese, and boron. The total flow of the 71 brine inputs, however, is approximately 2.2 million gallons per day, while the other discharges totaled some 11.2 million gallons per day,

TABLE IV-5
BIOLOGICAL USE CRITERIA*

	Threshold Limits in H_2
Salinity	± 10% of maximum and minimum over 5-year average
Sulfates	10% above maximum average for 5 years
Dissolved Solids	± 10% of maximum and minimum over 5 year average
BOD-organic carbon	Not to exceed 10% over gross primary productivity as related to specific area on a monthly basis
NO_3^- NO_2^- NO_4^+	Maximum average values for bay or regional area as measured in past years
O_2	Minimum 50% saturation
pH	6.5 - 8.5 for salinities >15 parts per thousand, 5.5 - 10.5 for salinities <15 parts per thousand
Coliforms	10,000/100ml
Temperature	4° F. - September - May 1.5° F. - June-August Maximum above daytime high temp as averaged from area of input.
Suspended Solids & Turbidity	5000 mg/l and 24-hr settling rate to 16 Jackson Units
Radionuclides:	
Strontium	10 picocurie/liter
Gross Beta	1000 picocurie/liter
Radium	3 picocurie/liter
Phenols	1.0 mg/l - except in areas with normal high polyphenols, then at maximum observed values
Pesticide	10 µg/l
Oil	No visible sheen
Detergents, cationic	1 µg/l
Organic Mercurial	1 mg/l
Cyanide	0.02 mg/l
H_2S	0.50 mg/l

* Table abstracted from Biological Uses Year I Interim Report

TABLE IV-6
BIOLOGICAL USE CRITERIA
FOR TRACE METALS

Trace Elements:

	mg/l*	mg/l**
Mercury	0.00003	0.01
Copper	0.003	0.01
Lead	0.00003	0.05
Nickel	0.0054	0.05
Zinc	0.01	5.00
Chromium	0.00005	1.00
Cadmium	0.08	0.10
Arsenic	0.003	1.00
Silver	0.0003	0.01
Vanadium	0.002	1.00
Flourine	1.30	10.00
Manganese	0.002	0.10
Cobalt	0.0005	0.01
Beryllium	0.0000006	0.001
Selenium	0.004	0.01
Yttrium	0.0003	0.01
Antimony	0.0005	0.01
Boron	4.60	10.00

*mg/l - normal oceanic seawater
**mg/l - upper threshold limits

TABLE IV-7
TOXIC ELEMENTS & COMPOUNDS IN INDUSTRIAL WASTEWATERS DISCHARGED INTO THE CORPUS CHRISTI BAY SYSTEM

Standard Industrial Classification	1970 Flow MGD	Sulfates mg/l	Phenols	Oil & Grease	Hg	Cu	Po	Ni	Zn	Cr	Cd	As	Ag	V	F	Mn	Co	Be	Se	Yt	Sb	B	Mg	Fe	Cn
Threshold Limits		± 10% 5 Year avg.	1 mg/l	mg/l	.01	.01	.05	.05	5.0	1.0	0.1	1.0	0.01	1.0	10.0	0.1	.01	.001	.01	.01	.01	10.0			
3333	1.0	PR	AB	PR	PR	PR	PR	PR	PR	PR	PR	PR	PR	NR	PR	PR	PR	AB	PR	NR	PR	AB			
3241	1.4	3060	AB	32.6	AB	AB	AB	AB	AB	AB	AB	AB	AB		AB	AB	AB	AB	AB		AB	AB			
4911	1.098	1125	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB		PR	AB	AB	AB	AB		AB	AB	275	AB	
2911	0.472	406	3810	17.3	AB	277	.26	50	205	2560	AB	.099	AB			3.2	AB	AB	AB		AB	AB	AB	100	
2911		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA		NA	NA	NA	NA	
2046	2.2	90	ABS	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB		AB	AB	AB	AB	AB		AB	AB	AB	PR	
4463	0.84	PR	PR	PR	?	?	?	?	?	?	?	?	?		?	?	AB	AB	?		AB	?	?	?	Ballast Water
4953	0.033	PR	PR	PR	AB	AB	AB	AB	AB	AB	AB	AB	AB		AB	AB	AB	AB	AB		AB	AB	PR	PR	
9176	0.127	PR	18	48	AB	AB	.03	.01	AB	35.1	.53	AB	AB		AB	AB	AB	AB	AB		AB	AB	AB	AB	.67
2818		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA		NA	NA	NA	NA	NA
2911	0.82	266	60	111	.005	0.2	0.07	.01	0.1	0.3	.004	.02	?		28	.01	.03	?	.02		?	1.6	7.8	0.2	

PR - Present in discharge but no quantity reported
NR - Not reported in ACE's
AB - Absent in discharge
NA - No ACE available

TABLE IV-8
AVERAGE CONCENTRATIONS OF TOXIC MATERIALS PRESENT IN OIL & GAS PRODUCTION BRINES DISCHARGED INTO THE CORPUS CHRISTI BAY SYSTEM

Constituent	Threshold Limit* (mg/l)	Avg. Concentration in Brine	No. of discharges which met or exceeded Threshold Limit	No. times constituent reported as present	Range (mg/l)
Sulfates	---	96.1 mg/l		48	(1-1300)
Phenols	1.0	7.5	8	14	(0.04-28.1)
Oil & Grease	---	13.3		65	(0.1-78)
Mercury	0.01	0.002	2	36	(0.001-1.4)
Copper	0.01	0.15	54	54	(0.01-1)
Lead	0.05	0.15	45	42	(0.007-0.45)
Nickel	0.05	0.30	53	53	(0.05-1.7)
Zinc	5.0	0.63	2	60	(0.006-9)
Chromium	1.0	0.36	2	57	(0.01-11)
Cadmium	0.1	0.035	7	46	(0.0006-0.25)
Arsenic	1.0	0.03	0	12	(0.002-0.05)
Silver	0.01	0.06	13	13	(0.05-0.09)
Flouride	10.0	1.3	0	57	(0.09-5.9)
Manganese	0.1	1.5	64	64	(0.2-21.5)
Sesium	0.01	0.0158	14	14	(0.01-0.044)
Boron	10.0	44.6	42	43	(2-75)

SOURCE: U.S. Army Corps of Engineers Permits to Discharge to Navigable Waters almost five times the total brine discharge. However, no data is available to permit a comparison of the reported brine discharges with the actual brine release.

This compilation and evaluation of the data available on specific potentially toxic constituents indicate that:

(1) insufficient data pertaining to discharges from manufacturing plants prevented an analysis of toxicity by specific elements and compounds in the Corpus Christi Bay System;
(2) some industrial discharges contain significant quantities of toxic metals such as zinc and cadmium but the actual quantities being released are not reported;
(3) brine discharges are a significant source of potentially toxic materials such as sulfates, copper, lead, nickel, manganese, and boron; and
(4) no information relating to antagonistics and synergistic effects is available.

Relative Toxicity

Another approach to the assessment of industrial and municipal wastewater toxicity is to analyze the effects of the composite wastestream on some chosen organism. In general, toxicity of a complete wastestream cannot be estimated from data on toxicity of individual compounds in the wastestream. Synergistic or antagonistic effects usually are present and these effects may cause greater or lesser impact on marine organisms than that expected.

The method used to assess gross effects is called a bioassay and involves the exposure of some species indigenous to the waterway into which the effluent is discharged to some concentration of the potentially toxic material. The mortality of the organisms is observed at 24-, 48-, and 96-hour intervals at various dilutions. The results are reported in terms of LD_{50} or the concentration at which 50 percent of the organisms survive after a 96-hour period. This figure can be used to estimate the impact on receiving bodies of water from an acute toxicity standpoint.

The LD_{50} is used in conjunction with the flow of the wastestream in question to derive relative toxicity of the effluent. The relationships are defined as follows:

$$\text{Toxic Units} = \frac{100}{TL_m \ (\%)}$$

$$\text{Relative Toxicity (MGD)} = \frac{Q(MGD) \times 100}{TL_m \ (\%)}$$

$$\text{Relative Toxicity} = \text{Toxic Units} \times \text{Flow} \quad (Q)$$

The relationship of toxic units of a wastestream to a concentration was used in the bay model. The toxic units, however, relate to acute toxicity but this parameter also is useful in estimating chronic toxic effects. Values ranging from 0.01 to 0.3 toxic units are generally accepted as the upper limits of safe concentrations, i.e. causing no known chronic effects.

No direct bioassay data was available for industrial or municipal effluents discharged into the Corpus Christi Bay System. Therefore, it was necessary to extract estimates from the literature.

Estimates of the toxicity of municipal wastewater treatment plant effluents were obtained from a study by Esvelt, et al (1973). In that study, bioassays were conducted on the three-spined stickelback to determine the toxicity of municipal treatment plant effluents. Toxicity expressed in terms of toxic units, were generated for effluents resulting from various stages of treatment. In addition, the effects of chlorination on effluent toxicity were assayed.

An interesting conclusion of the study was that chlorination significantly increased the effluent toxicity. For the purposes of this study, it was assumed that the increased toxicity associated with chlorinated effluents was short lived in comparison to the time cycles in the bay transport model and the non-chlorinated effluent toxicities were used instead. It is believed that the increased toxic effect of chlorination will be felt primarily near the treatment plant outfalls.

The toxicity values used are presented on the next page.

TABLE IV-9
TOXICITY OF MUNICIPAL WASTEWATERS*

Process Effluent	Toxicity Range	Average Toxicity
Primary	1.8 - 3.0	2.2
Activated Sludge, Standard Rate	0.5 - 1.2	0.5
Lime Precipitation	1.2 - 1.5	1.3

*Esvelt, L.A., et al (1973)

The municipal wastewater treatment plants were analyzed as to treatment scheme and effluent quality reported. Values for toxicity concentrations were assigned according to the processes and operation of the plant. If some secondary process was in operation but the effluent quality was close to that of untreated wastewater, as was the case with three plants, the effluent was assigned a value of 3 toxic units (T.U.). If operation was satisfactory for an activated sludge plant the value was 0.5TU, and if the effluent was somewhere between untreated wastewater and the effluent of a well operated biological system, 1.0 - 1.2TU were used. The municipal treatment plants, degree of treatment, operation status (1970) and assigned effluent toxicity are presented in Table IV-10. These data are based on the assumption that the characteristics of municipal wastewaters are the same regardless of geographical location.

The results of a study by Pearson, et al, (1969) on waste discharges and loadings into the San Francisco Bay System enabled estimation of toxicity of industrial effluents. The toxicity loading to the bay was determined from data observed for various industrial wastewaters. The test organism also was the three-spined stickleback.

Industries discharging to the Corpus Christi Bay System were listed along with the products produced. This list was compared to the list of industries studied in the San Francisco Bay project. If sufficient similarity between two plants on either list existed the toxicity value was assigned to the effluent for Corpus Christi Bay. The plants and assigned toxicity value are listed in Table IV-11. A comparison of Tables IV-11 and IV-3 will show that toxicity estimates were possible for only 6.13 million gallons per day out of industrial discharges totaling 10.97 million gallons per day, excluding cooling water. Since estimates were not available for almost 5 million gallons per day, no further comparison of toxicity loading between municipal and industrial discharges was attempted.

TABLE IV-10

TOXICITY ESTIMATES OF MUNICIPAL SEWAGE TREATMENT PLANTS DISCHARGING INTO THE CORPUS CHRISTI BAY SYSTEM

TREATMENT PLANT	PROCESS TREATMENT	OPERATION STATUS* (1972)	ASSIGNED TOXICITY (TU)**	FLOW MGD
Aransas Pass	Activated Sludge	Unsatisfactory	3.0	0.69
Rock Port	Activated Sludge	Satisfactory-Overload	1.2	0.5
Port Aransas	Activated Sludge	Satisfactory-Overload	0.5	0.86
Gregory	Activated Sludge	Unsatisfactory-Overload	3.0	0.21
Ingleside	Trickling Filter	Satisfactory	1.0	0.18
Portland	Activated Sludge	Satisfactory	0.5	0.44
Corpus Christi Broadway	Trickling Filter	Satisfactory	0.5	10.00
Corpus Christi Oso	Activated Sludge	Satisfactory	0.5	8.6
Corpus Christi Laguna Shores	Activated Sludge	Satisfactory-Overload	1.0	0.03
Corpus Christi Westside	Trickling Filter	Unsatisfactory	3.0	1.8
Corpus Christi Allison	Activated Sludge	Satisfactory	0.5	1.89
Corpus Christi Flour Bluff	Activated Sludge	Satisfactory	0.5	0.2

*SOURCE: Texas State Department of Health

**TU = Toxic Units

TABLE IV-11
TOXICITY ESTIMATES OF INDUSTRIAL EFFLUENTS ENTERING THE CORPUS CHRISTI BAY SYSTEM

SIC	FLOW MGD	PRODUCTS	ASSIGNED TOXICITY (TU)*
3333	1.0	Zinc, Cadmium, H_2SO_4	26.47
2911	0.82	Oil Products	10
2911	.1	Oil Products	10
2812	2.0	Caustic Soda, Inorganics	3.3
2911	1.13	Oil Products	10
2911	0.26	Oil Products	10
2911	0.47	Oil Products	10
2911	0.35	Oil Products	10

*TU = Toxic Units

Urban Runoff

An assessment of the total pollutant loads into the Corpus Christi Bay System must go beyond the municipal and industrial discharges and include non-point sources or storm runoff. Considerable amounts of waste materials collect on pavements and other land surfaces during dry periods, only to be washed into receiving bodies of water during rain storms. The magnitude of pollutant loads that may enter the bay system in this way could conceivably play a dominant role, influencing water quality for some period after the storm. Estimates of the quantity and quality of storm runoff into the Corpus Christi Bay System were made as a part of the total assessment of wastewater flows into the bay, but were limited to an urban runoff model.

Models

Various models have been developed which quantify runoff relationships for urban watersheds. The Unit Hydrograph has been used to estimate the time-flow relationship based on parameters such as channel length, slope, drainage area, and impervious cover. The rainfall-runoff relationship can be approximated by use of variables like total rainfall, soil moisture, soil permeability, and impervious cover. The Unit Hydrograph equations and the rainfall-runoff equation are derived by fitting general equations to data collected in the urban watersheds. Multiple linear regression analyses were used to determine constants and exponents in the relationship.

Water quality equations can be derived, in a similar manner, by assuming that the concentrations of pollutants are dependent on the flow and drainage area. These relationships, in general, are logarithmic.

The model chosen for estimating the runoff loads to Corpus Christi Bay was developed by Winslow and Espey and was originally intended for use in estimating runoff quantity and quality from a proposed development near Houston, Texas. The model combines the Unit Hydrograph with the rainfall-runoff and water quality equations in a computor program. The data, upon which the coefficients of the model are based, were collected in the Houston area and describes the urbanized runoff loads in that city. For the purposes of this study, it was assumed that the Houston model would more closely approximate conditions in Corpus Christi than models based on other urban areas in the state or nation. The model developed by Winslow and Espey is the only documented, readily available runoff model for the Gulf Coast and has the added advantage of the Unit Hydrograph approach.

The basic equations used in the model are listed to enable discussion of some of the important parameters. The Unit Hydrograph equations used in the model are illustrated in Tables IV-12a and IV-12b. These equations were developed from rainfall and runoff data taken from eleven urban and six rural watersheds in the Houston area and twenty-two urban and eleven rural watersheds from elsewhere in the country. These data were used to derive the equations of best fit listed in the table.

The rainfall-runoff equation used to predict the Hydrograph was developed from data reported by Johnson and Sayre (1973) for the Houston area. The equation relates total runoff to the various physical parameters and rainfall as follows:

$$Run = 0.325\ R^{1.23}\ M^{0.23}\ I^{0.067}\ SI^{-0.12}$$

where:

Run = Total runoff, inches
R = Total rainfall, inches
M = Soil moisture index
I = Percentage of impervious cover
SI = Soil Index

The data observed for Houston indicated only small effects on total runoff resulting from increases in the percentage of impervious cover while all other parameters remained the same. Other publications on the effects on total runoff of urbanization do not support this conclusion, however, the model was used with this limitation in mind.

The water quality equations are listed in Table IV-13. The calculated concentrations are dependent only on the area and the flow which in turn is dependent on some physical characteristics. The equations also were developed by Winslow and Espey (1972) from Houston data.

Calibration Check on Runoff Model

A calibration check was made on the sensitivity of the model to changes in the input variables. Various hypothetical runs were made to determine what variables were critical to the various analyses for a two inch rainfall. The results are tabulated in Table IV-14 and the conclusions of the study are listed below.

(1) Total runoff flow (Q) is relatively insensitive to changes in impervious cover. For a 100 percent increase in impervious cover (30 to 60 percent) the total predicted flow increased only 4 percent.

TABLE IV-12a

RUNOFF MODEL-UNIT HYDROGRAPH EQUATIONS*

$$Q = 3.54 \times 10^{4} \; A^{1.0} \; T_R^{-1.0}$$

$$T_R = 16.4 \; I\Phi L^{0.316} \; I^{-0.490} \; S^{-0.0488}$$

$$T_B = 3.67 \times 10^{5} \; A^{1.14} \; Q^{-1.15}$$

$$W_{50} = 4.14 \times 10^{4} \; A^{1.02} \; Q^{-1.04}$$

$$W_{75} = 1.34 \times 10^{4} \; A^{-0.92} \; Q^{-0.94}$$

in which:

T_R = Time of rise, minutes

Q = Peak discharge, cubic feet per second (cfs)

T_B = Base time, minutes

W_{50} = Time between points on the hydrograph when the discharge is equal to 1/2 peak discharge, minutes

W_{75} = Time between points on the hydrograph when the discharge is equal to 3/4 peak discharge, minutes

A = Drainage area, square miles

Φ = Urbanization factor (see next page)

L = Channel length, feet

S = Channel slope, foot/foot

I = Impervious cover, percent

*from Winslow, Espey (1972)

TABLE IV-12b

Φ CLASSIFICATION* - URBANIZATION FACTOR

$$\Phi = \Phi_1 + \Phi_2$$

Φ_1	Channel Improvement Factor
0.6	extensive channel improvement and storm sewer system, closed conduit channel system.
0.8	Some channel improvement and storm sewers; mainly clearing and enlarging of existing channel.
1.0	Natural channel conditions.
Φ_2	Channel Vegetation Factor
0.0	No channel vegetation
0.1	Light channel vegetation
0.2	Moderate channel vegetation
0.3	Heavy channel vegetation

*from Winslow, Espey (1972).

TABLE IV-13
WATER QUALITY EQUATIONS*

(1)	Suspended Solids, mg/l	=	$21.55 + 4.36 \text{ Log } (Q/A)$ $Q/A \leq 0.75$
	Suspended Solids, mg/l	=	$37.83 + 134.7 \text{ Log } (Q/A)$ $(Q/A) > 0.75$
(2)	Dissolved Solids, mg/l	=	$155.02 - 40.25 \text{ Log } (Q/A)$
(3)	Ammonia, mg/l	=	$0.465 - 0.078 \text{ Log } (Q/A)$
(4)	Organic Nitrogen, mg/l	=	$0.306 + 0.071 \text{ Log } (Q/A)$
(5)	Nitrates, mg/l	=	$0.188 + 0.148 \text{ Log } (Q/A)$
(6)	Total Phosphorus, mg/l	=	$0.0366 - 0.956 \text{ Log } (Q/A)$ $Q/A \leq .305$
	Total Phosphorus, mg/l	=	$0.508 - 0.042 \text{ Log } (Q/A)$ $Q/A > .305$
(7)	BOD, mg/l	=	$4.11 - 0.282 \text{ Log } (Q/A)$
(8)	COD, mg/l	=	$34.43 + 10.12 \text{ Log } (Q/A)$ $Q/A \leq 5.6$
	COD, mg/l	=	$46.32 - 5.77 \text{ Log } (Q/A)$ $Q/A > 5.6$
(9)	Fecal Streptococci, 1000 counts/100 ML	=	$1010\ (Q/A)^{3.24}$ $Q/A \leq .22$
	Fecal Streptococci, 1000 counts/100 ML	=	$15.35\ (Q/A)$ $Q/A > .22$
(10)	Total Coliform, 1000 counts/100 ML	=	$17.4\ (\text{Fecal Strep})^{1.463}$
(11)	Fecal Coliform, 1000 counts/100 ML	=	$0.152\ (\text{Total Coliform})^{0.767}$
(12)	Total Insecticides, $\mu g/l$	=	$0.269 + 0.11 \text{ Log } (Q/A)$
(13)	Total Pesticides, $\mu g/l$	=	$0.158 + 0.038 \text{ Log } (Q/A)$

Q = Total Flow
A = Drainage Area

*from Winslow, Espey (1972).

TABLE IV-14

RUNOFF MODEL SENSITIVITY - FLOW AND QUALITY FOR HYPOTHETICAL DRAINAGE BASIN AND 2 INCH RAINFALL

INPUT						MEAN CONC. mg/l					
Percent Impervious	Φ_1	API	SI	Φ	$(Q(10^7))$ (F+3)	SS	BOD	Total Phosphorus	Ammonia Nitrogen	Organic Nitrogen	Total Colif 1000/100 ML
32.8	1.0	0.21	5.0	1.0	2.052	233	4.86	0.687	0.493	0.474	10859
2.8	0.6	0.21	5.0	0.6	2.027	229	4.38	0.599	0.438	0.442	11198
32.8	0.8	0.21	5.0	0.8	2.041	235	4.82	0.734	0.491	0.467	11213
32.8	0.8	0.21	5.0	0.9	2.041	240	4.92	0.750	0.502	0.477	11457
32.8	0.8	0.21	5.0	1.0	2.041	246	5.03	0.766	0.512	0.487	11702
32.8	0.8	0.21	5.0	1.1	2.041	251	5.13	0.782	0.523	0.498	11947
32.8	1.0	0.21	5.0	1.3	2.052	248	5.16	0.730	0.524	0.504	11540
65.6	1.0	0.21	5.0	1.0	2.138	338	6.40	0.858	0.637	0.649	16575
32.8	1.0	1.00	5.0	1.0	2.938	257	4.80	0.661	0.478	0.488	13922
32.8	1.0	0.21	2.0	1.0	2.297	241	4.84	0.679	0.488	0.478	11741

(2) The total flow calculation is only sensitive to changes in the antecedent precipitation index and the soil permeability.

(3) The urbanization factor plays only a minor role in influencing runoff patterns. Changes in the rainfall intensity yielded the same patterns concluded above.

Therefore, the concentration of effort in obtaining input data should be directed toward producing accurate estimates of antecedent precipitation index and permeability (soil index) if this model is to be applied to the Corpus Christi area.

Application of the Runoff Model to Corpus Christi

The method employed in applying the model to the Corpus Christi Bay System involved delineation of runoff basins and estimations of the various parameters for each basin.

Insufficient data on soil permeability was available resulting in one estimate being used for the entire area. In reality the soil composition changes from basin to basin and even within basins the soil permeability also can be expected to change.

The basins were estimated using two maps of the Corpus Christi Bay Area. A topographic map enabled delineation of the boundaries of the basins draining into the bay. The area surrounding the bay was broken down into smaller segments. A map of the storm sewers in Corpus Christi was used to estimate drainage basin boundaries within the city limits. In essence, the entire area was divided into 19 basins which, for the purpose of the model, were simplified to represent uniform drainage canals of uniform slope and length. The drainage basins are illustrated in Figure IV-4. The data for each basin are presented in Table IV-15.

A methodology based on housing units was developed to assess the effects of development resulting from demographic changes. The economic and land use task force supplied the number of housing units, both multi-family and single family, in each of six economic categories for each census tract. An impervious cover relationship was developed to link the housing units to the runoff model. This relationship provides an impervious cover in percent based on housing density expressed as acres/unit for each economic category. These data are presented in Table IV-16. This information was used to translate projections for 1980 and 1990 into increased impervious cover in the drainage basins, and used to estimate the runoff loads to the bay.

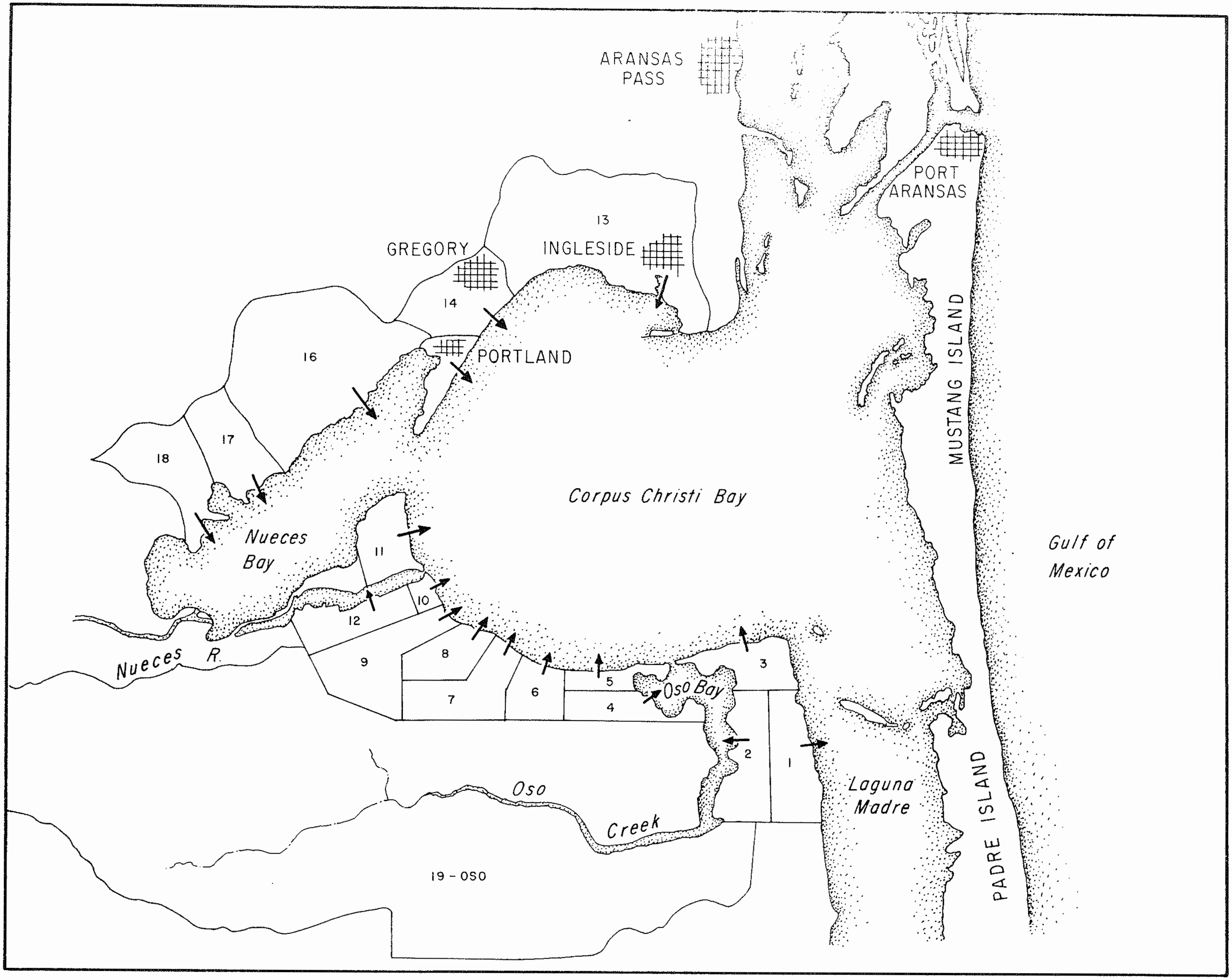


FIGURE IV-4. STORM RUNOFF BASINS FOR CORPUS CHRISTI BAY

TABLE IV-15
DRAINAGE BASIN DATA FOR RUNOFF MODEL

Area #	Channel Length Ft.	Channel Slope feet/foot	Impervious Cover percent	Urbanization Factor Φ	Urbanization Factor Φ_1	Soil Moisture (SI)	Antecedent Precipitation Index	Area (mi^2)
			70					
1	6750	0.0029	2	1.0	.8	5.0	0.213	7.03
2	4125	0.0048	2	1.0	.8	"	"	6.09
3	6000	0.0025	4	1.0	.8	"	"	4.23
4	9000	0.0022	12.7	.9	.8	"	"	2.97
5	3000	0.0066	14.8	.6	.6	"	"	0.89
6	10500	0.0028	21.6	1.0	.8	"	"	3.30
7	22125	0.0017	17.9	1.0	.8	"	"	6.29
8	12750	0.0030	20.3	1.0	.8	"	"	3.17
9	16500	0.0027	6.9	.6	.6	"	"	7.75
10	4500	0.0088	10.4	.6	.6	"	"	1.17
11	1800	0.0026	4.3	.6	.6	"	"	0.60
12	11625	0.0042	13.4	.8	.8	"	"	6.88
13	29250	0.008	2	1.0	1.0	"	"	36.06
14	13000	0.0028	2	1.2	1.0	"	"	20.81
15	5107	0.0068	10	1.0	.8	"	"	7.86
16	27393	0.0021	1	1.2	1.0	"	"	25.35
17	12536	0.0051	1	1.2	1.0	"	"	7.51
18	22750	0.0030	1	1.2	1.0	"	"	6.48
19	200,640	0.00045	2	1.3	1.0	"	"	169

TABLE IV-16

IMPERVIOUS COVER-ACRES PER UNIT RELATIONSHIPS FOR CORPUS CHRISTI CENSUS TRACT DATA

SINGLE FAMILY DWELLINGS

1970 Economic Category	Acres/Unit*	Impervious Cover[1] percent	1980 - 1990 Economic Category	Acres/Unit**	Impervious Cover[1] percent
1	0.10	35.0	1	0.45	23.2
2	0.12	34.5	2	0.58	15.8
3	0.15	33.6	3	0.75	12.0
4	0.30	29.3	4	0.92	10.3
5	0.70	12.6	5	1.08	9.7
6	1.00	9.9	6	1.50	8.5

MULTI FAMILY DWELLINGS

1970 Rental Category	Acres/Unit+	Impervious Cover percent	1980 - 1990 Economic Category	Acres/Unit++	Impervious Cover percent
1	0.035	99.9	1	0.080	95.0
2	0.049	99.9	2	0.092	86.5
3	0.057	99.9	3	0.099	82.0
4	0.066	99.9	4	0.107	76.0
5	0.080	93.0	5	0.121	67.0
6	0.093	86.0	6	0.131	60.0

* $y = a + bx$; $y = -7151.4658 + 19869.707\,X$

\+ $y = a + bx$; $y = -60.143 + 2271.429\,X$

** $y = -2291.084 + 20444.413\,X$

++ $y = -185.7 + 2270.668\,X$

Where y = house or rental value in dollars ($)

x = acres

1 (Felton, P.N., 1963)

Runoff Evaluation for Corpus Christi

A summary of the output of the runoff model for a rainfall of 4.31 inches over 24 hours for 1970 is presented in Table IV-17. Among the limitations of the method is the prediction of pollutant loads for non-urbanized areas equivalent to those for urbanized areas. The non-urbanized areas (drainage basins 13, 16, 17, 18 and most of 19-050) were included since development within these areas is possible between 1970 and 1990. The estimated BOD, COD, and suspended solids concentrations are relatively low compared to results of some other studies on the subject. (Condon, 1973; Weibel, 1964; Akerlinch, 1950). Insufficient data on flow in Oso Creek prohibit comparison of the estimated runoff with actual conditions.

Agricultural Return Flows

The original plan for the evaluation of wastewater flows included an analysis of agricultural return flows resulting from irrigation of crops in the Coastal Bend. However no data were available for such an evaluation and the results of studies conducted in other areas around the State and nation were not applicable to the Corpus Christi Area.

As mentioned in Chapter III, irrigation in the Coastal Bend is primarily supplemental and resultant return flows are likely to be intermittent in nature and small in volume. There is, however, a research need to (1) conduct a survey to determine if significant amounts of water used for agricultural purposes are being returned to rivers and creeks in the area; and (2) if such return flows appear to be significant, a study of water quality characteristics is needed.

Insecticide and Herbicide Loads to Rivers and Creeks

Insecticides and herbicides are usually associated with agricultural activity but are used in residential neighborhoods as well. Pesticides enter rivers, creeks, and estuaries via both return flows and storm runoff. The pesticides entering Corpus Christi Bay from urban watersheds can be estimated from urban storm runoff models as discussed earlier in the chapter. The presence of pesticides in return flows would be incorporated in the study outlined in the agricultural return flows section of this chapter. The other possible method of entry into the Corpus Christi Bay System is via storm runoff from agricultural lands. There presently exists no data on methodology for an accurate assessment of the three above mentioned sources of pesticides and the resultant effects on the water quality and marine organisms of the Corpus Christi Bay System.

TABLE IV-17
RUNOFF DATA FOR CORPUS CHRISTI BAY DRAINAGE BASINS
1970 ESTIMATES FOR 4.31 INCH RAINFALL

Drainage Basin	Flow (million gallons)	TDS (total dissolved solids) mg/l	(Ammonia-Nitrogen) mg/l	Organic Nitrogen mg/l	Nitrate Nitrogen mg/l	Total Phosphorus mg/l	BOD_5 mg/l	Time (Minutes)
1	142.1	169.6	0.37	0.30	0.25	0.54	3.4	2430
2	123.0	162.6	0.36	0.31	0.26	0.53	3.4	2132
3	89.7	157.8	0.36	0.32	0.28	0.52	3.5	1884
4	68.2	170.0	0.40	0.37	0.33	0.60	3.9	1636
5	20.7	122.7	0.35	0.36	0.37	0.45	3.5	1309
6	78.1	166.8	0.43	0.42	0.38	0.60	4.3	1527
7	147.2	169.6	0.42	0.40	0.35	0.58	4.1	1745
8	74.8	169.7	0.43	0.41	0.37	0.60	4.2	1582
9	169.9	138.6	0.34	0.31	0.27	0.47	3.3	1636
10	26.2	133.4	0.35	0.35	0.32	0.49	3.5	1364
11	12.7	132.9	0.33	0.32	0.28	0.48	3.3	1473
12	158.7	164.0	0.40	0.37	0.33	0.57	3.9	1636
13	729.1	194.3	0.39	0.30	0.23	0.59	3.6	5073
14	420.8	196.6	0.40	0.31	0.25	0.62	3.7	3421
15	177.0	148.5	0.38	0.36	0.32	0.53	3.7	1438
16	489.3	203.4	0.40	0.30	0.22	0.58	3.7	6764
17	145.0	195.2	0.40	0.30	0.23	0.59	3.6	4612
18	125.1	204.6	0.41	0.30	0.22	0.60	3.7	6273
19	3417.1	222.1	0.43	0.30	0.21	0.60	3.8	9982

As a preliminary means of determining the significance of pesticide loadings to the Corpus Christi System,water and sediment analyses for the Nueces River and Oso Creek, conducted by the United States Geological Survey, were tabulated and can be found in Table IV-18. The data indicate that traces of DDE, Diazinon, Methyl-Parathion, Parathion and 2,4-Dichlorophenoxyacetic acid were present in the water analyzed. Sediment analyses indicated significant concentrations of DDD, DDE, and Chlordane. While indicating the presence of these pesticides at the time the samples were taken, the data cannot be readily incorporated into the objectives of the project because:

(1) no conclusion as to their source can be drawn;
(2) no correlation of the source with acres planted or population density can be made; and
(3) no conclusion relating to the concentrations to be expected at different times of the year can be estimated.

For these reasons assessment of pesticide loads on the Corpus Christi Bay System was not incorporated into the analysis of wastewater impact.

In order to incorporate an analysis of pesticides a study would be required in which:

(1) a survey of the use of pesticides by farms, ranches and households in the area is conducted;
(2) monitoring of pesticides concentration in water and sediment samples at frequent intervals for at least a year is instigated;
(3) pesticide concentrations in water and sediments are correlated with levels in the tissues of marine organisms; and
(4) the data are analyzed to provide loading coefficients associated with crops and number of acres planted for agricultural concerns and housing densities for urban sources.

Summary

Wastewater flows into the Corpus Christi Bay System were identified and analyzed in order to associate the quantity and quality characteristics with projections of economic activity and population growth associated with alternative management policies for the Coastal Bend. Flows from municipal wastewater treatment plants, industrial facilities, brine from oil and gas fields, and urban storm runoff were identified as the major sources of wastewaters. Agricultural return flows and pesticide loads also were analyzed but insufficient data prohibited their incorporation into the study.

TABLE IV-18

INSECTICIDE AND HERBICIDE ANALYSIS OF WATER AND SEDIMENT FROM THE NUECES RIVER AND OSO CREEK - UNITED STATES GEOLOGICAL SURVEY DATA

	Water Analysis µg/l			Sediment Analysis µg/kg	
	Nueces River	Oso Creek*		Nueces River	Oso Creek*
Insecticide	Near Mathis (11/04/71)	(7/27/72)	(11/09/72)	(11/04/71)	(11/09/72)
Aldrin	0.00	0.00	0.00	< 0.2	<0.2
DDD	0.00	0.00	0.00	< 0.2	0.9
DDE	0.01	0.00	0.00	2.6	5.4
DDT	0.00	0.00	0.00	< 0.2	<0.2
Dieldrin	0.00	0.00	0.00	< 0.2	<0.2
Endrin	0.00	0.00	0.00	< 0.2	<0.2
Heptachlor	0.00	0.00	0.00	< 0.2	<0.2
Heptachlor-Epoxide	0.00	0.00	0.00	< 0.2	<0.2
Lindane	0.00	0.00	0.00	< 0.2	<0.2
Chlordane	0.00	0.00	0.00	10.0	<1.0
Diazinon	0.00	0.03	0.04		
Malathion	0.00	0.00	0.00		
Methyl-Parathion	0.00	0.06	0.00		
Parathion	0.00	0.19	0.00		
Herbicide					
2,4-Dichlorophenoxyacetic Acid	0.02	0.00	0.00		
Silvex (2 Propionic Acid)	0.00	0.00	0.00		
2,4,5-Trichlorophenoxyacetic Acid	0.00	0.00	0.00		

*Unpublished Data (Subject to Revision)

CHAPTER V
MATHEMATICAL MODEL FOR WASTEWATER TREATMENT COST EVALUATION

The computer model described in this section selects the lowest cost treatment sequence that will meet a specified effluent quality. The parameters considered are BOD, COD, SS, Total Nitrogen, Phosphorus and Total Dissolved Solids. In addition, the program has the capability of adding neutralization, equalization and chlorination as required. The output from the program is the required treatment sequence along with the capital cost, operation and maintenance costs, and the total combined treatment cost (expressed as cents/1000 gal.). The quality of the effluent also is listed.

The following assumptions are made:

(1) percent removals for all parameters remain constant, independent of the incoming concentration;
(2) cost functions are of the form $y = ax^b$, where x is the flow (i.e., functions are linear in log-log relationship);
(3) cost is a function only of flow;
(4) an effluent has received primary treatment if the SS concentration is less than 100 mg/l; secondary treatment if the BOD concentration is less than 100 mg/l; and
(5) an effluent BOD of greater than 500 mg/l will require a roughing trickling filter. (This trickling filter will reduce the BOD to 500 mg/l and the COD to an amount such that the BOD to COD ratio will be the same as in the untreated waste.)

Cost updating has been made using the Engineering-News Record Construction Cost Index. All values are updated to an index of 1942, which corresponds to April 1974. Table V-1 shows the values used for the parameters in the cost functions.

The different alternatives for treatment are shown in Figure V-1. The removal efficiencies for individual processes are presented in Table V-2. The percent removal for any given sequence was evaluated from the individual processes using:

$$E_j = 1 - \prod_{i=1}^{n} (1 - e_i)$$

where:

E_j = removal efficiency of the jth. sequence
e_i = removal efficiency of the ith process
n = number of processes in series

TABLE V-1

COST EQUATIONS

Equations are of the form cost = A x $(Flow)^B$. Capital costs are given in millions of dollars and operation and maintenance and total treatment cost in cents/1000 gallons. Flow is in MGD.

Process	Capital Cost		Operation and Maintenance		Total Treatment		Reference
	A	B	A	B	A	B	
1. Preliminary Treatment	0.0274	0.62	0.0	1.0	.54	-0.45	2
2. Gravity Clarifier	0.635	0.71	8.0	-0.17	21.7	-0.24	2
3. Dissolved Air Flotation	0.60	0.70	8.0	-0.17	21.0	-0.15	4
4. Activated Sludge	0.366	0.86	6.7	-0.18	14.5	-0.16	2
5. Trickling Filter	0.241	0.93	6.7	-0.18	12.9	-0.25	2
6. Aerated Lagoon	0.19	0.74	5.2	-0.22	9.35	-0.22	1
7. Chemical Coagulation	0.098	0.90	5.45	-0.03	7.44	-0.05	2
8. Ammonia Stripping	0.076	0.88	2.1	-0.04	3.81	-0.07	2
9. Nitrification-Denitrification	0.366	0.86	6.7	-0.18	14.5	-0.16	Estimate
10. Multimedia Filter	0.163	0.66	10.9	-0.37	14.5	-0.36	2
11. Microstraining	0.098	0.91	1.45	-0.10	13.6	-0.09	2
12. Carbon Absorption	0.69	0.63	18.0	-0.27	32.8	-0.31	2
13. Ion Exchange	0.92	0.70	25.0	-0.18	90.0	-0.25	3
14. Reverse Osmosis	0.95	0.20	20.0	-0.15	85.0	-0.19	3
15. Electrodialysis	0.87	0.72	21.7	-0.13	40.3	-0.19	2
16. Chlorination	0.0272	0.66	1.63	-0.10	2.23	-0.15	2
17. Equalization	0.0817	0.86	0.0	1.0	2.85	-0.14	1
18. Neutralization	0.0855	0.57	2.38	-0.43	4.28	-0.43	1

References

1. Projected Wastewater Treatment Costs in the Organic Chemicals Industry (1970).
2. Smith (1968).
3. Kurtz, et al (1972).
4. Shell, et al (1972).

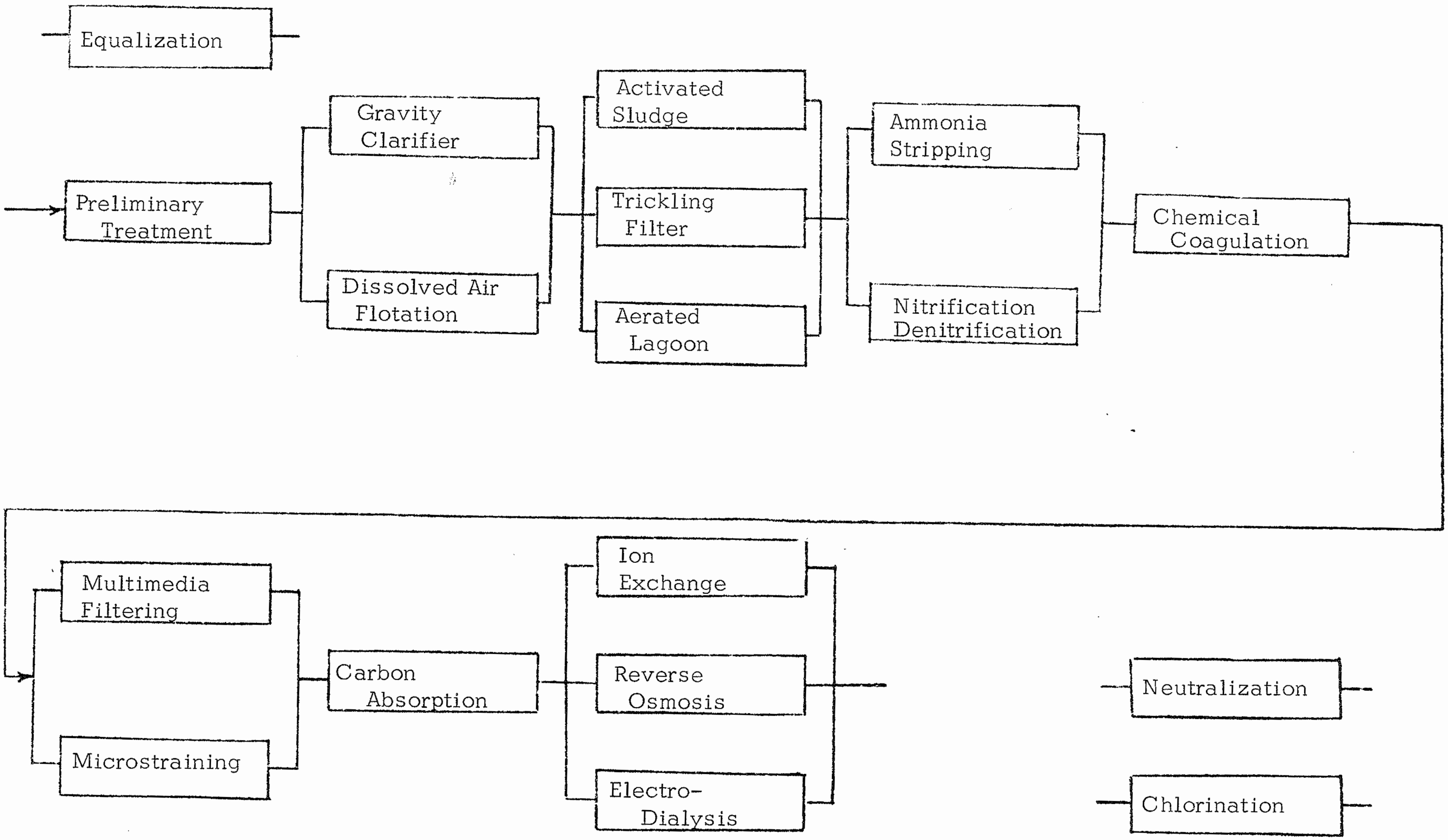


FIGURE V-1
TREATMENT ALTERNATIVES OF THE COST MODEL FOR WASTEWATER TREATMENT

TABLE V-2
REMOVAL EFFICIENCIES[a]
(percent)

	Process	SS	BOD	COD	TOTAL N	P	TDS
1.	Preliminary Treatment	10					
2.	Gravity Clarifier	75[b]	40[b]	40[b]			10[b]
3.	Dissolved Air Flotation	70			10		
4.	Activated Sludge	60[c]	90	81[c]	20[c]	20[c]	30[b]
5.	Trickling Filter	30[c]	70[b]	63[c]	20[c]	20[c]	15[b]
6.	Aerated Lagoon	30[c]	85[b]	77[c]	20[c]	20[c]	10[b]
7.	Chemical Coagulation	70	83	65	22	93	20
8.	Ammonia Stripping				92		
9.	Nitrification-Denitrification				78		
10.	Multimedia Filter	85	60	50	12		
11.	Microstraining	65	55	45	12		
12.	Carbon Absorption	85	80	73	28		
13.	Ion Exchange		50	40	90	92	97
14.	Reverse Osmosis	97	97	93	97	97	97
15.	Electrodialysis				24	40	40

a- Metcalf and Eddy (1973).

b-Projected Wastewater Treatment Costs in the Pulp and Paper Industry (1970).

c-Estimated.

The program scans all the possible treatment alternatives and selects the unit processes that satisfy the effluent quality requirements. The total combined treatment cost for this feasible alternative is evaluated and the system with the lowest cost is selected. The capital cost and the operation and maintenance costs of this optimal sequence is evaluated and together with the sequence description and effluent quality form the output.

This program has been implemented in the TAURUS Time-Sharing System using The University of Texas CDC 6600 Computer. The program is written in a conversational mode and does not require any programming knowledge to use.

In order to illustrate the program an example was selected. Typical concentrations of pollutants in municipal sewage, along with a desired quality of the effluent, were selected as listed in Table V-3.

TABLE V-3
QUALITY OF RAW SEWAGE FOR EXAMPLE PROBLEM

CONSTITUENT	RAW SEWAGE CONCENTRATION mg/l	DESIRED CONCENTRATION IN EFFLUENT
BOD	200	1
Suspended Solids	200	1
COD	350	5
Phosphorus	10	$<$ 1
Nitrogen	14	$<$ 1
Total Dissolved Solids	500	$<$ 20

These values were fed into the program which responded with treatment Scheme I as outlined in Figure V-2. The removal of pollutants can be seen in sequence as the quality of effluent at each state of the treatment is listed. The arrows indicate which process, in cases where more than one are listed, was selected.

Two flows were selected to give some idea of the economics of scale, 1 million gallons per day and 10 million gallons per day. The cost data for plants designed to handle these flows are summarized in Table V-4 while Figures V-3 and V-4 describe the cumulative cost analysis at each stage of the sequence.

FIGURE V-2
REMOVAL OF POLLUTANTS BY TREATMENT SCHEME I

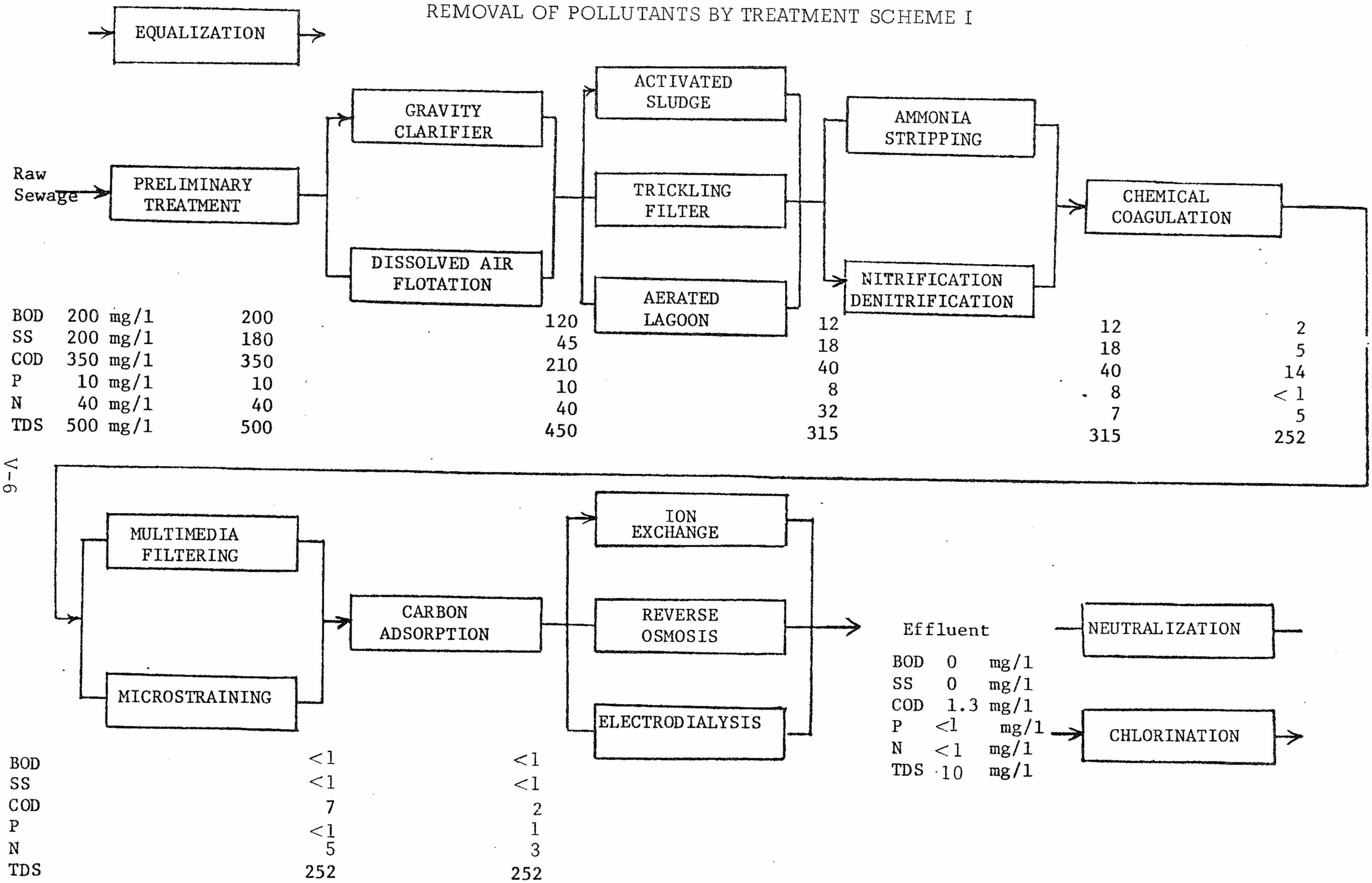


TABLE V-4

TREATMENT COSTS

(SCHEME I)

	1 MGD			10 MGD		
	(10^6) CAPITAL	O & M ¢/1000 GAL	TOTAL ¢/1000 GAL	(10^6) CAPITAL	O & M ¢/1000 GAL	TOTAL ¢/1000 GAL
EQUALIZATION	.0817	0	2.85	0.592	0	2.06
PRETREATMENT	.0274	0	0.54	0.114	0	0.19
GRAVITY CLARIFIER	.635	8.0	21.7	3.26	5.7	12.5
ACTIVATED SLUDGE	.366	6.7	14.5	2.65	4.65	10.0
NITRIFICATION - DENITRIFICATION	.366	6.7	14.5	2.65	4.65	10.0
CHEMICAL COAGULATION	.098	5.45	7.44	0.78	5.4	6.62
FILTRATION	.163	10.9	14.5	0.745		
CARBON ADSORPTION	.69	18.0	32.8	2.94	9.7	16.0
ION EXCHANGE	.92	25.0	90.0	4.6	16.5	54.0
CHLORINATION	.0272	1.63	2.23	0.124	0.16	1.58
TOTALS	$3.3743	82.38	201.06	18.455	51.41	119.27

CAPITAL = TOTAL CAPITAL COST IN MILLIONS OF DOLLARS (APRIL 1974 $)

O & M = OPERATION AND MAINTENANCE COST IN ¢ PER THOUSAND GALLONS

TOTAL = AMORTIZATION OF CAPITAL COST (5%, 20 YEARS)
PLUS OPERATION AND MAINTENANCE COST IN ¢ PER THOUSAND GALLONS

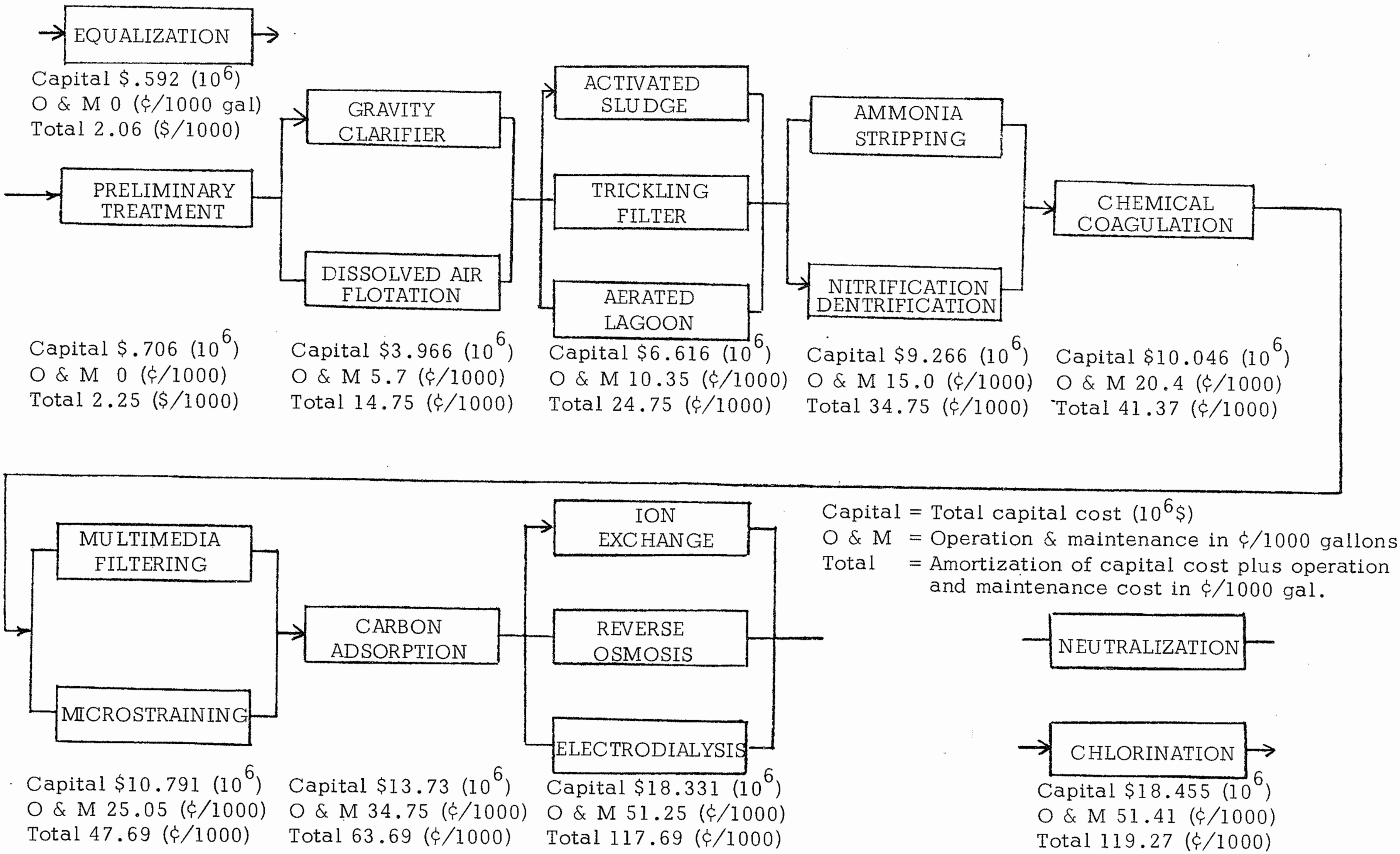


FIGURE V-3
CUMULATIVE COST ANALYSIS FOR 10 MGD PLANT TREATMENT SCHEME I

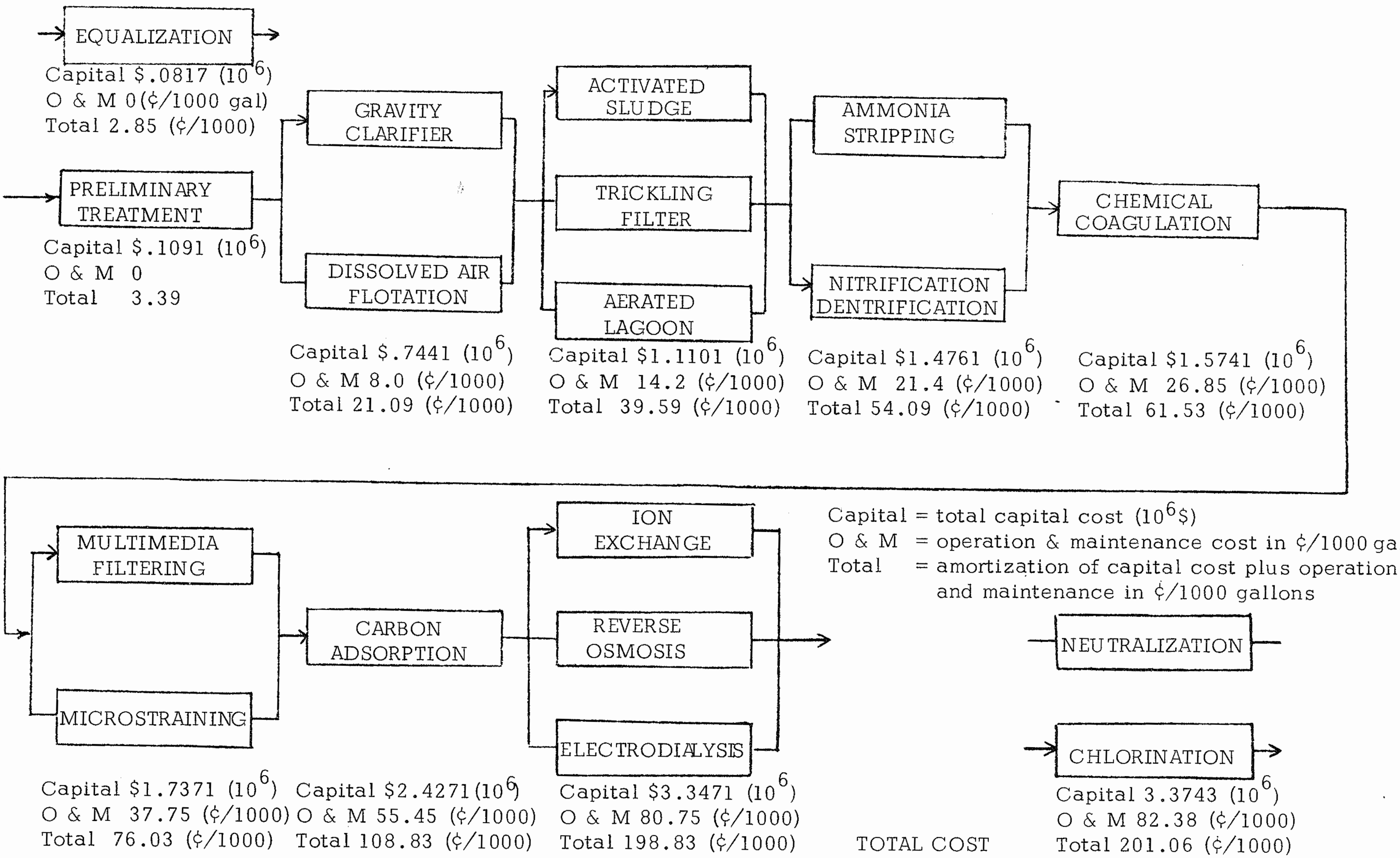


FIGURE V-4
CUMULATIVE COST ANALYSIS FOR 1 MGD PLANT TREATMENT SCHEME I

CHAPTER VI
SOLID WASTE

The disposal of solid wastes in Texas is predominantly on the land. The mode of operation ranges from open dumps to sanitary landfills. Therefore, the environmental effects are significant in the case of the dumps and should be negligible for a properly located and operated sanitary landfill.

The importance of proper landfill site selection and engineering to preserve environmental quality in the Texas Coastal Zone was recently emphasized by Brown, et al (1972). The results of their investigation indicate that about twenty percent of the 102 solid waste land disposal sites in the Texas Coastal Zone are located in geologically and hydrologically unsatisfactory areas and constitute potential health, as well as pollution, hazards. Fifty percent of the sites are marginal depending on a highly variable substrate and may be either secure or may present significant pollution problems. The remaining thirty percent of the sites were located in geologically and hydrologically satisfactory land. The predicted volumes of solid waste require more effective disposal than the present situation, in which only one of every three sites is considered satisfactory. It is not unreasonable to expect disposal of solid wastes to be a major environmental problem in the next twenty years.

Municipal Solid Wastes

Municipal solid wastes generated in the study area were estimated by tabulating municipal disposal sites, calculating solid waste generation coefficients by site and by county, and estimating the useful life of present and planned sites. The cost of disposal in the Coastal Bend Area also was assessed.

The municipal solid waste data are tabulated in Table VI-1 based on the result of a 1968 survey of solid waste sites in Texas conducted by the Texas State Department of Health. More recent data would have been more useful, but simply are not available. In the 1968 survey, site operators were requested to provide estimates on loadings to the site, population served, and remaining life of the facility. The accuracy of these estimates is at best questionable since the quantities are based on the assumption that all vehicles arriving at the site are completely full to capacity with compacted refuse. Very few cities, if any, routinely weigh each collection vehicle. This assumption, coupled with an estimate of the population served, is the basis for developing waste

TABLE VI-1

MUNICIPAL SOLID WASTE DISPOSAL SITE CHARACTERISTICS FOR THE COASTAL BEND

County	Facility	Population Served 1968	Population Served Present	Refuse Tons/Yr.	lb/capita -day	Cost of Collection $/Yr.	Cost of Collection $/Ton	Disposal Cost $/Ton	Remaining Life of Facility	Comments
Aransas	Rockport	3,700	4,500	9,000	13.30	18,200	2.02	0.44	5 years	
	Fulton & Co.	5,900		1,800	1.67			1.71	0 years	
Bee	Beeville	15,080	18,111	17,000	6.16				5 years	
	Skidmore	450		300	3.64			0.16	0 years	7,470
	Pettus	500		200	2.18				0 years	unserved
Brooks	Falfurias	7,480	9,573	6,902	5.04	29,481	4.27	1.04	0 years	1,520 unserved
Duval	San Diego	6,617	3,800	2,300	1.90				0 years	
	Freer	3,262		1,200	2.01				0 years	
	Benavides	3,821		1,400	2.00				0 years	
Jim Wells	Alice	24,480	25,000	25,600	5.72	75,794	2.96	0.05	0 years	of remain-
	Premont	5,767	3,600	3,850	3.65	12,994	4.64	0.10	10 years	ing 2860
	Orange Grove	1,253	1,200	660	2.88			1.21	0 years	some served by OG some by Premont
Karnes	Karnes City	4,454	3,000	2,200	2.70	11,391	5.17	0.22	5 years	
	Kenedy	6,154	5,000	4,000	3.56			0.87	0 years	
	Runge	2,033	1,036	1,700	4.57			1.64	1 year	Lots of co. waste
	Falls City	1,504		300	1.09			0.16	0 years	

TABLE VI-1
(contd.)

County	Facility	Population Served		Refuse	lb/capita	Cost of Collection		Dis-posal Cost	Remaining Life of	Comments
		1968	Present	Tons/Yr.	-day	$/Yr.	$/Ton	$/Ton	Facility	
Kleberg	Kingsville	27,530	27,459	24,000	4.76	14,000	0.58	0.62	0 years	
	Prec. #3 Rivera	1,719		185	0.59				0 years	
	Loyola Beach	1,651		175	0.58					
Live Oak	George West	1,870	2,160	1,300	3.80			0.46	0 years	
	Three Rivers	5,230	2,400	1,500	1.57			0.66	25 years	
McMullen	Tilden	1,200		150	0.68			1.33	5 years	
Nueces	CC Flour Bluff	6,037		1,600	1.45	844,628	62.56	8.93	0 years	
	CCS Staples	122,590		70,000	3.12	844,628	62.56	8.93	0 years	
	CC Greenwood	85,190		49,000	3.15	844,628	62.56	8.93	0 years	
	CC Prec. #2 (Agua Dulce)	1,363	4,051	350	1.40			10.28	0 years	
	Bishop	5,641	4,100	4,700	4.56	14,000	2.97	0.17	0 years	
	Port Aransas	1,300	2,200	1,700	7.15			2.94	5 years	
	Robstown	12,750	22,730	14,600	6.26	62,682	4.29	0.57	10 years	
San Patricio	Mathis	7,714	6,000	4,305	3.05				5 years	
	Sinton	8,708	7,000	7,042	4.42				0 years	
	Aransas Pass	8,303	7,000	7,800	5.14	26,516	4.41	0.57	10 years	
	Ingleside	5,589	4,500	3,010	2.95	15,600	9.45	0.30	20 years	
	Gregory	2,118	2,000	1,954	5.05				0 years	
	Taft	3,697	3,400	3,460	5.12				0 years	
	Odem	3,216	2,500	1,840	3.13			2.63	5 years	
	Portland	7,973	7,000	6,420	4.40	18,793	4.63	0.94	0 years	
Refugio	Woodsboro	2,100	2,200	1,260	3.28	2,000	1.59	0.89	0 years	
	Refugio	7,440	4,900	10,000	7.35	21,050	2.24	0.38	0 years	
	Tivoli	830		200	1.32			3.00	5 years	
	Austwell	830		200	1.32			0.75	5 years	

SOURCE: Texas State Department of Health

generation coefficients in terms of pounds per capita per day. The data presented in Table VI-1 indicate a wide variation in the coefficients; however, an average coefficient of 3.60 lb/capita-day was calculated based on the estimated total solid waste generated and the population served. This estimate compares with the national and state wide estimates of about 5.0 lb/capita-day, but it is on the low side. The municipal waste generation coefficient is assumed to include wastes generated by the commercial establishments and disposed of in municipal sites since no data to the contrary was reported.

The per site waste generation coefficients ranged from 0.58 lb/capita-day to 13.30 lb/capita-day. It can be assumed that low coefficients, less than 2 lb/capita-day, indicate that not all refuse generated by the municipal sector in the area was disposed of in the municipal sites. Likewise, coefficients greater than 5 lb/capita-day can be interpreted to mean that considerable wastes from sources other than the municipality are disposed of in the sites. The additional solid wastes could be hauled to the site by private collectors servicing other communities or private entities not serviced by the municipal system. These conclusions are based on the assumption that the data on site loadings are accurate, which may or may not be the case.

The costs associated with disposal presented in Table VI-1 vary from \$0.05 per ton to \$10.28 per ton. These costs do not necessarily represent the actual cost of collection and disposal but merely indicate the total amount of money appropriated by the municipalities for refuse disposal. The data represent non-capital expenditures and are low in comparison to nationally reported operating costs of \$1.00 to \$3.00 per ton, which are typical for properly operated sanitary landfills. (Sorg, 1968) If a majority of the sites are maintained properly, some of the costs are not properly reported. However, on the other hand, if the cost data are accurate and complete, then a majority of the sites are probably maintained poorly.

The final column in Table VI-1 is the response of the site operators to the question of remaining life of the facility in years. The date of the survey was 1968. Therefore, those operators indicating five years remaining should have no useful life in 1973 and new sites should have been located. Therefore, about 25 of the 40 sites are closed and new sites need to be located. These 25 sites were responsible for the disposal of 77 percent of the solid waste disposed of in municipal facilities in 1968. However by 1972, only 7 new applications for waste disposal sites had been received by the Texas State Department of Health, and one of those locations was not approved. It seems unlikely that the estimates of remaining life of facilities is accurate but it does seem likely that some problems do exist.

As a part of the methodology, some of the data in Table VI-1 was summarized to the county level and tabulated in Table VI-2. The summary enabled prediction, on the county level, of increased solid waste loadings resulting from increased population. Essentially the problem of disposal is county-wide and the efforts of each municipality must be coordinated especially in the less densely populated areas.

The basic equipment for proper sanitary landfill operations is a bulldozer or similar equipment required to spread, compact, and cover the refuse. The cost of a single unit is independent of the population of the community and the cost is the same for a site handling the solid wastes generated by 500 people or 25,000 people. Therefore, coordination on the location of municipal solid waste disposal facilities on a county-wide basis should result in more effective solid waste management and disposal. Only in the case of the Corpus Christi Bay area was data used on individual sites to assess a loading impact. Location of individual sites in the Corpus Christi Bay area are presented in Figure VI-1. The new sites, those coming into use after 1968, are included on the map and supportive information about the sites is supplied in Table VI-3.

Industrial Solid Wastes

A study of industrial solid waste generation in Texas was conducted by the Texas Water Quality Board and a summary of these data are included in Appendix D. This survey included randomly selected industries throughout Texas. The data are grouped according to sector numbers of the input/output economic model. The yearly waste generation per employee were based on the total employment of the facility at which the wastes were generated. Although total employment was not the desired data, it was the only employment data included in the survey.

Arithmetic averages of the data for each economic sector were generated as a preliminary means of deriving industrial solid waste generation coefficients for use in estimating future waste loads of hypothetical economic futures. These data are summarized in Appendix E. These averages summarized the standard industrial classifications within the sectors and were of limited use for predictive purposes. The range of the data within any sector varied by one to two orders of magnitude resulting in averages that tended to reflect those industries with high waste generation.

The best use of the Texas Water Quality Board survey would require direct use of data from the Coastal Bend Region with the use of state wide data as a check on the calculations. These data included some 40

TABLE VI-2
COUNTY-WIDE SUMMARY OF MUNICIPAL
SOLID WASTE DATA

County	Estimated Pop. Served, 1968*	Actual Pop. 1970	% Unserved (1970-1968/1970)	Coefficient lb/cap day**
Aransas	9,600	8,902	-7.8%	6.16
Bee	16,030	22,737	+29.5%	5.98
Brooks	7,480	8,005	+6.6%	5.04
Duval	13,700	11,722	-16.9%	1.96
Jim Wells	31,500	33,032	+4.6%	5.24
Karnes	14,145	13,467	-5.1%	3.18
Kleborg	30,900	33,166	+6.8%	4.32
Live Oak	7,100	6,697	-6.0%	2.16
McMullen	1,200	1,095	-9.6%	.68
Nueces	234,871	237,544	+1.1%	3.31
Refugio	11,200	9,494	-18.0%	5.7
San Patricio	47,318	47,288	-.1%	4.15

* 1968 Department of Health Survey

** 1968 Survey Loading/Estimated Pop. Served, 1968.

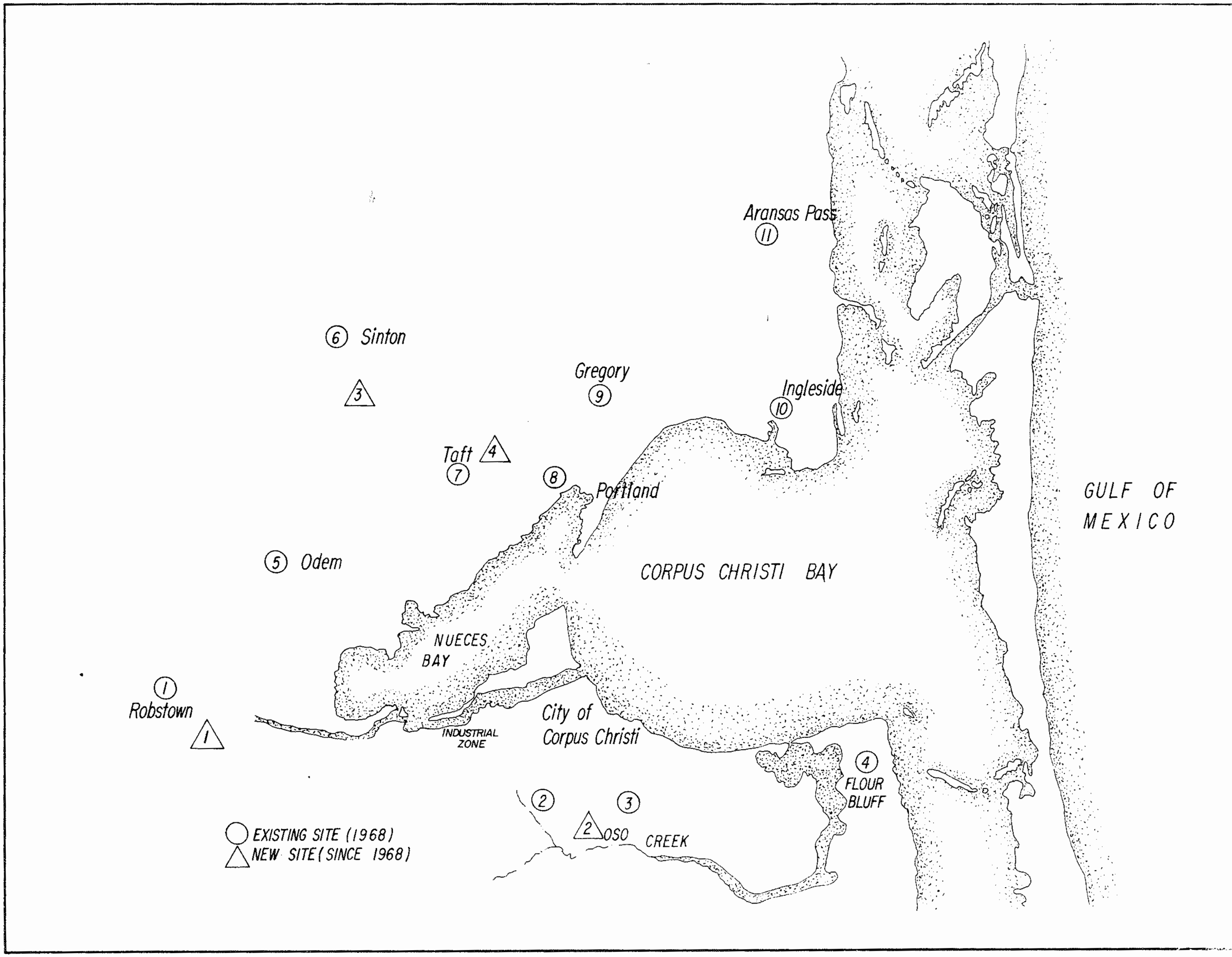


FIGURE VI-1. LOCATION OF MUNICIPAL SOLID WASTE DISPOSAL SITES IN THE CORPUS CHRISTI BAY AREA

TABLE VI-3

SOLID WASTE DISPOSAL DATA FOR SITES IN THE

CORPUS CHRISTI BAY AREA

Site Number (Figure V-1) (Old Sites)	Community Served	Estimated Population Served (1968)	Waste Loading in 1968 Tons/Year
1.	Robstown	12,750	14,600
2.	Corpus Christi	85,190	49,000
3.	Corpus Christi	122,590	70,000
4.	Corpus Christi-Flour Bluff	6,037	1,600
5.	Odem	3,216	1,840
6.	Sinton	8,708	7,042
7.	Taft	3,697	3,460
8.	Portland	7,973	6,420
9.	Gregory	2,118	1,954
10.	Ingleside	5,589	3,010
11.	Aransas Pass	8,303	7,800
NEW SITES			
1.	Corpus Christi/ Nueces Co.	------	
2.	City of Corpus Christi	------	
3.	San Patricio Co. - Rural	10,000-12,000 (1970)	------
4.	Taft-Portland	4,200 (1970)	------

industries or companies located in the Coastal Bend Region. Unfortunately 24 of the sources were in the same economic sector. A comparison of solid waste coefficients based on state wide data and Coastal Bend data were presented in Table VI-4. As an intermediate method coefficients were calculated for economic sectors based on Standard Industrial Classifications of those industries located in the Coastal Bend Region.

The complete analysis of industrial solid wastes involved not only calculation of waste generation coefficients but also tabulation of waste components and methods of disposal. The Coastal Bend data were tabulated in Table VI-5 to accomplish this end. In cases where the survey data did not include any Coastal Bend firms in a given economic sector, the waste generation coefficient and components of the waste were calculated from other firms in the state with the same standard industrial classification. The disposal methods were assumed to be the same as those listed in Table VI-5 for the same components. In this way, at least the final waste disposal method was assumed to be the same as practiced in the Coastal Bend Region.

The state wide data are summarized by economic sector in Table VI-6 along with disposal methods summarized by component.

The solid waste generation coefficients and other data in the table, along with the economic projections translated into employment figures, were used to estimate the total wastes generated, components of the total, and final disposal methods used for each.

TABLE VI-4

SUMMARIZATION OF INDUSTRIAL SOLID WASTE COEFFICIENTS BY ECONOMIC SECTOR

SECTOR	NO. FIRMS REPORTING FOR WHOLE STATE	NUMBER REPORTING FROM C.B. COG	WASTE GENERATION FACTORS TONS/YR./EMP.			
			STATE	JUST SIC'S IN COG	ACTUAL COG DATA	COMMENTS
* 10	518	24	3.94		5.89	CONSTRUCTION
11	14	0	26.05	26.05	----	
12	9	0	0.55	0.63	----	
13	10	1	2.32	3.25	1.32	
14	48	0	0.86	0.62	----	
15	15	2	3.85	1.80	1.73	
16	94	1	1.04	.38	.33	
17	106	2	11.23	34.93	1.23	
18	99	5	2.36	2.06	1.78	
* 19	71	1	66.73	66.73	1.61	CHEMICALS & ALLIED
* 20	7	0	30.6	30.6	----	PETROCHEM. & REFINING
21	60	0	5.46	1.83	----	
22	Combined with 21		48.23	48.23	----	
* 23	37	1	8.6	12.04	626.72	REYNOLDS ALUM.
24	80	0	3.09	2.34	----	
25	113	2	1.92	5.51	1.41	
26	44	0	1.13	3.85	----	
27	33	1	2.06	3.19	.25	
28	unknown	----	0.93	1.34		
29	101	8	2.69	3.38	1.30	
30	12	1	1.82	1.94	2.50	
31	12	0	1.00			
32	11	0	16.47			

SOURCE: Texas Water Development Board - Industrial Solid Waste Survey

TABLE VI-5
COASTAL BEND INDUSTRIAL SOLID WASTE DATA
COMPONENTS AND DISPOSAL METHODS

ECONOMIC SECTOR (Standard Industrial Classification)	COMPONENT	%	DISPOSAL METHOD
10	SOIL-STONE-ASH	76.2%	85% FILL MATERIAL
			15% MUNICIPAL SANITARY LANDFILL
(1511, 1611, 1621	RUBBLE (Brick, Concrete)	5.5%	FILL
1711, 1731, 1741	TEXTILES	5.4%	MUNICIPAL SANITARY LANDFILL
	WOOD	4.6%	MUNICIPAL SANITARY LANDFILL
1752, 1761, 1771	PAPER	4.1%	MUNICIPAL SANITARY LANDFILL
	ASBESTOS & ASPHALT TILE	3.1%	MUNICIPAL SANITARY LANDFILL
1793, 1799)	FERROUS METALS	1.6%	SALVAGE
	NON FERROUS METALS	0.1%	SALVAGE
13	PAPER	90.0%	MUNICIPAL SANITARY LANDFILL
(2036)	CROP & FOOD WASTES	9.1%	DUMPED INTO BAY
15	GLASS & POTTERY	57.4%	MUNICIPAL SANITARY LANDFILL
	PAPER	30.6%	SALVAGE
(2042, 2086)	WOOD	6.6%	MUNICIPAL SANITARY LANDFILL
	FERROUS METALS	4.0%	MUNICIPAL SANITARY LANDFILL
	SLUDGE	1.5%	MUNICIPAL SANITARY LANDFILL
	CROP & FOOD WASTES	.5%	CATTLE FEED
16	PLASTICS	50.0%	MUNICIPAL SANITARY LANDFILL
	FERROUS METALS	50.0%	MUNICIPAL SANITARY LANDFILL
(2298)			
17	WOOD (WASTE)	57.14%	MUNICIPAL SANITARY LANDFILL
	WOOD (CHIPS)	42.44%	SALVAGE
(2421,2511)			
18	PAPER	100%	93% MUNICIPAL SANITARY LANDFILL
			7% BURN
(2711,2751)			

TABLE VI-5 (continued)

19 (2895)	WOOD AND PAPER	100.0%	MUNICIPAL SANITARY LANDFILL
23	SLAG	99.7%	COMPANY OWNED LAGOONS
(3334)	METALS (FERROUS & NON FERROUS)	0.2%	SALVAGE
	RUBBISH (WOOD & PAPER)	0.1%	COMPANY OWNED SANITARY LANDFILL
24	FERROUS METALS	78.5%	SALVAGE
	INORGANIC CHEMICALS	12.6%	MUNICIPAL DUMP
(3522, 3599)	PAPER	8.9%	MUNICIPAL SANITARY LANDFILL
27 (3732)	FIBERGLASS	100.0%	MUNICIPAL SANITARY LANDFILL
29	PAPER	34.9%	MUNICIPAL SANITARY LANDFILL
	FERROUS METALS	26.1%	SALVAGE
(4214, 4213, 4221	RUBBER	14.4%	30% M.S.L. 70% MUNICIPAL DUMP
	WOOD	13.3%	MUNICIPAL SANITARY LANDFILL
4222, 4225)	CROP & FOOD WASTES	11.3%	MUNICIPAL SANITARY LANDFILL
30 (4459)	PAPER	100.0%	MUNICIPAL SANITARY LANDFILL

SOURCE: Texas Water Quality Board, Industrial Solid Waste Survey

TABLE VI-6
INDUSTRIAL SOLID WASTE COMPONENTS FOR
NON-COASTAL BEND FIRMS

		DISPOSAL METHOD
SECTOR 11		
Animal Remains	97.2%	SALVAGE
Trash	0.5%	MUNICIPAL SANITARY LANDFILL
SECTOR 12		
Trash	95.8%	MUNICIPAL SANITARY LANDFILL
SECTOR 14		
Paper	35.8%	MUNICIPAL SANITARY LANDFILL
Trash	30.1%	MUNICIPAL SANITARY LANDFILL
Food Processing Wastes	17.5%	MUNICIPAL SANITARY LANDFILL
Glass	7.0%	MUNICIPAL SANITARY LANDFILL
SECTOR 20		
Organic Chemicals	48.0%	SPREAD ON LAND
Rubble	15.0%	FILL
Sludge	14.0%	MUNICIPAL SANITARY LANDFILL
Inorganic Chemicals	13.0%	DUMP
SECTOR 21		
Rubble	51.3%	FILL
Trash	34.3%	MUNICIPAL SANITARY LANDFILL
Paper	8.2%	MUNICIPAL SANITARY LANDFILL
SECTOR 22		
Rubble	98.8%	FILL
Ferrous Metals	0.3%	SALVAGE
SECTOR 24		
Paper	13.8%	MUNICIPAL SANITARY LANDFILL
Ferrous Metals	53.9%	SALVAGE
Non Ferrous Metals	5.0%	SALVAGE
Rubble	7.5%	FILL
Trash	9.0%	MUNICIPAL SANITARY LANDFILL
SECTOR 26		
Ferrous Metals	54.9%	SALVAGE
Non Ferrous Metals	36.5%	SALVAGE

TABLE VI-6
(continued)

SECTOR 27		
Paper	7.9%	MUNICIPAL SANITARY LANDFILL
Ferrous Metals	31.6%	SALVAGE
Wood	12.9%	MUNICIPAL SANITARY LANDFILL
Rubble	34.7%	FILL
SECTOR 28		
Crop Wastes	31.8%	MUNICIPAL SANITARY LANDFILL
Trash	34.1%	MUNICIPAL SANITARY LANDFILL
Ferrous Metals	13.0%	SALVAGE
Wood	9.1%	MUNICIPAL SANITARY LANDFILL
Paper	6.6%	MUNICIPAL SANITARY LANDFILL
SECTOR 31		
Trash	47.0%	MUNICIPAL SANITARY LANDFILL
Garbage	36.0%	MUNICIPAL SANITARY LANDFILL
Ferrous Metals	13.0%	SALVAGE
Non Ferrous Metals	4.0%	SALVAGE
SECTOR 32		
Manure	41.0%	SPREAD ON LAND
Wood	5.0%	MUNICIPAL SANITARY LANDFILL
Trash	54.0%	MUNICIPAL SANITARY LANDFILL

CHAPTER VII
AIR POLLUTION

Air pollution has not been identified as a significant problem in the Coastal Bend Region. Atmospheric conditions in the area rarely support severe episodes as encountered elsewhere around the country. The land is very flat and strong southerly winds provide good mixing and dispersion of pollutants. Stagnation periods, episodes when pollutants concentrate because of inadequate mixing of air masses, are rare in occurrence and tend to break up quickly. The southerly winds which predominate carry most of the industrial pollutants, which are located north of the city, away from the populated areas.

There are several methods of assessing air pollution in an area. Air pollution potential methods constitute one category. Air pollution potential is defined as the "inability of the atmosphere to disperse and dilute pollutants which may be admitted into it." (Stern, et al., 1973) The most simple models require some estimates on mixing depth, half-life of pollutants, dimensions of the study area, and atmospheric stability of the area. Some studies have summarized historical atmospheric data into simple indices which, when combined with data on source strength of pollutants and dimensions of a city, will enable estimates of the relative concentration of a pollutant in that city. More complex models, usually computerized, add the effects of different sources at different locations for various combinations of wind-speed, direction and stability classes. The output generally contains prediction of ground concentration at various points throughout the study area by adding the effects of scattered sources.

As a general statement concerning the best method to use for a given problem, no more sophisticated model should be used than is necessary. If a simple and quick calculation assuming worst conditions results in no significant concentrations of pollutants, there is no advantage to using a more complex model to conclude the same thing. If, on the other hand, the worst possible conditions approach the concentrations that may be harmful to plants and animals, a more sophisticated model would be justified.

After consideration of the facts about the climate and measured ambient pollutant concentrations in the Corpus Christi area, the decision was made to use the approach of assessing air pollution potential. A "box" model was used in which air pollutants originating from both industries and private autos were assumed to concentrate without mixing with air masses outside the area. The "box" was actually a cylinder with a radius of 4.25 miles and height of 1500 feet. The 4.25 mile radius, centered in the middle of the industrial sector enclosed the sources of industrial air pollution in or adjacent to the City of Corpus Christi in addition to most of the downtown business district. The exact location of the base of the cylinder is illustrated in Figure VII-1. The numbered pollutant sources are tabulated in Table VII-1. Although other industries around the Corpus Christi Bay System emit significant quantities of air pollutants, the industrial channel area was chosen since the major concentration of sources and the potential for affecting the greatest number of people are located in this area.

Industries in the defined area which were identified as potential sources of gaseous pollutants were tabulated in Table VII-1. The records of the Texas Air Control Board, were the source for actual air emissions for the listed industries. However data for only one of the eleven potential sources were available. (It is possible that some of the files were in use when the data collection was in progress.) In the absence of actual data on the industries, emissions were estimated using average emission factors for typical technology and no air pollution control devices for each industrial type taken from the Environmental Protection Agency Document, "Compilation of Air Pollution Emission Factors, AP-42". It is not known what control devices, if any, were in use. The pollutants estimated were particulates, sulfur dioxide, carbon monoxide, nitric oxides, and hydrocarbons. Sulfur dioxide was assumed to have a half life of 45 minutes while the other pollutants were assumed to be conservative.

In addition to the industrial sources, automotive emissions also were estimated. The number of autos registered in the county was obtained from the Texas Department of Public Safety and the emission factors per car was taken from AP-42. To enable estimation of their contribution to pollutant concentrations in the defined area, the following assumptions were made:

(1) The same ratio of cars per person was assumed to hold for all the county. This assumption enabled prediction that 86 percent of the cars were located within the Corpus Christi city limits (about 86,110 cars in 1970).

(2) A nation-wide average of 11,560 miles per car per year was used and it was assumed that 50 percent of those miles were driven inside city limits or 5,780 miles per car per year resulting in a total mileage figure of 1,363,604.9 miles per day driven inside the city limits.

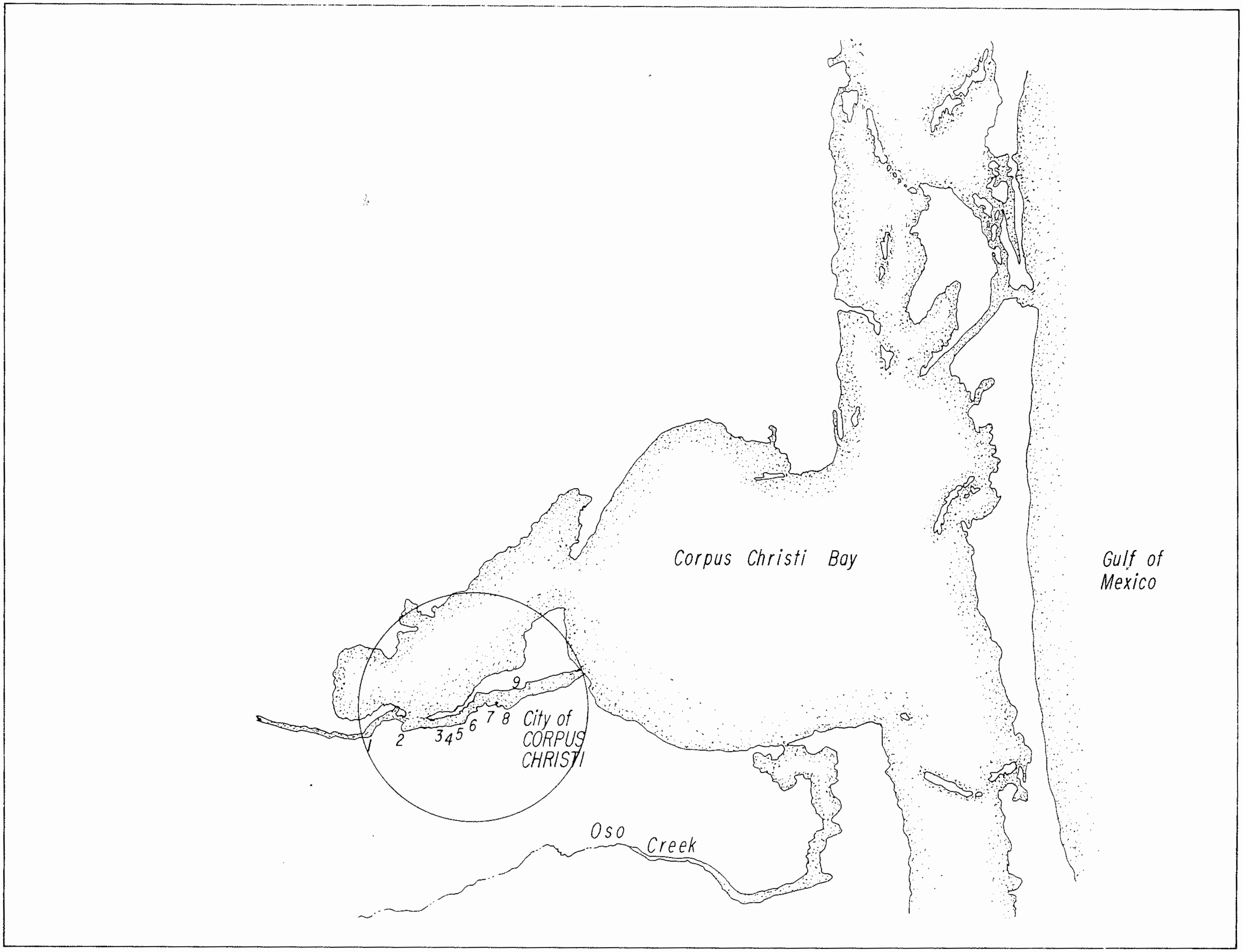


FIGURE VII-1. LOCATION OF INDUSTRIAL AIR EMISSIONS IN THE CORPUS CHRISTI INDUSTRIAL CHANNEL AREA

TABLE VII-1
ESTIMATED AIR EMISSIONS FOR INDUSTRIAL ZONE AND
DOWNTOWN CORPUS CHRISTI AREA 1970

INDUSTRY NUMBER FROM FIGURE VI-1	STANDARD INDUSTRIAL CLASSIFICATION	EMISSIONS IN GRAMS/MINUTE				
		PARTICULATES	SO_2	CO	NO_x	HC
1,4,5,6,7,8	2911 (Refineries)	116,153	52,921	1,470,698	318,937	104,130
2	2046 (Corn Milling)	393	628		1,882	
3	3334 (Smelting)	30,334	103,948			
9	3241 (Cement)	66,207			3,068	
Automobiles (Light Duty Gasoline Powered)		153	37	10,227	1,449	1,023
TOTALS		213,240	157,533	1,480,925	325,336	105,153

(3) It was assumed that 30 percent of the inter city limits driving was contained in the downtown area encompassed by the boundaries of the study, resulting in 409,081.5 miles per day driven in the area.

(4) Emission factors used were those for low altitude light duty gasoline powered vehicles. Factors for carbon monoxide, hydrocarbons, and nitrogen oxides were averages for 1970 vehicles. Trucks were not included in the analysis although they are recognized as being significant contributors to the total emissions from mobile sources.

Carbon Monoxide	-	36 grams/mile
Hydrocarbons	-	3.6 grams/mile
Nitrogen Oxides	-	5.1 grams/mile

Particulate emission factors were averages for all vehicles and included both exhaust particulates and tire wear. Sulfur oxides were based on fuel with a 0.032 percent sulfur content.

Particulates - 0.54 grams/mile
Sulfur Oxides - 0.13 grams/mile

(5) The same emission factors were used to estimate emissions in 1980 and 1990. Population projections were used along with the assumption that the number of cars per person would remain constant. These assumptions are consistent with the basic assumption of constant technological coefficients.

The assumptions made to enable estimation of emissions from automobiles are liberal in nature resulting in figures that should be higher than actual, thus insuring that the final estimate will be that for a worst condition. If all vehicles in the Corpus Christi area, including trucks, were assumed to be in the study area, the total emissions would still be lower than those for the refineries.

In addition to the industries and autos, one power plant, the Tule Channel Unit of Central Power and Light Company, also was within the area of study. The plant burns natural gas. No attempt was made to estimate the gaseous emissions from the power plant as such emissions are primarily dependent on the operation of the plant and insufficient data was available to enable the use of emission factors, reported in pounds per million cubic feet of air. It is not believed that the emissions from the plant, with the possible exception of nitrogen oxides, are of the same order of importance as the industrial totals.

The analysis of air pollution potential as compared to air quality standards for 1970 are presented in Table VII-2. It can be concluded that the unrealistically stable condition used would have to persist for many hours before pollutants would reach concentrations that might endanger vegetation and animals. In general, the one hour concentrations corresponding to alert levels are much higher than the 24-hour concentrations. In the case of Nitric Oxides the one-hour level is four times the 24-hour standard. The emission levels do not constitute potential harm on a short term basis, less than 24 hours, and stable atmospheric conditions would have to persist for more than 24 hours to produce ambient concentrations resulting in an alert condition.

TABLE VII-2

COMPARISON OF HYPOTHETICAL AIR QUALITY WITH TEXAS AIR QUALITY STANDARDS

POLLUTANTS	1970 Hypothetical Case Air Quality (1 Hour) $\mu g/m^3$	(2 Hours) $\mu g/m^3$	TEXAS AIR CONTROL BOARD AIR QUALITY STANDARDS: Alert Level $\mu g/m^3$	Warning Level $\mu g/m^3$	Emergency Level $\mu g/m^3$
Carbon Monoxide	1323	2646	17,000(8 hour)	34,000(8 hour)	46,000(8 hour)
Particulates	191	382	375(24 hour)	625(24 hour)	875(24 hour)
Sulfur Oxides	153	306	800(24 hour)	1,600(24 hour)	2,100(24 hour)
Product Sulfur Oxides x Particulates	$29.2x10^3$	$116.9x10^3$	$65x10^3$(24 hour)	$261x10^3$(24 hour)	$393x10^3$(24 hour)
Nitrogen Oxides	291	582	1130(1 hour) 282(24 hour)	2,260(1 hour) 565(24 hour)	3,000(1 hour) 750(24 hour)

APPENDIX A
STANDARD INDUSTRIAL CLASSIFICATIONS

A. AGRICULTURE, FORESTRY, AND FISHING

Code	*Short Title*
01	**AGRICULTURAL PRODUCTION—CROPS**
011	**Cash Grains**
0111	Wheat
0112	Rice
0115	Corn
0116	Soybeans
0119	Cash grains, nec
013	**Field Crops, Except Cash Grains**
0131	Cotton
0132	Tobacco
0133	Sugar crops
0134	Irish potatoes
0139	Field crops, except cash grains, nec
016	**Vegetables and Melons**
0161	Vegetables and melons
017	**Fruits and Tree Nuts**
0171	Berry crops
0172	Grapes
0173	Tree nuts
0174	Citrus fruits
0175	Deciduous tree fruits
0179	Fruits and tree nuts, nec
018	**Horticultural Specialties**
0181	Ornamental nursery products
0182	Food crops grown under cover
0189	Horticultural specialties, nec
019	**General Farms, Primarily Crop**
0191	General farms, primarily crop
02	**AGRICULTURAL PRODUCTION—LIVESTOCK**
021	**Livestock, exc. Dairy, Poultry, etc.**
0211	Beef cattle feedlots
0212	Beef cattle, except feedlots
0213	Hogs
0214	Sheep and goats
0219	General livestock, nec
024	**Dairy Farms**
0241	Dairy farms
025	**Poultry and Eggs**
0251	Broiler, fryer, and roaster chickens
0252	Chicken eggs
0253	Turkeys and turkey eggs
0254	Poultry hatcheries
0259	Poultry and eggs, nec
027	**Animal Specialties**
0271	Fur-bearing animals and rabbits

Code	*Short Title*
0272	Horses and other equines
0279	Animal specialties, nec
029	**General Farms, Primarily Livestock**
0291	General farms, primarily livestock
07	**AGRICULTURAL SERVICES**
071	**Soil Preparation Services**
0711	Soil preparation services
072	**Crop Services**
0721	Crop planting and protection
0722	Crop harvesting
0723	Crop preparation services for market
0724	Cotton ginning
0729	General crop services
074	**Veterinary Services**
0741	Veterinary services, farm livestock
0742	Veterinary services, specialties
075	**Animal Services, Except Veterinary**
0751	Livestock services, exc. specialties
0752	Animal specialty services
076	**Farm Labor and Management Services**
0761	Farm labor contractors
0762	Farm management services
078	**Landscape and Horticultural Services**
0781	Landscape counseling and planning
0782	Lawn and garden services
0783	Ornamental shrub and tree services
08	**FORESTRY**
081	**Timber Tracts**
0811	Timber tracts
082	**Forest Nurseries and Seed Gathering**
0821	Forest nurseries and seed gathering
084	**Gathering of Misc. Forest Products**
0843	Extraction of pine gum
0849	Gathering of forest products, nec
085	**Forestry Services**
0851	Forestry services
09	**FISHING, HUNTING, AND TRAPPING**
091	**Commercial Fishing**
0912	Finfish
0913	Shellfish
0919	Miscellaneous marine products
092	**Fish Hatcheries and Preserves**
0921	Fish hatcheries and preserves
097	**Hunting, Trapping, Game Propagation**
0971	Hunting, trapping, game propagation

B. MINING

Code	Short Title
10	METAL MINING
101	**Iron Ores**
1011	Iron ores
102	**Copper Ores**
1021	Copper ores
103	**Lead and Zinc Ores**
1031	Lead and zinc ores
104	**Gold and Silver Ores**
1041	Gold ores
1044	Silver ores
105	**Bauxite and Other Aluminum Ores**
1051	Bauxite and other aluminum ores
106	**Ferroalloy Ores, Except Vanadium**
1061	Ferroalloy ores, except vanadium
108	**Metal Mining Services**
1081	Metal mining services
109	**Miscellaneous Metal Ores**
1092	Mercury ores
1094	Uranium-radium-vanadium ores
1099	Metal ores, nec
11	ANTHRACITE MINING
111	**Anthracite Mining**
1111	Anthracite
1112	Anthracite mining services
12	BITUMINOUS COAL AND LIGNITE MINING
121	**Bituminous Coal and Lignite Mining**
1211	Bituminous coal and lignite
1213	Bituminous & lignite mining services
13	OIL AND GAS EXTRACTION
131	**Crude Petroleum and Natural Gas**
1311	Crude petroleum and natural gas
132	**Natural Gas Liquids**
1321	Natural gas liquids
138	**Oil and Gas Field Services**
1381	Drilling oil and gas wells
1382	Oil and gas exploration services
1389	Oil and gas field services, nec
14	NONMETALLIC MINERALS, EXCEPT FUELS
141	**Dimension Stone**
1411	Dimension stone
142	**Crushed and Broken Stone**
1422	Crushed and broken limestone
1423	Crushed and broken granite
1429	Crushed and broken stone, nec
144	**Sand and Gravel**
1442	Construction sand and gravel
1446	Industrial sand
145	**Clay and Related Minerals**
1452	Bentonite
1453	Fire clay
1454	Fuller's earth
1455	Kaolin and ball clay
1459	Clay and related minerals, nec
147	**Chemical and Fertilizer Minerals**
1472	Barite
1473	Fluorspar
1474	Potash, soda, and borate minerals
1475	Phosphate rock
1476	Rock salt
1477	Sulfur
1479	Chemical and fertilizer mining, nec
148	**Nonmetallic Minerals Services**
1481	Nonmetallic minerals services
149	**Miscellaneous Nonmetallic Minerals**
1492	Gypsum
1496	Talc, soapstone, and pyrophyllite
1499	Nonmetallic minerals, nec

C. CONSTRUCTION

Code	Short Title
15	GENERAL BUILDING CONTRACTORS
152	**Residential Building Construction**
1521	Single-family housing construction
1522	Residential construction, nec
153	**Operative Builders**
1531	Operative builders
154	**Nonresidential Building Construction**
1541	Industrial buildings and warehouses
1542	Nonresidential construction, nec
16	HEAVY CONSTRUCTION CONTRACTORS
161	**Highway and Street Construction**
1611	Highway and street construction
162	**Heavy Construction, Except Highway**
1622	Bridge, tunnel, & elevated highway
1623	Water, sewer, and utility lines
1629	Heavy construction, nec

Code	Short Title
17	SPECIAL TRADE CONTRACTORS
171	**Plumbing, Heating, Air Conditioning**
1711	Plumbing, heating, air conditioning
172	**Painting, Paper Hanging, Decorating**
1721	Painting, paper hanging, decorating
173	**Electrical Work**
1731	Electrical work
174	**Masonry, Stonework, and Plastering**
1741	Masonry and other stonework
1742	Plastering, drywall and insulation
1743	Terrazzo, tile, marble, mosaic work
175	**Carpentering and Flooring**
1751	Carpentering
1752	Floor laying and floor work, nec
176	**Roofing and Sheet Metal Work**
1761	Roofing and sheet metal work
177	**Concrete Work**
1771	Concrete work
178	**Water Well Drilling**
1781	Water well drilling
179	**Misc. Special Trade Contractors**
1791	Structural steel erection
1793	Glass and glazing work
1794	Excavating and foundation work
1795	Wrecking and demolition work
1796	Installing building equipment, nec
1799	Special trade contractors, nec

D. MANUFACTURING

Code	Short Title
20	FOOD AND KINDRED PRODUCTS
201	**Meat Products**
2011	Meat packing plants
2013	Sausages and other prepared meats
2016	Poultry dressing plants
2017	Poultry and egg processing
202	**Dairy Products**
2021	Creamery butter
2022	Cheese, natural and processed
2023	Condensed and evaporated milk
2024	Ice cream and frozen desserts
2026	Fluid milk
203	**Preserved Fruits and Vegetables**
2032	Canned specialties
2033	Canned fruits and vegetables
2034	Dehydrated fruits, vegetables, soups
2035	Pickles, sauces, and salad dressings
2037	Frozen fruits and vegetables
2038	Frozen specialties
204	**Grain Mill Products**
2041	Flour and other grain mill products
2043	Cereal breakfast foods
2044	Rice milling
2045	Blended and prepared flour
2046	Wet corn milling
2047	Dog, cat, and other pet food
2048	Prepared feeds, nec
205	**Bakery Products**
2051	Bread, cake, and related products
2052	Cookies and crackers
206	**Sugar and Confectionery Products**
2061	Raw cane sugar
2062	Cane sugar refining
2063	Beet sugar
2065	Confectionery products
2066	Chocolate and cocoa products
2067	Chewing gum
207	**Fats and Oils**
2074	Cottonseed oil mills
2075	Soybean oil mills
2076	Vegetable oil mills, nec
2077	Animal and marine fats and oils
2079	Shortening and cooking oils
208	**Beverages**
2082	Malt beverages
2083	Malt
2084	Wines, brandy, and brandy spirits
2085	Distilled liquor, except brandy
2086	Bottled and canned soft drinks
2087	Flavoring extracts and sirups, nec
209	**Misc. Foods and Kindred Products**
2091	Canned and cured seafoods
2092	Fresh or frozen packaged fish
2095	Roasted coffee
2097	Manufactured ice
2098	Macaroni and spaghetti
2099	Food preparations, nec
21	TOBACCO MANUFACTURES
211	**Cigarettes**
2111	Cigarettes
212	**Cigars**
2121	Cigars
213	**Chewing and Smoking Tobacco**
2131	Chewing and smoking tobacco
214	**Tobacco Stemming and Redrying**
2141	Tobacco stemming and redrying

Code	Short Title
22	**TEXTILE MILL PRODUCTS**
221	**Weaving Mills, Cotton**
2211	Weaving mills, cotton
222	**Weaving Mills, Synthetics**
2221	Weaving mills, synthetics
223	**Weaving and Finishing Mills, Wool**
2231	Weaving and finishing mills, wool
224	**Narrow Fabric Mills**
2241	Narrow fabric mills
225	**Knitting mills**
2251	Women's hosiery, except socks
2252	Hosiery, nec
2253	Knit outerwear mills
2254	Knit underwear mills
2257	Circular knit fabric mills
2258	Warp knit fabric mills
2259	Knitting mills, nec
226	**Textile Finishing, Except Wool**
2261	Finishing plants, cotton
2262	Finishing plants, synthetics
2269	Finishing plants, nec
227	**Floor Covering Mills**
2271	Woven carpets and rugs
2272	Tufted carpets and rugs
2279	Carpets and rugs, nec
228	**Yarn and Thread Mills**
2281	Yarn mills. except wool
2282	Throwing and winding mills
2283	Wool yarn mills
2284	Thread mills
229	**Miscellaneous Textile Goods**
2291	Felt goods, exc. woven felts & hats
2292	Lace goods
2293	Paddings and upholstery filling
2294	Processed textile waste
2295	Coated fabrics, not rubberized
2296	Tire cord and fabric
2297	Nonwoven fabrics
2298	Cordage and twine
2299	Textile goods, nec
23	**APPAREL AND OTHER TEXTILE PRODUCTS**
231	**Men's and Boys' Suits and Coats**
2311	Men's and boys' suits and coats
232	**Men's and Boys' Furnishings**
2321	Men's and boys' shirts and nightwear
2322	Men's and boys' underwear
2323	Men's and boys' neckwear
2327	Men's and boys' separate trousers
2328	Men's and boys' work clothing
2329	Men's and boys' clothing, nec

Code	Short Title
233	**Women's and Misses' Outerwear**
2331	Women's & misses' blouses & waists
2335	Women's and misses' dresses
2337	Women's and misses' suits and coats
2339	Women's and misses' outerwear, nec
234	**Women's and Children's Undergarments**
2341	Women's and children's underwear
2342	Brassieres and allied garments
235	**Hats, Caps, and Millinery**
2351	Millinery
2352	Hats and caps, except millinery
236	**Children's Outerwear**
2361	Children's dresses and blouses
2363	Children's coats and suits
2369	Children's outerwear, nec
237	**Fur Goods**
2371	Fur goods
238	**Miscellaneous Apparel and Accessories**
2381	Fabric dress and work gloves
2384	Robes and dressing gowns
2385	Waterproof outergarments
2386	Leather and sheep lined clothing
2387	Apparel belts
2389	Apparel and accessories, nec
239	**Misc. Fabricated Textile Products**
2391	Curtains and draperies
2392	House furnishings, nec
2393	Textile bags
2394	Canvas and related products
2395	Pleating and stitching
2396	Automotive and apparel trimmings
2397	Schiffli machine embroideries
2399	Fabricated textile products, nec
24	**LUMBER AND WOOD PRODUCTS**
241	**Logging Camps & Logging Contractors**
2411	Logging camps & logging contractors
242	**Sawmills and Planing Mills**
2421	Sawmills and planing mills, general
2426	Hardwood dimension and flooring
2429	Special product sawmills, nec
243	**Millwork, Plywood & Structural Members**
2431	Millwork
2434	Wood kitchen cabinets
2435	Hardwood veneer and plywood
2436	Softwood veneer and plywood
2439	Structural wood members, nec
244	**Wood Containers**
2441	Nailed wood boxes and shook
2448	Wood pallets and skids
2449	Wood containers, nec

Code	Short Title
245	**Wood Buildings and Mobile Homes**
2451	Mobile homes
2452	Prefabricated wood buildings
249	**Miscellaneous Wood Products**
2491	Wood preserving
2492	Particleboard
2499	Wood products, nec
25	FURNITURE AND FIXTURES
251	**Household Furniture**
2511	Wood household furniture
2512	Upholstered household furniture
2514	Metal household furniture
2515	Mattresses and bedsprings
2517	Wood TV and radio cabinets
2519	Household furniture, nec
252	**Office Furniture**
2521	Wood office furniture
2522	Metal office furniture
253	**Public Building & Related Furniture**
2531	Public building & related furniture
254	**Partitions and Fixtures**
2541	Wood partitions and fixtures
2542	Metal partitions and fixtures
259	**Miscellaneous Furniture and Fixtures**
2591	Drapery hardware & blinds & shades
2599	Furniture and fixtures, nec
26	PAPER AND ALLIED PRODUCTS
261	**Pulp Mills**
2611	Pulp mills
262	**Paper Mills, Except Building Paper**
2621	Paper mills, except building paper
263	**Paperboard Mills**
2631	Paperboard mills
264	**Misc. Converted Paper Products**
2641	Paper coating and glazing
2642	Envelopes
2643	Bags, except textile bags
2645	Die-cut paper and board
2646	Pressed and molded pulp goods
2647	Sanitary paper products
2648	Stationery products
2649	Converted paper products, nec
265	**Paperboard Containers and Boxes**
2651	Folding paperboard boxes
2652	Set-up paperboard boxes
2653	Corrugated and solid fiber boxes
2654	Sanitary food containers
2655	Fiber cans, drums & similar products
266	**Building Paper and Board Mills**
2661	Building paper and board mills

Code	Short Title
27	PRINTING AND PUBLISHING
271	**Newspapers**
2711	Newspapers
272	**Periodicals**
2721	Periodicals
273	**Books**
2731	Book publishing
2732	Book printing
274	**Miscellaneous Publishing**
2741	Miscellaneous publishing
275	**Commercial Printing**
2751	Commercial printing, letterpress
2752	Commercial printing, lithographic
2753	Engraving and plate printing
2754	Commercial printing, gravure
276	**Manifold Business Forms**
2761	Manifold business forms
277	**Greeting Card Publishing**
2771	Greeting card publishing
278	**Blankbooks and Bookbinding**
2782	Blankbooks and looseleaf binders
2789	Bookbinding and related work
279	**Printing Trade Services**
2791	Typesetting
2793	Photoengraving
2794	Electrotyping and stereotyping
2795	Lithographic platemaking services
28	CHEMICALS AND ALLIED PRODUCTS
281	**Industrial Inorganic Chemicals**
2812	Alkalies and chlorine
2813	Industrial gases
2816	Inorganic pigments
2819	Industrial inorganic chemicals, nec
282	**Plastics Materials and Synthetics**
2821	Plastics materials and resins
2822	Synthetic rubber
2823	Cellulosic man-made fibers
2824	Organic fibers, noncellulosic
283	**Drugs**
2831	Biological products
2833	Medicinals and botanicals
2834	Pharmaceutical preparations
284	**Soap, Cleaners, and Toilet Goods**
2841	Soap and other detergents
2842	Polishes and sanitation goods
2843	Surface active agents
2844	Toilet preparations
285	**Paints and Allied Products**
2851	Paints and allied products
286	**Industrial Organic Chemicals**

Code	Short Title
2861	Gum and wood chemicals
2865	Cyclic crudes and intermediates
2869	Industrial organic chemicals, nec
287	**Agricultural Chemicals**
2873	Nitrogenous fertilizers
2874	Phosphatic fertilizers
2875	Fertilizers, mixing only
2879	Agricultural chemicals, nec
289	**Miscellaneous Chemical Products**
2891	Adhesives and sealants
2892	Explosives
2893	Printing ink
2895	Carbon black
2899	Chemical preparations, nec
29	PETROLEUM AND COAL PRODUCTS
291	**Petroleum Refining**
2911	Petroleum refining
295	**Paving and Roofing Materials**
2951	Paving mixtures and blocks
2952	Asphalt felts and coatings
299	**Misc. Petroleum and Coal Products**
2992	Lubricating oils and greases
2999	Petroleum and coal products, nec
30	RUBBER AND MISC. PLASTICS PRODUCTS
301	**Tires and Inner Tubes**
3011	Tires and inner tubes
302	**Rubber and Plastics Footwear**
3021	Rubber and plastics footwear
303	**Reclaimed Rubber**
3031	Reclaimed rubber
304	**Rubber and Plastics Hose and Belting**
3041	Rubber and plastics hose and belting
306	**Fabricated Rubber Products, nec**
3069	Fabricated rubber products, nec
307	**Miscellaneous Plastics Products**
3079	Miscellaneous plastics products
31	LEATHER AND LEATHER PRODUCTS
311	**Leather Tanning and Finishing**
3111	Leather tanning and finishing
313	**Boot and Shoe Cut Stock and Findings**
3131	Boot and shoe cut stock and findings
314	**Footwear, Except Rubber**
3142	House slippers
3143	Men's footwear, except athletic
3144	Women's footwear, except athletic
3149	Footwear, except rubber, nec
315	**Leather Gloves and Mittens**
3151	Leather gloves and mittens

Code	Short Title
316	**Luggage**
3161	Luggage
317	**Handbags and Personal Leather Goods**
3171	Women's handbags and purses
3172	Personal leather goods, nec
319	**Leather Goods, nec**
3199	Leather goods, nec
32	STONE, CLAY, AND GLASS PRODUCTS
321	**Flat Glass**
3211	Flat glass
322	**Glass and Glassware, Pressed or Blown**
3221	Glass containers
3229	Pressed and blown glass, nec
323	**Products of Purchased Glass**
3231	Products of purchased glass
324	**Cement, Hydraulic**
3241	Cement, hydraulic
325	**Structural Clay Products**
3251	Brick and structural clay tile
3253	Ceramic wall and floor tile
3255	Clay refractories
3259	Structural clay products, nec
326	**Pottery and Related Products**
3261	Vitreous plumbing fixtures
3262	Vitreous china food utensils
3263	Fine earthenware food utensils
3264	Porcelain electrical supplies
3269	Pottery products, nec
327	**Concrete, Gypsum, and Plaster Products**
3271	Concrete block and brick
3272	Concrete products, nec
3273	Ready-mixed concrete
3274	Lime
3275	Gypsum products
328	**Cut Stone and Stone Products**
3281	Cut stone and stone products
329	**Misc. Nonmetallic Mineral Products**
3291	Abrasive products
3292	Asbestos products
3293	Gaskets, packing and sealing devices
3295	Minerals, ground or treated
3296	Mineral wool
3297	Nonclay refractories
3299	Nonmetallic mineral products, nec
33	PRIMARY METAL INDUSTRIES
331	**Blast Furnace and Basic Steel Products**
3312	Blast furnaces and steel mills
3313	Electrometallurgical products
3315	Steel wire and related products

Code	*Short Title*
3316	Cold finishing of steel shapes
3317	Steel pipe and tubes
332	**Iron and Steel Foundries**
3321	Gray iron foundries
3322	Malleable iron foundries
3324	Steel investment foundries
3325	Steel foundries, nec
333	**Primary Nonferrous Metals**
3331	Primary copper
3332	Primary lead
3333	Primary zinc
3334	Primary aluminum
3339	Primary nonferrous metals, nec
334	**Secondary Nonferrous Metals**
3341	Secondary nonferrous metals
335	**Nonferrous Rolling and Drawing**
3351	Copper rolling and drawing
3353	Aluminum sheet, plate, and foil
3354	Aluminum extruded products
3355	Aluminum rolling and drawing, nec
3356	Nonferrous rolling and drawing, nec
3357	Nonferrous wire drawing & insulating
336	**Nonferrous Foundries**
3361	Aluminum foundries
3362	Brass, bronze, and copper foundries
3369	Nonferrous foundries, nec
339	**Miscellaneous Primary Metal Products**
3398	Metal heat treating
3399	Primary metal products, nec
34	FABRICATED METAL PRODUCTS
341	**Metal Cans and Shipping Containers**
3411	Metal cans
3412	Metal barrels, drums, and pails
342	**Cutlery, Hand Tools, and Hardware**
3421	Cutlery
3423	Hand and edge tools, nec
3425	Hand saws and saw blades
3429	Hardware, nec
343	**Plumbing and Heating, Except Electric**
3431	Metal sanitary ware
3432	Plumbing fittings and brass goods
3433	Heating equipment, except electric
344	**Fabricated Structural Metal Products**
3441	Fabricated structural metal
3442	Metal doors, sash, and trim
3443	Fabricated plate work (boiler shops)
3444	Sheet metal work
3446	Architectural metal work
3448	Prefabricated metal buildings
3449	Miscellaneous metal work
345	**Screw Machine Products, Bolts, etc.**
3451	Screw machine products
3452	Bolts, nuts, rivets, and washers
346	**Metal Forgings and Stampings**
3462	Iron and steel forgings
3463	Nonferrous forgings
3465	Automotive stampings
3466	Crowns and closures
3469	Metal stampings, nec
347	**Metal Services, nec**
3471	Plating and polishing
3479	Metal coating and allied services
348	**Ordnance and Accessories, nec**
3482	Small arms ammunition
3483	Ammunition, exc. for small arms, nec
3484	Small arms
3489	Ordnance and accessories, nec
349	**Misc. Fabricated Metal Products**
3493	Steel springs, except wire
3494	Valves and pipe fittings
3495	Wire springs
3496	Misc. fabricated wire products
3497	Metal foil and leaf
3498	Fabricated pipe and fittings
3499	Fabricated metal products, nec
35	MACHINERY, EXCEPT ELECTRICAL
351	**Engines and Turbines**
3511	Turbines and turbine generator sets
3519	Internal combustion engines, nec
352	**Farm and Garden Machinery**
3523	Farm machinery and equipment
3524	Lawn and garden equipment
353	**Construction and Related Machinery**
3531	Construction machinery
3532	Mining machinery
3533	Oil field machinery
3534	Elevators and moving stairways
3535	Conveyors and conveying equipment
3536	Hoists, cranes, and monorails
3537	Industrial trucks and tractors
354	**Metalworking Machinery**
3541	Machine tools, metal cutting types
3542	Machine tools, metal forming types
3544	Special dies, tools, jigs & fixtures
3545	Machine tool accessories
3546	Power driven hand tools
3547	Rolling mill machinery
3549	Metalworking machinery, nec
355	**Special Industry Machinery**
3551	Food products machinery

Code	Short Title
3552	Textile machinery
3553	Woodworking machinery
3554	Paper industries machinery
3555	Printing trades machinery
3559	Special industry machinery, nec
356	**General Industrial Machinery**
3561	Pumps and pumping equipment
3562	Ball and roller bearings
3563	Air and gas compressors
3564	Blowers and fans
3565	Industrial patterns
3566	Speed changers, drives, and gears
3567	Industrial furnaces and ovens
3568	Power transmission equipment, nec
3569	General industrial machinery, nec
357	**Office and Computing Machines**
3572	Typewriters
3573	Electronic computing equipment
3574	Calculating and accounting machines
3576	Scales and balances, exc. laboratory
3579	Office machines, nec
358	**Refrigeration and Service Machinery**
3581	Automatic merchandising machines
3582	Commercial laundry equipment
3585	Refrigeration and heating equipment
3586	Measuring and dispensing pumps
3589	Service industry machinery, nec
359	**Misc. Machinery, Except Electrical**
3592	Carburetors, pistons, rings, valves
3599	Machinery, except electrical, nec
36	ELECTRIC AND ELECTRONIC EQUIPMENT
361	**Electric Distributing Equipment**
3612	Transformers
3613	Switchgear and switchboard apparatus
362	**Electrical Industrial Apparatus**
3621	Motors and generators
3622	Industrial controls
3623	Welding apparatus, electric
3624	Carbon and graphite products
3629	Electrical industrial apparatus, nec
363	**Household Appliances**
3631	Household cooking equipment
3632	Household refrigerators and freezers
3633	Household laundry equipment
3634	Electric housewares and fans
3635	Household vacuum cleaners
3636	Sewing machines
3639	Household appliances, nec

Code	Short Title
364	**Electric Lighting and Wiring Equipment**
3641	Electric lamps
3643	Current-carrying wiring devices
3644	Noncurrent-carrying wiring devices
3645	Residential lighting fixtures
3646	Commercial lighting fixtures
3647	Vehicular lighting equipment
3648	Lighting equipment, nec
365	**Radio and TV Receiving Equipment**
3651	Radio and TV receiving sets
3652	Phonograph records
366	**Communication Equipment**
3661	Telephone and telegraph apparatus
3662	Radio and TV communication equipment
367	**Electronic Components and Accessories**
3671	Electron tubes, receiving type
3672	Cathode ray television picture tubes
3673	Electron tubes, transmitting
3674	Semiconductors and related devices
3675	Electronic capacitors
3676	Electronic resistors
3677	Electronic coils and transformers
3678	Electronic connectors
3679	Electronic components, nec
369	**Misc. Electrical Equipment & Supplies**
3691	Storage batteries
3692	Primary batteries, dry and wet
3693	X-ray apparatus and tubes
3694	Engine electrical equipment
3699	Electrical equipment & supplies, nec
37	TRANSPORTATION EQUIPMENT
371	**Motor Vehicles and Equipment**
3711	Motor vehicles and car bodies
3713	Truck and bus bodies
3714	Motor vehicle parts and accessories
3715	Truck trailers
372	**Aircraft and Parts**
3721	Aircraft
3724	Aircraft engines and engine parts
3728	Aircraft equipment, nec
373	**Ship and Boat Building and Repairing**
3731	Ship bui..ing and repairing
3732	Boat building and repairing
374	**Railroad Equipment**
3743	Railroad equipment
375	**Motorcycles, Bicycles, and Parts**
3751	Motorcycles, bicycles, and parts
376	**Guided Missiles, Space Vehicles, Parts**
3761	Guided missiles and space vehicles

Code	*Short Title*
3764	Space propulsion units and parts
3769	Space vehicle equipment, nec
379	**Miscellaneous Transportation Equipment**
3792	Travel trailers and campers
3795	Tanks and tank components
3799	Transportation equipment, nec.
38	**INSTRUMENTS AND RELATED PRODUCTS**
381	**Engineering & Scientific Instruments**
3811	Engineering & scientific instruments
382	**Measuring and Controlling Devices**
3822	Environmental controls
3823	Process control instruments
3824	Fluid meters and counting devices
3825	Instruments to measure electricity
3829	Measuring & controlling devices, nec
383	**Optical Instruments and Lenses**
3832	Optical instruments and lenses
384	**Medical Instruments and Supplies**
3841	Surgical and medical instruments
3842	Surgical appliances and supplies
3843	Dental equipment and supplies
385	**Ophthalmic Goods**
3851	Ophthalmic goods
386	**Photographic Equipment and Supplies**
3861	Photographic equipment and supplies
387	**Watches, Clocks, and Watchcases**
3373	Watches, clocks, and watchcases

Code	*Short Title*
39	**MISCELLANEOUS MANUFACTURING INDUSTRIES**
391	**Jewelry, Silverware, and Plated Ware**
3911	Jewelry, precious metal
3914	Silverware and plated ware
3915	Jewelers' materials & lapidary work
393	**Musical Instruments**
3931	Musical instruments
394	**Toys and Sporting Goods**
3942	Dolls
3944	Games, toys, and children's vehicles
3949	Sporting and athletic goods, nec
395	**Pens, Pencils, Office and Art Supplies**
3951	Pens and mechanical pencils
3952	Lead pencils and art goods
3953	Marking devices
3955	Carbon paper and inked ribbons
396	**Costume Jewelry and Notions**
3961	Costume jewelry
3962	Artificial flowers
3963	Buttons
3964	Needles, pins, and fasteners
399	**Miscellaneous Manufactures**
3991	Brooms and brushes
3993	Signs and advertising displays
3995	Burial caskets
3996	Hard surface floor coverings
3999	Manufacturing industries, nec

E. TRANSPORTATION AND PUBLIC UTILITIES

Code	*Short Title*
40	**RAILROAD TRANSPORTATION**
401	**Railroads**
4011	Railroads, line-haul operating
4013	Switching and terminal services
404	**Railway Express Service**
4041	Railway express service
41	**LOCAL AND INTERURBAN PASSENGER TRANSIT**
411	**Local and Suburban Transportation**
4111	Local and suburban transit
4119	Local passenger transportation, nec
412	**Taxicabs**
4121	Taxicabs
413	**Intercity Highway Transportation**
4131	Intercity highway transportation
414	**Transportation Charter Service**
4141	Local passenger charter service
4142	Charter service, except local

Code	*Short Title*
415	**School Buses**
4151	School buses
417	**Bus Terminal and Service Facilities**
4171	Bus terminal facilities
4172	Bus service facilities
42	**TRUCKING AND WAREHOUSING**
421	**Trucking, Local and Long Distance**
4212	Local trucking, without storage
4213	Trucking, except local
4214	Local trucking and storage
422	**Public Warehousing**
4221	Farm product warehousing and storage
4222	Refrigerated warehousing
4224	Household goods warehousing
4225	General warehousing and storage
4226	Special warehousing and storage, nec
423	**Trucking Terminal Facilities**
4231	Trucking terminal facilities

Code	Short Title
43	**U.S. POSTAL SERVICE**
431	**U.S. Postal Service**
4311	U.S. Postal Service
44	WATER TRANSPORTATION
441	**Deep Sea Foreign Transportation**
4411	Deep sea foreign transportation
442	**Deep Sea Domestic Transportation**
4421	Noncontiguous area transportation
4422	Coastwise transportation
4423	Intercoastal transportation
443	**Great Lakes Transportation**
4431	Great Lakes transportation
444	**Transportation on Rivers and Canals**
4441	Transportation on rivers and canals
445	**Local Water Transportation**
4452	Ferries
4453	Lighterage
4454	Towing and tugboat service
4459	Local water transportation, nec
446	**Water Transportation Services**
4463	Marine cargo handling
4464	Canal operation
4469	Water transportation services, nec
45	TRANSPORTATION BY AIR
451	**Certificated Air Transportation**
4511	Certificated air transportation
452	**Noncertificated Air Transportation**
4521	Noncertificated air transportation
458	**Air Transportation Services**
4582	Airports and flying fields
4583	Airport terminal services
46	PIPE LINES, EXCEPT NATURAL GAS
461	**Pipe Lines, Except Natural Gas**
4612	Crude petroleum pipe lines
4613	Refined petroleum pipe lines
4619	Pipe lines, nec
47	TRANSPORTATION SERVICES
471	**Freight Forwarding**
4712	Freight forwarding
472	**Arrangement of Transportation**

Code	Short Title
4722	Passenger transportation arrangement
4723	Freight transportation arrangement
474	**Rental of Railroad Cars**
4742	Railroad car rental with service
4743	Railroad car rental without service
478	**Miscellaneous Transportation Services**
4782	Inspection and weighing services
4783	Packing and crating
4784	Fixed facilities for vehicles, nec
4789	Transportation services, nec
48	COMMUNICATION
481	**Telephone Communication**
4811	Telephone communication
482	**Telegraph Communication**
4821	Telegraph communication
483	**Radio and Television Broadcasting**
4832	Radio broadcasting
4833	Television broadcasting
489	**Communication Services, nec**
4899	Communication services, nec
49	ELECTRIC, GAS, AND SANITARY SERVICES
491	**Electric Services**
4911	Electric services
492	**Gas Production and Distribution**
4922	Natural gas transmission
4923	Gas transmission and distribution
4924	Natural gas distribution
4925	Gas production and/or distribution
493	**Combination Utility Services**
4931	Electric and other services combined
4932	Gas and other services combined
4939	Combination utility services, nec
494	**Water Supply**
4941	Water supply
495	**Sanitary Services**
4952	Sewerage systems
4953	Refuse systems
4959	Sanitary services, nec
496	**Steam Supply**
4961	Steam supply
497	**Irrigation Systems**
4971	Irrigation systems

APPENDIX B
STANDARD INDUSTRIAL CLASSIFICATIONS INCLUDED IN THE ECONOMIC SECTORS OF THE INPUT/OUTPUT MODEL

Sector Number	Sector Name	Standard Industrial Classification
1	Irrigated Crops	0313, 0122, 0123, 0119
2	Dry-Farmed Crops	0212, 0413, 0219, 0141
3	Range and Feedlot Livestock Production	0235, 0315, 0316
4	Dairy, Poultry, and Eggs	0132, 0133, 0134
5	Agricultural Supply	5962, 5969
6	Ginning	0712
7	Agricultural Services	0713, 0714, 0715, 0719, 0722, 0723, 0729, 0731, 0741
8	Fisheries	0912, 0913, 0914, 0919, 0989
9	Mining: Crude Petroleum, Natural Gas and Services	1311, 1321, 1381, 1382, 1389
10	Construction	1311, 1511, 1611, 1621, 1700
11	Meat Products	2011, 2013, 2015
12	Dairy Manufacturing	2021, 2022, 2023, 2024, 2026
13	Canned, Preserved, Pickled, Dried, and Frozen Food	2035, 2036, 2037, 2038, 2032, 2033
14	Other Food and Kindred Products	2041, 2042, 2044, 2045, 2046, 2042, 2051, 2052, 2061, 2062, 2063, 2069, 2071, 2072, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2121

15	Beverages	2082, 2084, 2086, 2089
16	Textile Mill Products, Furnishings, Apparel	2211, 2221, 2231, 2241, 2251, 2253, 2256, 2259, 2261, 2262, 2269, 2271, 2272, 2279, 2281, 2284, 2291, 2293, 2294, 2295, 2297, 2298, 2299, 2311, 2321, 2322, 2323, 2327, 2328, 2329, 2331, 2335, 2337, 2339, 2341, 2342, 2351, 2352, 2361, 2363, 2369, 2371, 2381, 2384, 2385, 2386, 2387, 2389, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2399
17	Wood Furniture and Other Wood and Paper Products	2431, 2432, 2433, 2441, 2442, 2443, 2445, 2491, 2499, 2511, 2512, 2515, 2519, 2521, 2541, 2591, 2599, 2641, 2642, 2643, 2645, 2646, 2647, 2649, 2651, 2652, 2653, 2654, 2655
18	Newspapers, Publishings and Printings	2711, 2721, 2731, 2741, 2732, 2751, 2752, 2753, 2761, 2781, 2782, 2789, 2791, 2793, 2794, 2799
19	Chemicals, Drugs, and Related Products	28121, 28122, 28123, 28124, 28132, 28133, 28134, 28182, 28183, 28185, 28191, 28192, 28193, 28194, 28195, 28196, 28197, 28198, 28199, 2879, 2871, 2872, 2879, 2851, 2871, 2891, 2892, 2893, 2895, 2899
20	Petroleum Refining and Products	2911, 2951, 2952, 2992, 2999

21	Clay, Cut Stone and Shell Products	3221, 3229, 3231, 3251, 3253, 3255, 3259, 3261, 3269, 3281, 3291, 3292, 3295, 3296, 3297, 3299, 3274, 3275, 3231, 3293
22	Cement and Concrete Products	3271, 3272, 3273, 3241
23	Primary Metals Foundaries, and Forging	3321, 3322, 3232, 3231, 3332, 3333, 3339, 3341, 3334, 3362, 3369, 3391, 3392, 3399, 3361
24	Fabricated Steel and Other Metal Products	3441, 3433, 3442, 3461, 3443, 3444, 3446, 3449, 3471, 3479, 3494, 3498, 3481, 3491, 3492, 3493, 3499
25	Machinery and Processing Equipment	3522, 3531, 3537, 3532, 3533, 3511, 3519, 3551, 3552, 3553, 3559, 3554, 3555, 3561, 3562, 3564, 3566, 3567, 3569, 3581, 3582, 3586, 3589, 3599
26	Electrical and Electronic Equipment	3611, 3612, 3613, 3621, 3622, 3623, 3624, 3641, 3642, 3643, 3644, 3629, 3651, 3661, 3662, 3671, 3672, 3673, 3674, 3679, 3691, 3693, 3694, 3652, 3699
27	Transportation Equipment	3713, 3715, 3714, 3711, 3731, 3732, 3729, 3741, 3742, 3791, 3751, 3799

28	Other Manufacturers	3011, 3069, 3079, 3293, 36312, 36443, 3111, 3121, 3131, 3141, 3142, 3151, 3161, 3171, 3172, 3199, 3841, 3842, 3843, 3851, 3861, 3871, 3831, 3941, 3942, 3949, 3941, 3942, 3949, 3911, 3913, 3914, 3931, 3951, 3952, 3953, 3955, 3961, 3962, 3963, 3964, 3991, 3982, 3983, 3984, 3987, 3993, 3994, 3995, 3999
29	Highway Motor Freight, Passenger Service and Warehousing	4131, 4132, 4213, 4231, 4212, 4214, 4224, 4221, 4222, 4223, 4224, 4226, 4225
30	Water Transportation	4411, 4421, 4441, 4452, 4453, 4454, 4459, 4463, 4464, 4469
31	Air Transportation	4511, 4521, 4582, 4583
32	Other Transportation Services	4011, 4013, 4021, 4041, 4612, 4613, 4619, 4111, 4119, 4121, 4140, 4150, 4141, 4142, 4151, 4171 4172, 4742, 4782, 4783, 4748, 4789, 4721
33	Communications	4811, 4821, 4832, 4833, 4899
34	Gas Services (Public and Private)	4922, 4923, 4932, 9149, 9249, 9349
35	Electric Services (Public and Private)	4911, 4931, 9151, 9251, 9351

36	Water and Sanitary Service Systems (Public and Private)	9102, 9202, 9302, 4941, 4952, 4953, 4959, 4961, 4971
37	Wholesale Groceries and Related Products	5041, 5042, 5043, 5044, 5045, 5046, 5047, 5048, 5049
38	Wholesale Livestock	5054, 4731
39	Wholesale Trade - Other	5012, 5013, 5014, 5052, 5053, 5059, 5081, 5082, 5084, 5085, 5083, 5088, 5087, 5092, 5022, 5028, 5029, 5033, 5034, 5036, 5037, 5039, 5063, 5064, 5065, 5072, 5074, 5077, 5091, 5093, 5094, 5095, 5096, 5097, 5098, 5099
40	Retail Food Stores	5411, 5421, 5431, 5441, 5451, 5462, 5499
41	Automobile Dealers, Repair Shops, and Gasoline Service Stations	5511, 7549, 5521, 5531, 7531, 7534, 7535, 7538, 7539, 7542, 554
42	All Other Retail Trade	5211, 5252, 5221, 5231, 5241, 5311, 5331, 5399, 5411, 5421, 5431, 5441, 5451, 5462, 5499, 5611, 5621, 5631, 5641, 5681, 5699, 5712, 5713, 5714, 5715, 5019, 5722, 5723, 5733, 5812, 5813, 5321, 5912, 5921, 5932, 5933, 5942, 5943, 5952, 5953, 5591, 5592, 5599, 5971, 5582, 5983, 5984, 5992, 5993, 5994, 5996, 5997, 5999, 5995, 5341, 5351
43	Banking, Insurance, Real Estate and Finance	60, 61, 63, 6411, 62, 64, 65, 66, 67

44	Education (Public and Private)	8211, 8221, 8222, 8231, 8341, 8242, 8299
45	Services - Other	7011, 7021, 7041, 7031, 7032, 7211, 7212, 7213, 7214, 7215, 7216, 7217, 7218, 7231, 7241, 7251, 7261, 7271, 7299, 7311, 7312, 7313, 7319, 7331, 7332, 7339, 7361, 7813, 7814, 7815, 7821, 7395, 7221, 7391, 8921, 7341, 7342, 7349, 7351, 7392, 7393, 7394, 7396, 7397, 73, 7398, 7309, 7816, 7817, 7818, 7832, 7833, 7911, 7929, 7932, 7933, 7941, 7942, 7943, 7945, 7946, 7947, 7948, 7949, 7512, 7513, 7519, 7523, 7525, 7622, 7623, 7629, 7631, 7641, 6792, 7694, 7699, 8011, 8021, 8031, 8041, 8061, 8071, 8072, 8092, 8099, 8111, 8911, 8931, 8411, 8421, 8611, 8621, 8631, 8641, 8651, 8661, 8671, 8699, 8811
46	Household	
47	Federal Government	
48	State Government	
49	Local Government	
50	Depreciation	
51	Imports	
52	Residual	

APPENDIX C

INDUSTRIAL WATER USE - EVALUATION OF WATER USE AS A FUNCTION OF EMPLOYMENT

From Marshall, J. L. (1973)

FIGURE C-1

SIC 1311, DATA FROM A.C.E. PERMIT APPLICATIONS

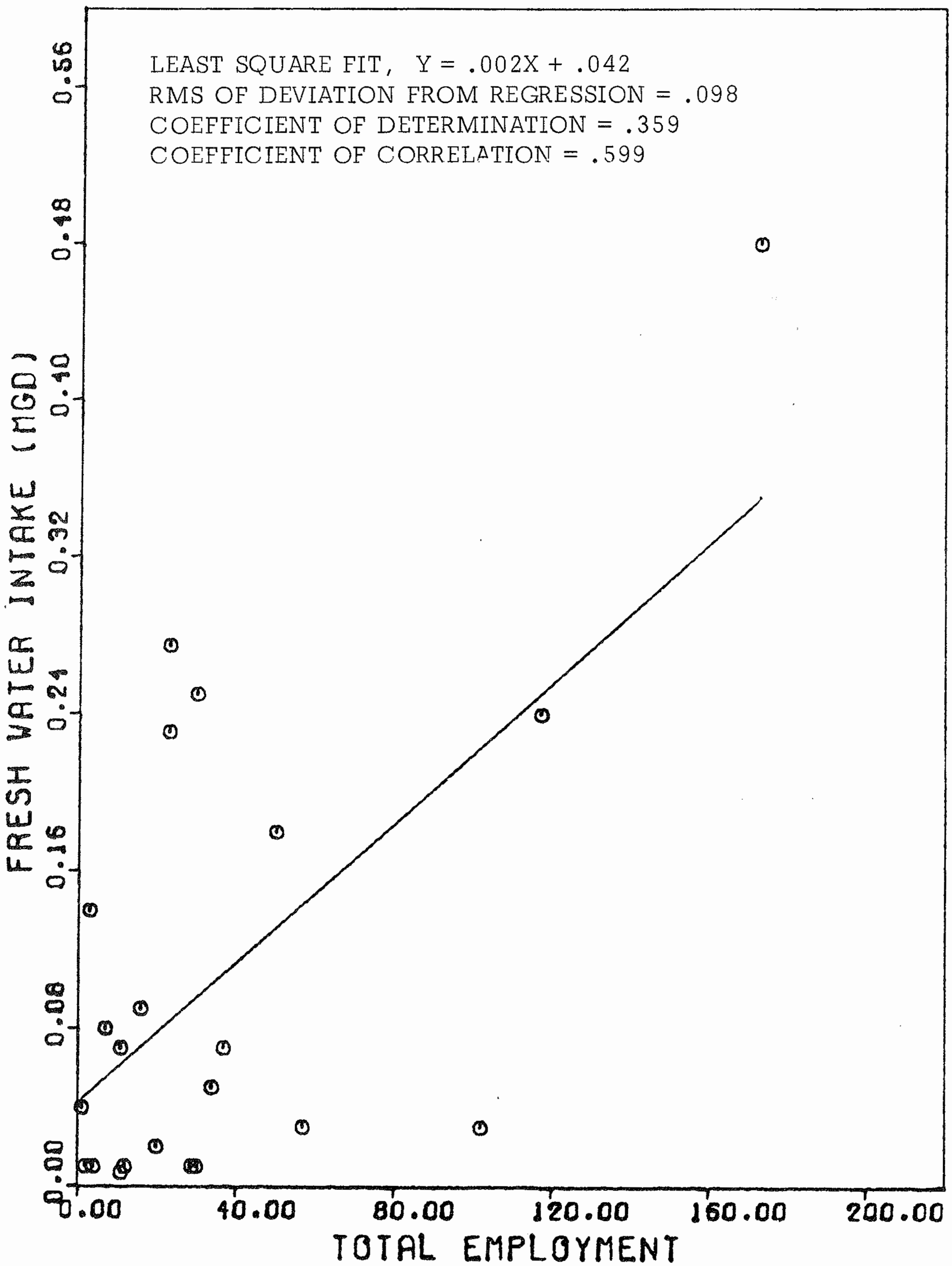


FIGURE C-2
SIC 1321, DATA FROM 1970 TWDB WATER SUMMARY

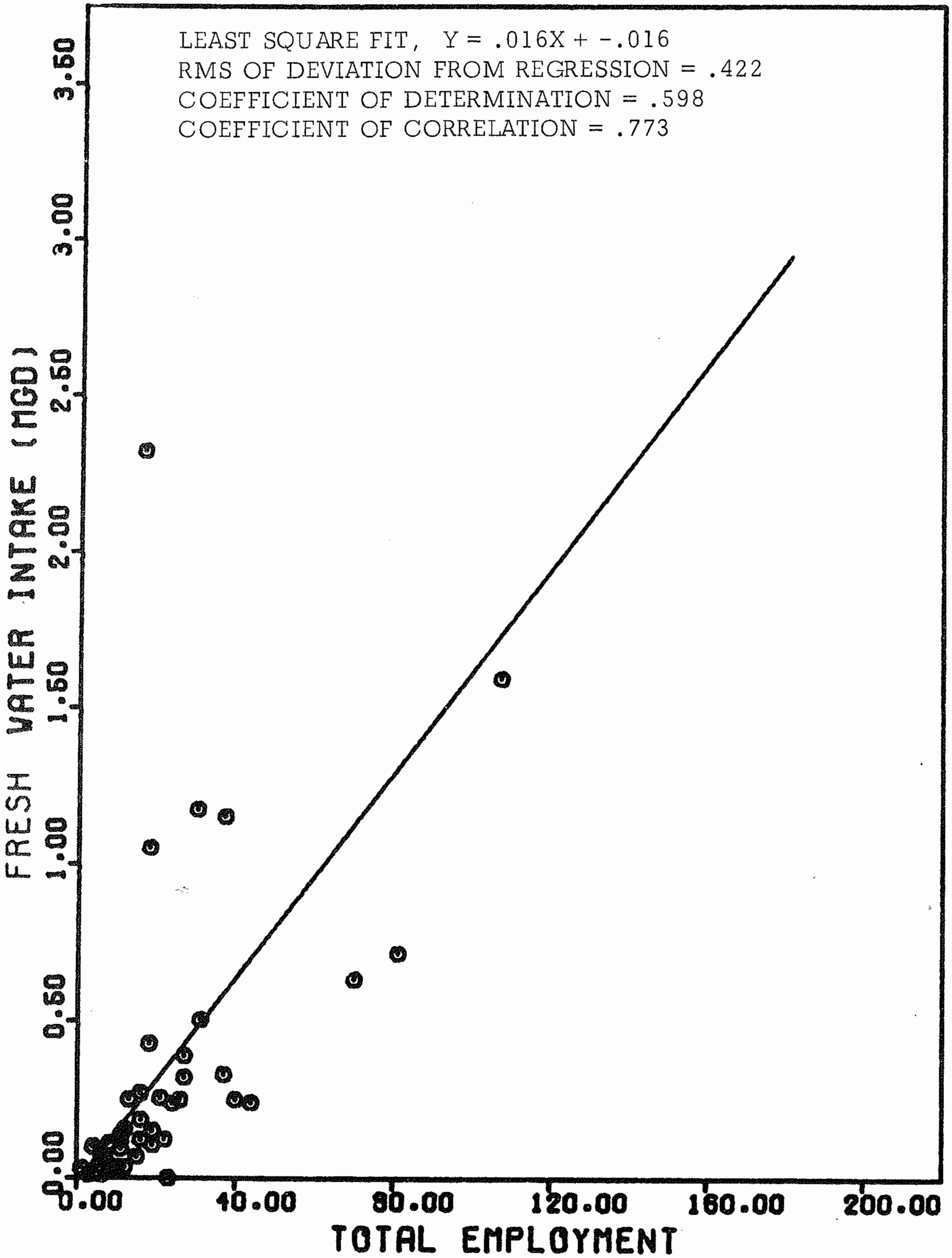


FIGURE C-3
SIC 20, DATA FROM 1970 TWDB WATER SUMMARY

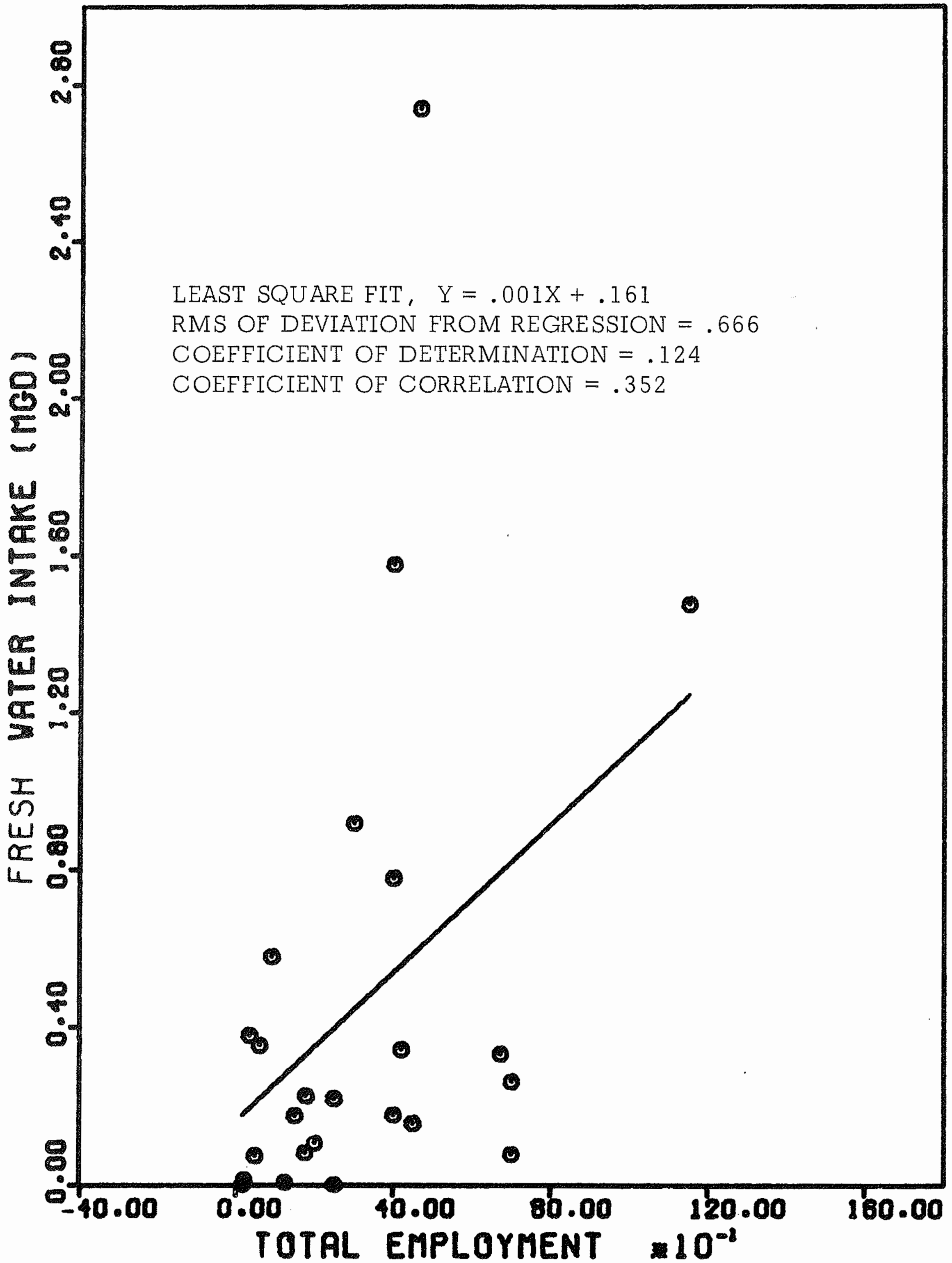


FIGURE C-4
SIC 26, DATA FROM 1970 TWDB WATER SUMMARY

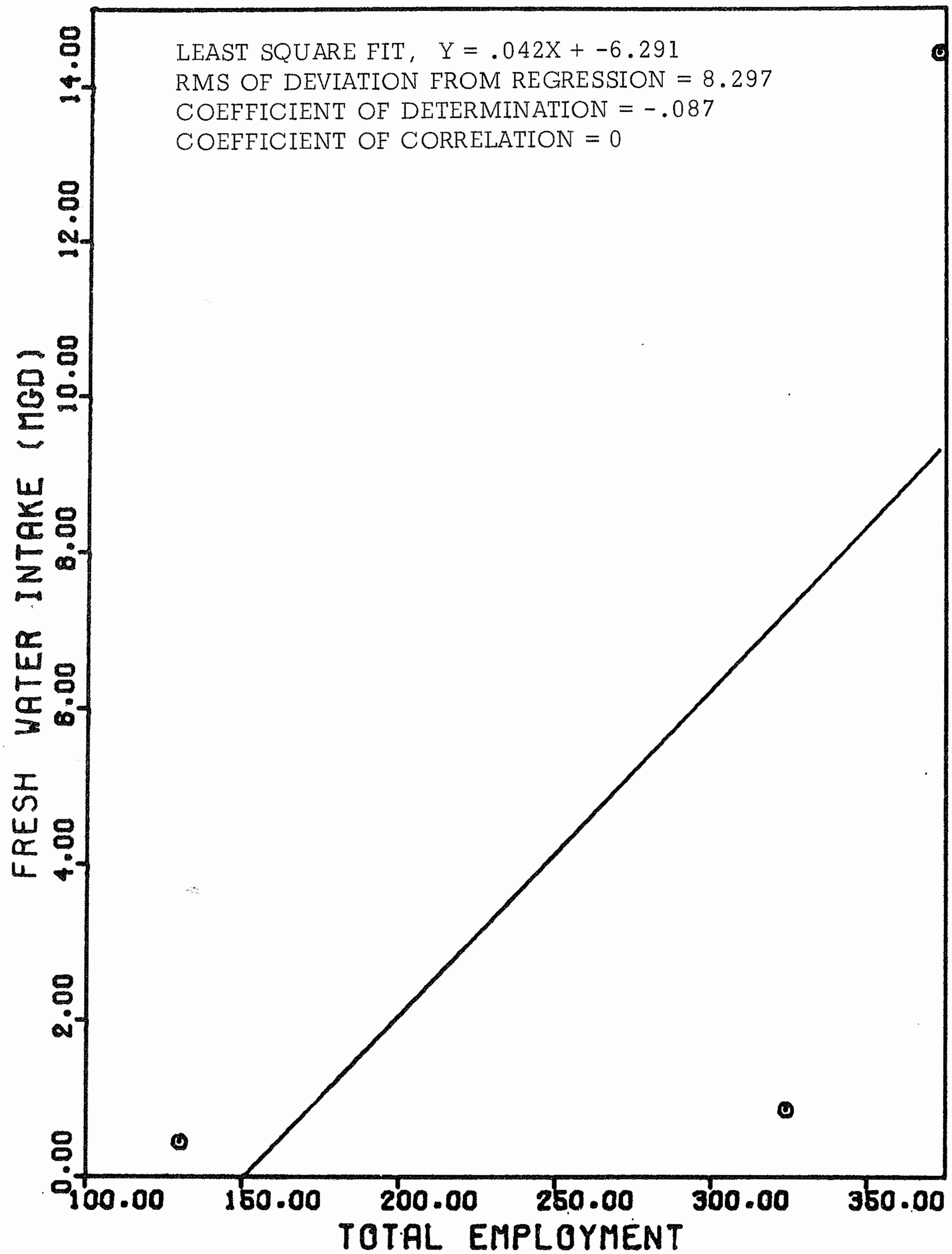


FIGURE C-5
SIC 28, DATA FROM 1970 TWDB WATER SUMMARY

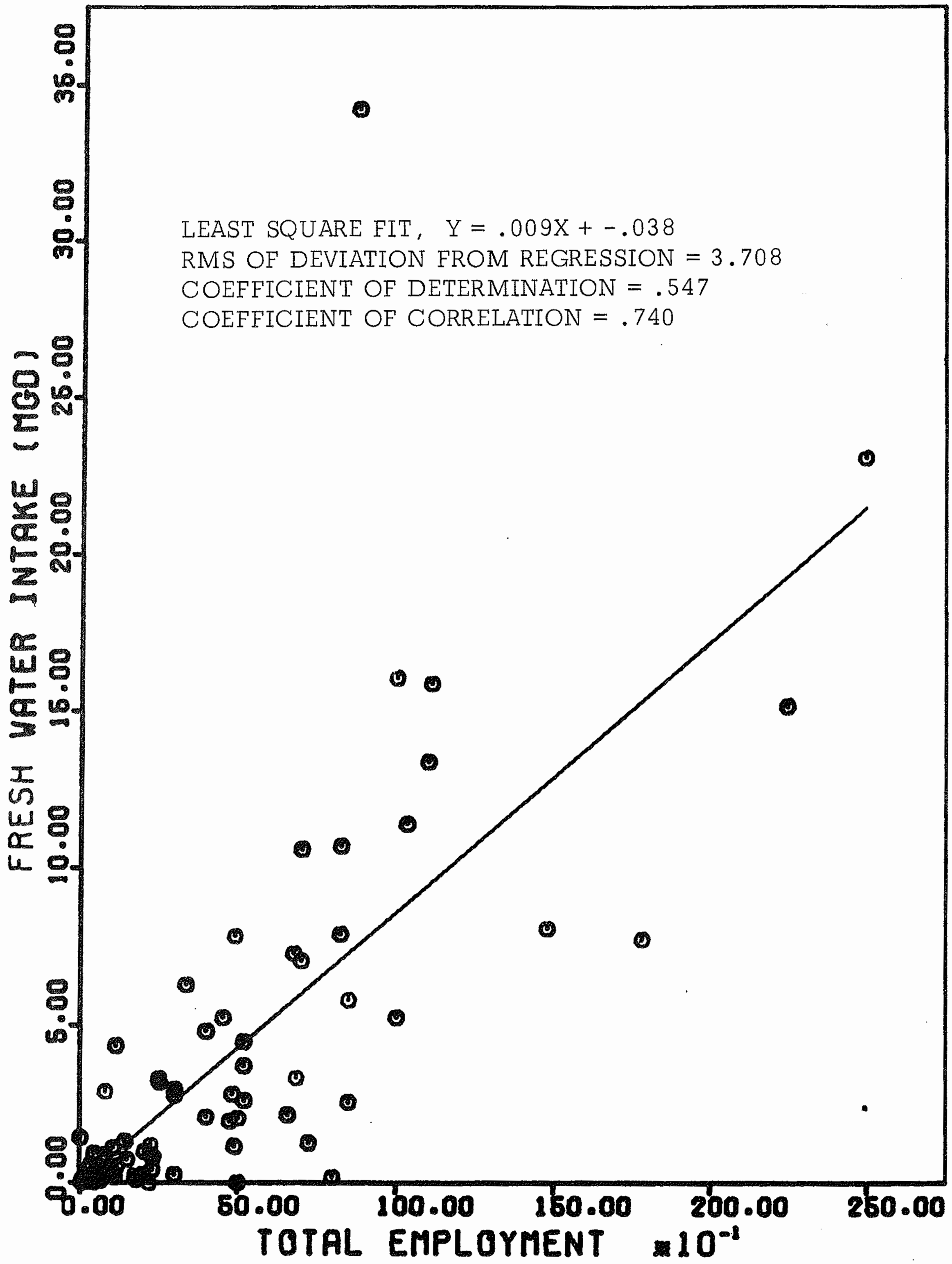


FIGURE C-6
SIC 2815, DATA FROM 1970 TWDB WATER SUMMARY

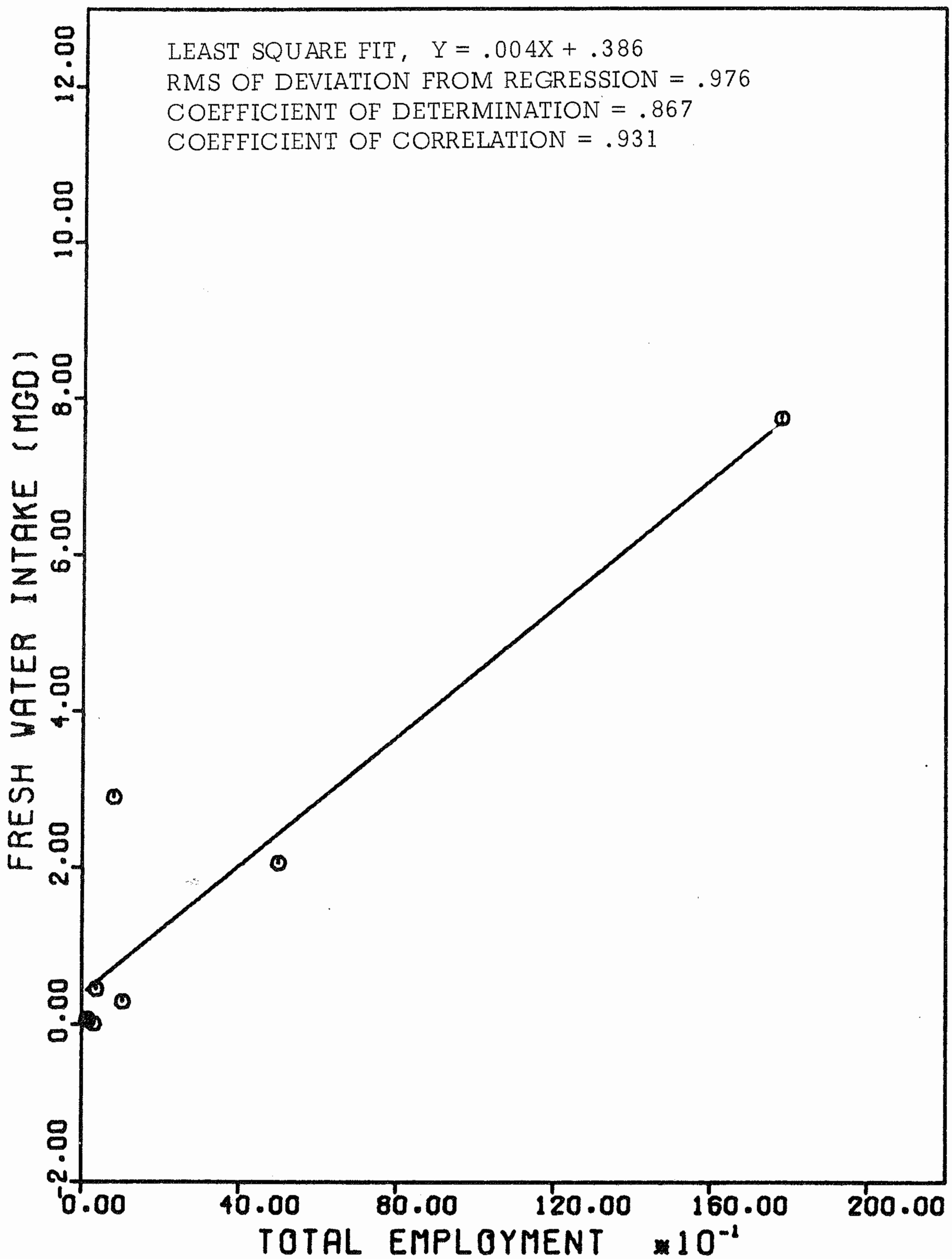


FIGURE C-7

SIC 2818, DATA FROM 1970 TWDB WATER SUMMARY

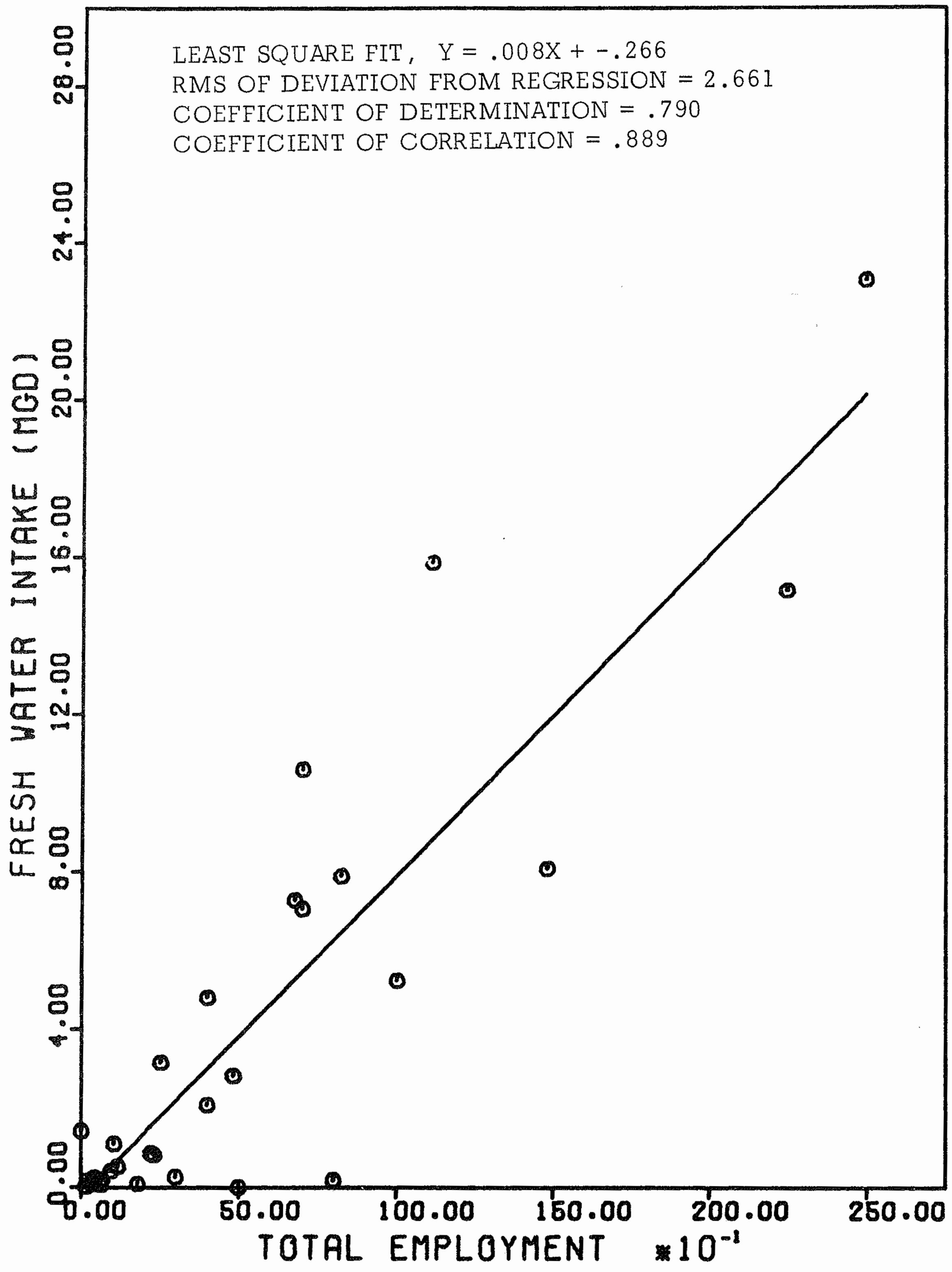


FIGURE C-8

SIC 2821, DATA FROM 1970 TWDB WATER SUMMARY

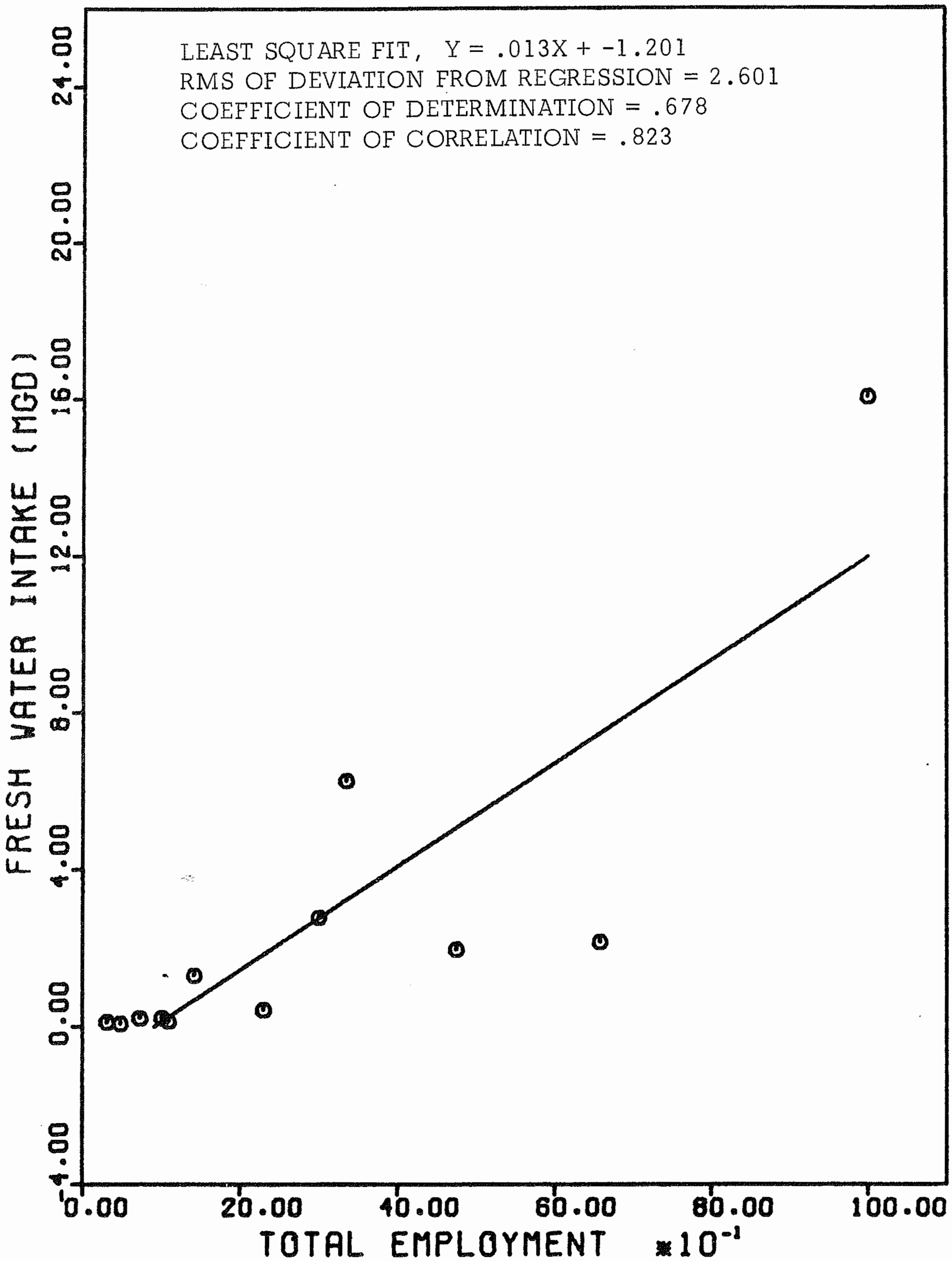


FIGURE C-9
SIC 2822, DATA FROM 1970 TWDB WATER SUMMARY

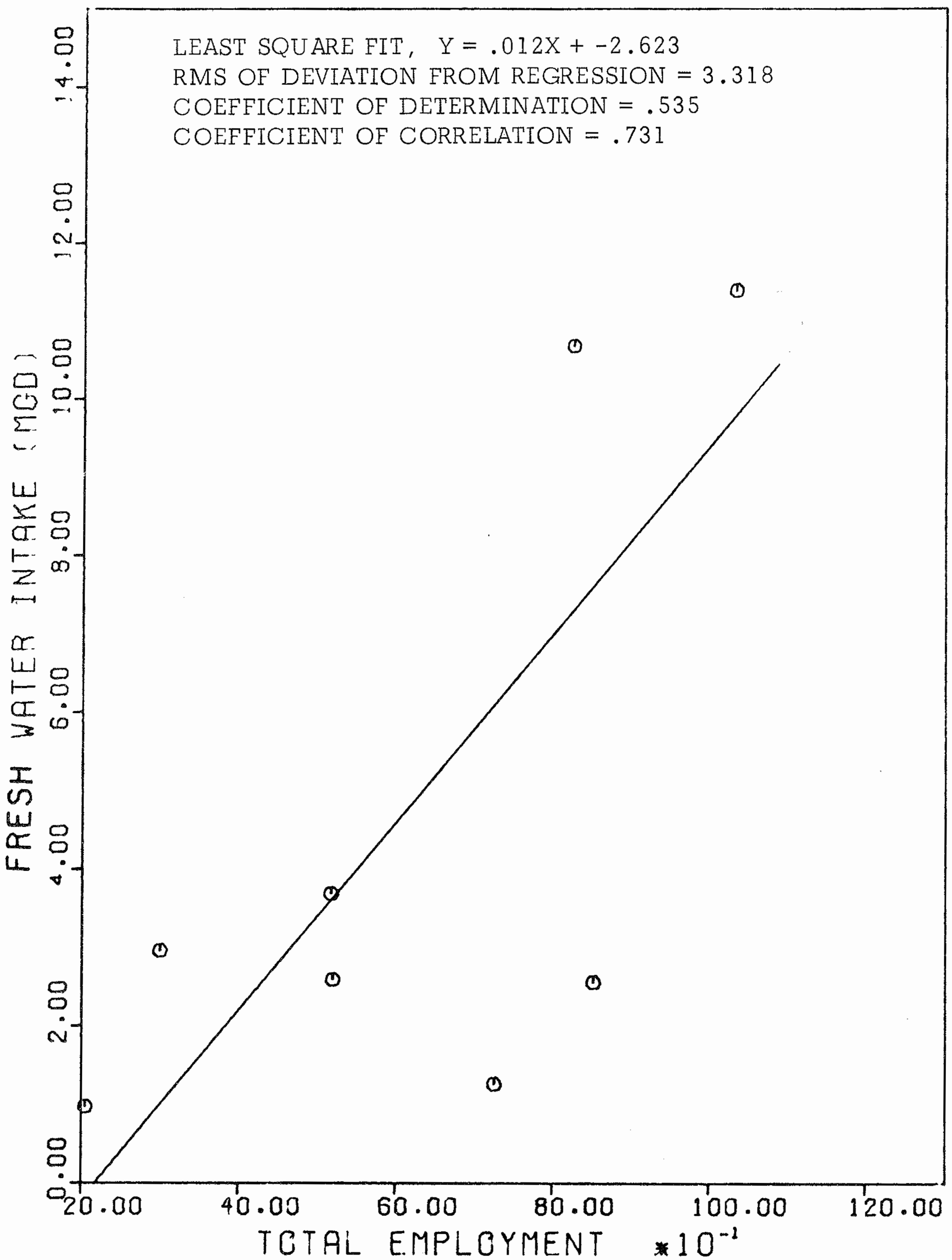


FIGURE C-10
SIC 2895, DATA FROM 1970 TWDB WATER SUMMARY

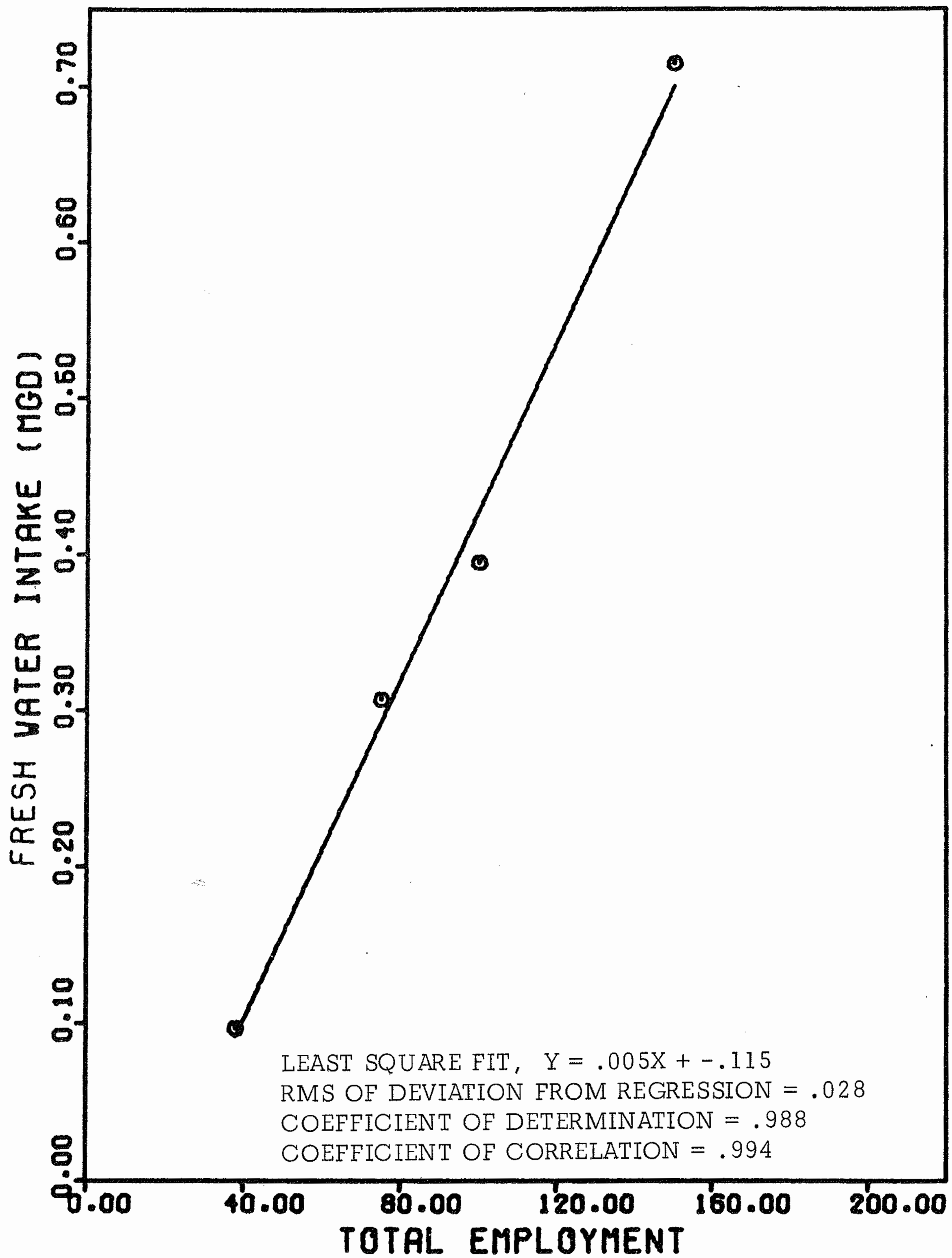


FIGURE C-11
SIC 2911, DATA FROM A.C.E. PERMIT APPLICATIONS

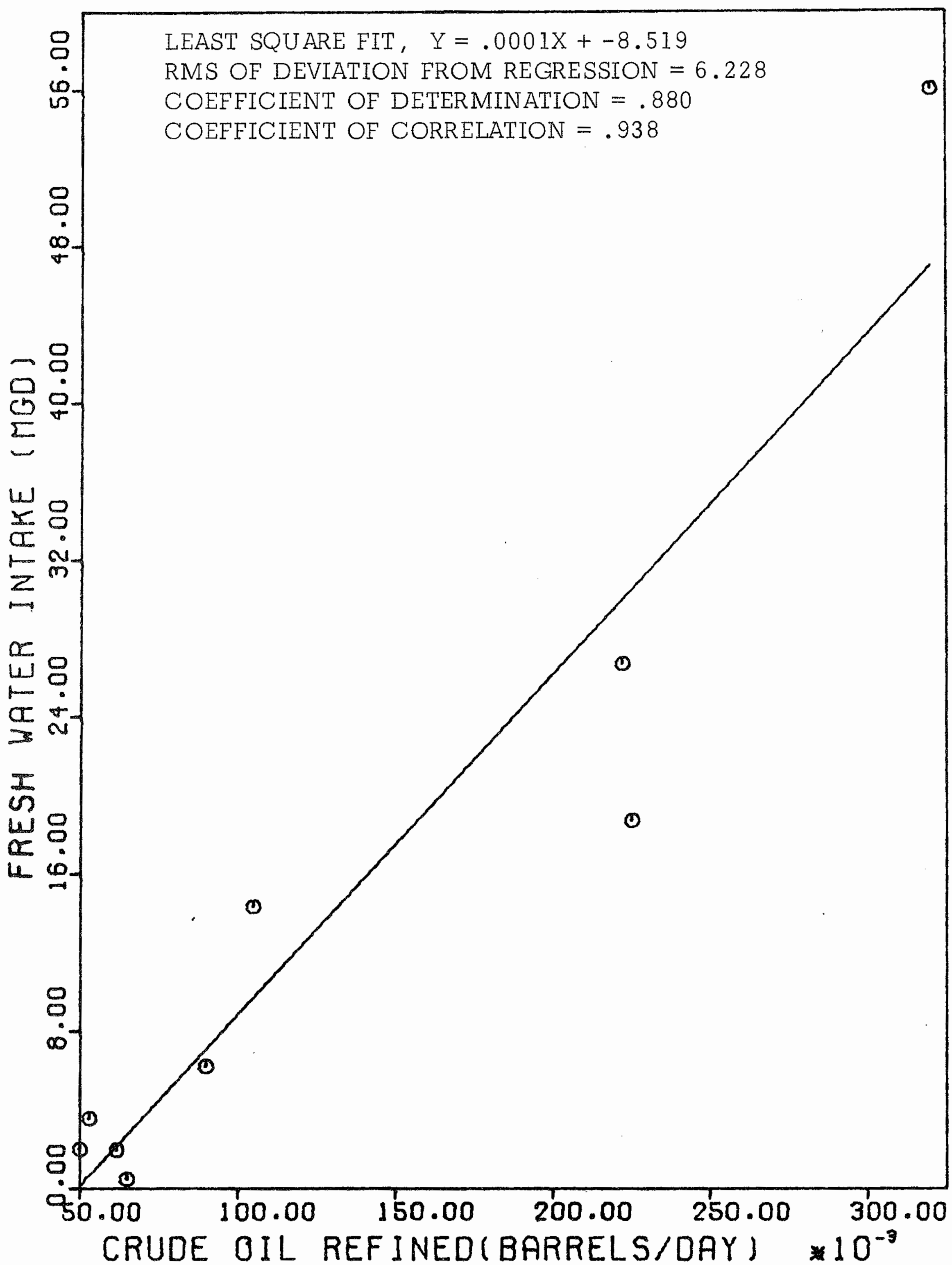


FIGURE C-12
SIC 2911, DATA FROM A.C.E. PERMIT APPLICATIONS

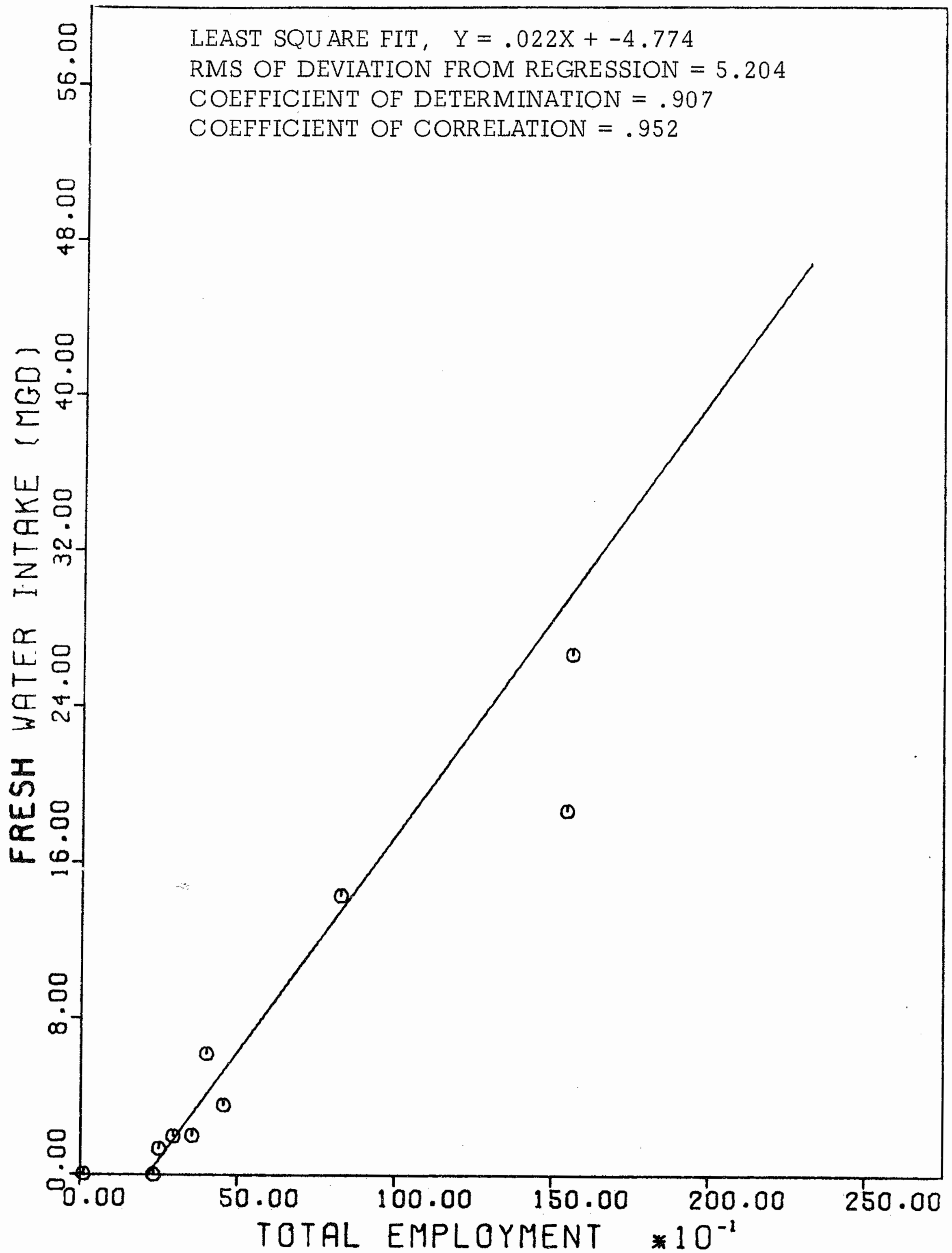


FIGURE C-13
SIC 2911, DATA FROM 1970 TWDB WATER SUMMARY

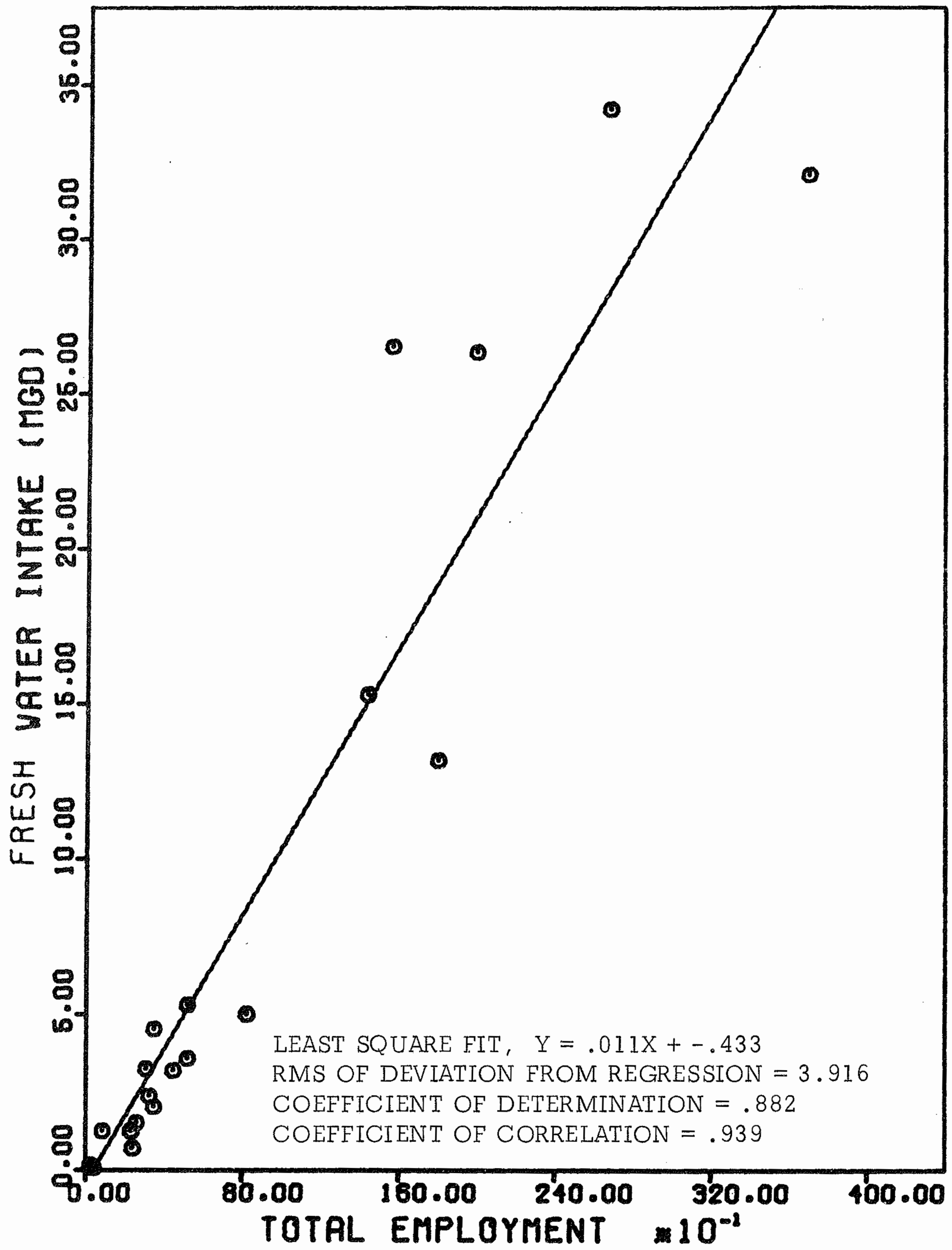


FIGURE C-14
SIC 33, DATA FROM 1970 TWDB WATER SUMMARY

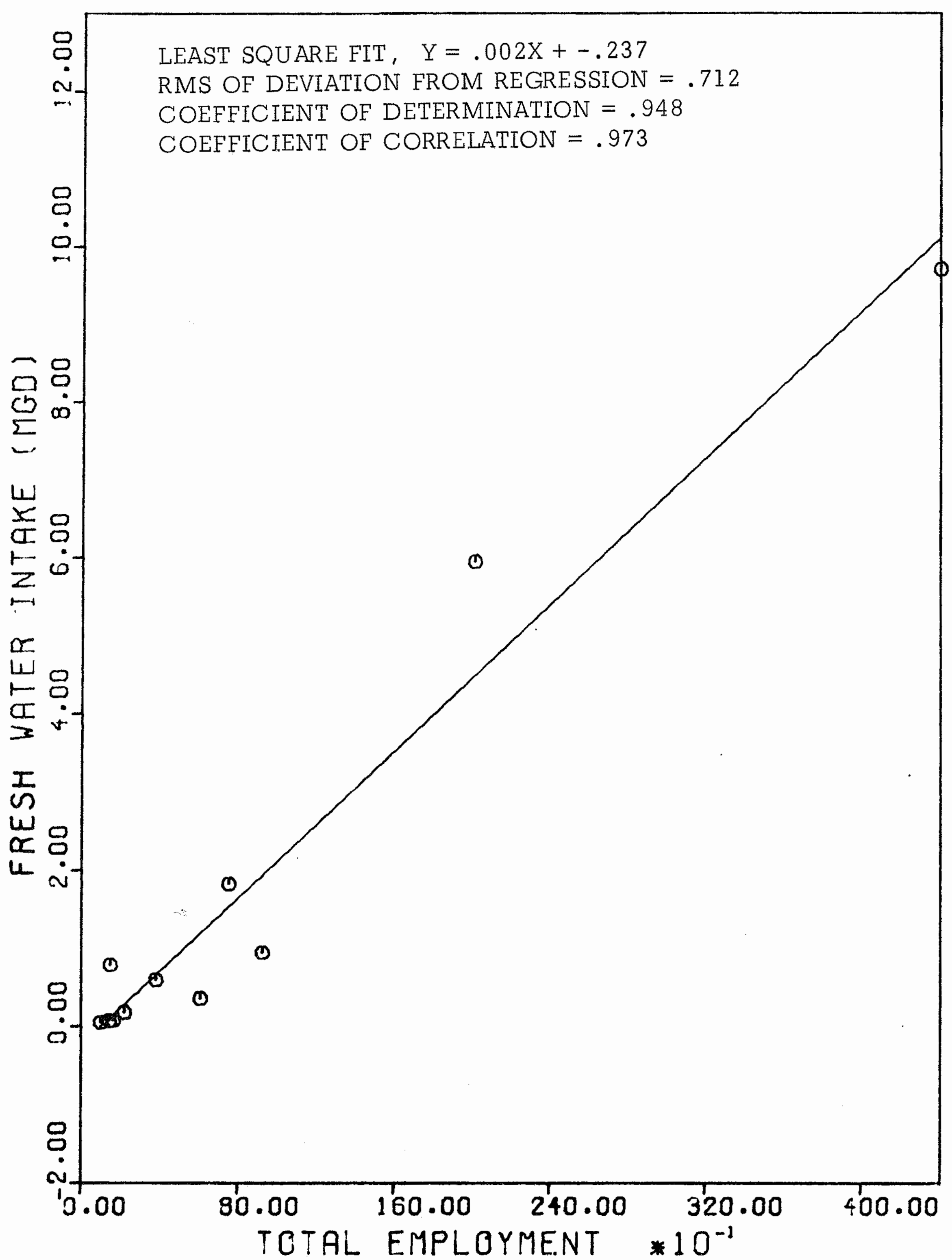


FIGURE C-15
SIC 34, DATA FROM A.C.E. PERMIT APPLICATIONS

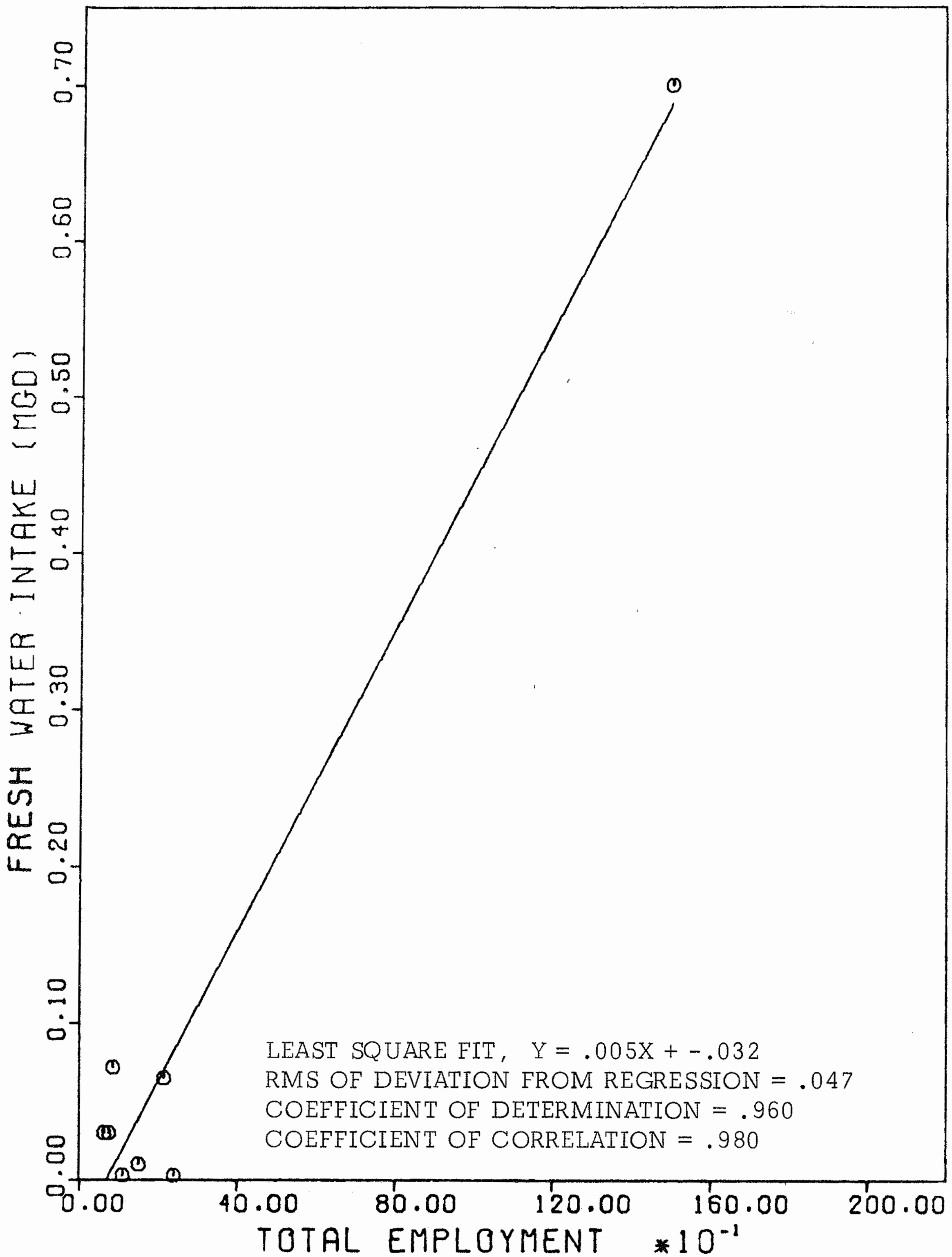


FIGURE C-16
SIC 35, DATA FROM 1970 TWDB WATER SUMMARY

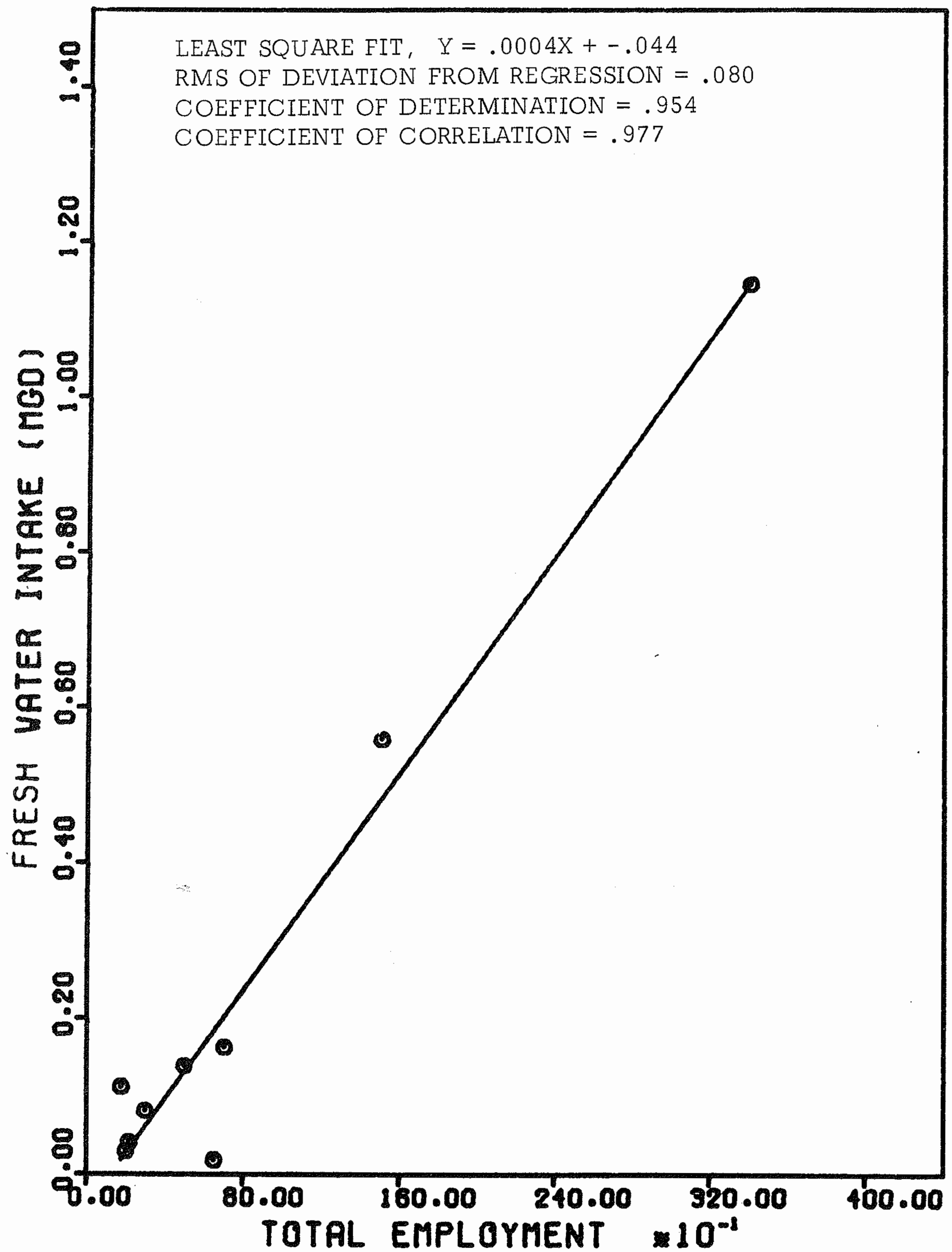
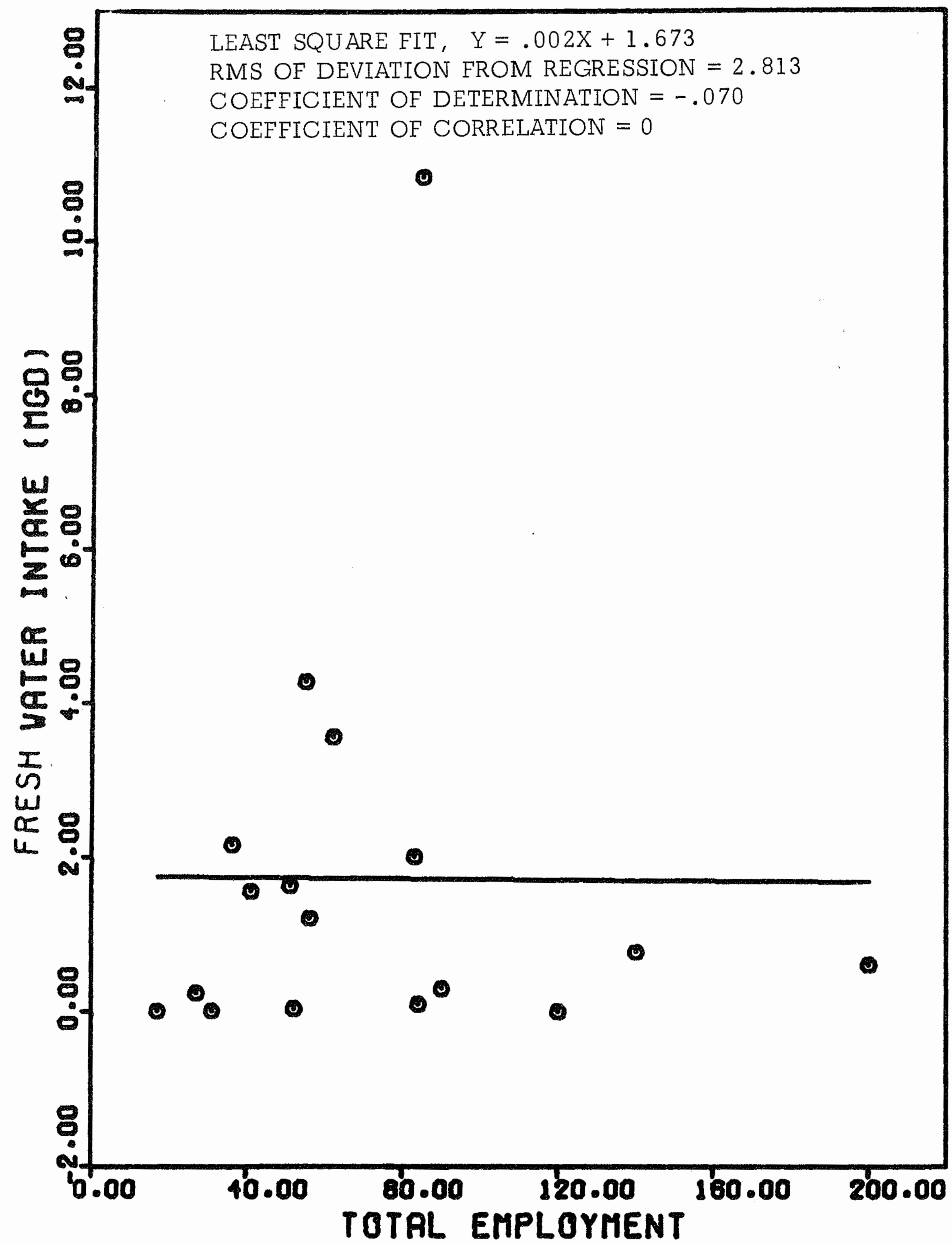


FIGURE C-17
SIC 4911, DATA FROM 1970 TWDB WATER SUMMARY



EXPLANATION OF STATISTICAL ANALYSIS USED

Residuals = the deviation of the ordinate value from the estimate made by the regression equation

$$(y - y_c)$$

Standard Error of Estimate = root mean square of the residuals

$$S_{yx} = \sqrt{\frac{(y - y_c)^2}{n - 1}}$$

where n is the number of data points

Variance = scatter of the ordinate values about the arithmetic mean

$$S_y^2 = \frac{(y - \bar{y})^2}{n - 2}$$

Coefficient of determination = the fraction of the variation of the Y variable that is explained by the X variable

$$r^2 = 1 - \frac{S_{yx}^2}{S_y^2}$$

Coefficient of correlation

$$r = \sqrt{1 - \frac{S_{yx}^2}{S_y^2}}$$

The closer r is to 1.00 the higher the degree of correlation.
When r equals zero there is no correlation.

APPENDIX D
INDUSTRIAL SOLID WASTE SURVEY DATA

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
Sector 10				
1511	19.9	0.0	rubble 95%	oils and hydrocarbons 100%
1611	20.1	12.1	rubble 99%	oils and hydrocarbons 100%
1621	7.1	0.2	rubble 93%	oils and hydrocarbons 100%
1711	3.1	0.0	rubble 52%, trash 34%	oils and hydrocarbons 100%
1721	0.3	0.3	ferrous metals 59%, trash 26%	oils and hydrocarbons 67%, solvents 33%
1731	0.6	0.0	trash 56%, ferrous metals 17%, non-ferrous metals 15%	----
1741	5.5	0.0	rubble 86%	----
1742	0.4	0.0	trash 100%	----
1743	0.8	0.0	rubble 61%, trash 26%	----
1751	0.4	0.0	wood 74%, trash 26%	----
1752	1.2	0.0	textiles 57%, trash 32%	----
1761	8.3	0.0	rubble 74%, paper 15%	----
1771	1.0	0.0	rubble 90%	----
1781	2.1	7.9	ferrous metals 72%, trash 16%	oils and hydrocarbons 100%
1791	0.8	0.0	ferrous metals 46%, trash 45%	----
1793	0.7	0.0	trash 56%, glass 42%	----
1794	23,256.4	3.9	rubble 100%	oils and hydrocarbons 80%, organic chemicals 20%
1795	1.3	0.0	trash 45%, rubble 38%	----
1799	74.1	605.7	rubble 99%	organic chemicals 100%
1929	1.2	0.0	paper 46%, ferrous metals 31%, organic chemicals 10%	----
1941	1.6	0.0	paper 100%	----
1951	0.2	0.0	trash 100%	----
1961	1.0	0.0	trash 100%	----
1999	1.6	0.0	wood 46%, ferrous metals 38%	----

SIC No.	Yearly Waste/Employee Tons	Yearly Waste/Employee Gallons	Major Waste Components (percent) Tons	Major Waste Components (percent) Gallons
Sector 11				
2011	1.8	61,302.6	animal remains 76%, trash 15%	sludge 100%
2013	29.1	0.0	animal remains 97%	----
2015	23.0	0.0	animal remains 99%	----
Sector 12				
2021	0.2	208.7	trash 100%	food processing wastes 100%
2023	0.3	0.0	ferrous metals 80%, paper 20%	----
2024	1.5	1,317.9	trash 95%	food processing wastes 100%
2026	0.2	57,885.7	paper 90%	food processing wastes 100%
Sector 13				
2031	0.3	0.0	food processing wastes 91%	----
2032	21.7	35.5	trash 71%, food processing wastes 15%, ferrous metals 10%	organic chemicals 100%
2033	2.1	0.0	trash 57%, ferrous metals 25%	----
2035	2.7	0.0	food processing wastes 95%	----
2036	0.2	0.0	paper 84%, food processing wastes 16%	----
2037	6.3	0.0	food processing wastes 99%	----
Sector 14				
2041	3.1	0.0	food processing wastes 92%	----
2042	0.4	0.0	trash 77%, non-ferrous metals 20%	----
2044	28.4	0.0	food processing wastes 46% rubble 40%	----
2045	0.7	0.0	food processing wastes 91%	----
2046	0.3	0.0	paper 100%	----
2051	0.7	0.0	paper 61%, food processing wastes 37%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
2052	1.0	0.0	paper 75%, food processing wastes 22%	----
2062	1.8	0.0	paper 57%, trash 21%, food processing wastes 17%	----
2071	0.4	0.9	paper 81%, food processing wastes 19%	organic chemicals 100%
2091	0.3	0.0	trash 100%	----
2093	0.3	0.0	food processing wastes 83%, trash 17%	----
2094	0.5	0.0	trash 80%, ferrous metals 15%	----
2095	1.3	3.8	paper 46%, glass 20%, food processing wastes 16%	food processing wastes 100%.
2096	1.7	0.0	food processing wastes 90%	----
2097	0.2	0.0	trash 93%	----
2098	0.4	0.0	trash 77%, food processing wastes 15%	----
2099	0.7	0.0	trash 72%, food processing wastes 26%	----
Sector 15				
2082	9.4	0.0	crop wastes 55%, food processing wastes 19%, paper 14%	----
2084	1.0	0.0	food processing wastes 100%	----
2086	1.8	0.0	glass 40%, paper 36%, wood 22%	----
2087	3.2	0.0	glass 53%, paper 40%	----
Sector 16				
2211	0.4	0.0	textiles 73%, trash 26%	----
2221	0.7	0.0	paper 50%, glass 50%	----
2231	0.1	0.0	trash 100%	----
2241	1.0	0.0	trash 100%	----
2261	0.7	0.0	trash 100%	----
2269	3.5	0.0	trash 100%	----
2272	0.2	300,000.0	trash 100%	sludge 100%

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
2281	0.7	0.0	trash 100%	----
2291	2.2	0.0	crop wastes 82%, ferrous metals 12%	----
2293	6.8	0.0	textiles 39%, trash 30%, rubber 31%	----
2294	11.2	0.0	textiles 99%	----
2295	2.5	0.0	trash 100%	----
2297	42.0	0.0	sludge 100%	----
2298	0.1	0.0	trash 100%	----
2299	0.3	0.0	trash 63%, textiles 25%, paper 12%	----
2311	0.2	0.0	textiles 77%, trash 19%	----
2323	0.1	0.0	paper 75%, textiles 25%	----
2327	0.4	0.0	textiles 97%	----
2328	0.1	0.0	textiles 37%, paper 30%, trash 19%, garbage 15%	----
2329	0.0	0.0	paper 56%, textiles 33%, trash 11%	----
2331	0.2	0.0	trash 100%	----
2335	0.2	0.0	trash 80%, textiles 19%	----
2337	0.4	0.0	trash 68%, textiles 34%	----
2341	0.3	0.0	trash 49%, paper 29%, textiles 20%	----
2342	0.2	0.0	trash 85%, paper 10%	----
2351	0.3	0.0	trash 100%	----
2352	0.0	0.0	paper 89%	----
2361	0.3	0.0	trash 62%, textiles 26%, paper 12%	----
2363	0.0	0.0	textiles 100%	----
2381	0.6	0.0	trash 79%, textiles 21%	----
2384	0.1	0.0	textiles 55%, trash 45%	----
2385	0.1	0.0	textiles 50%, paper 40%, wood 10%	----

SIC No.	Yearly Waste/Employee Tons	Gallons.	Major Waste Components (percent) Tons	Gallons
2387	0.3	0.0	textiles 100%	----
2389	0.2	0.0	trash 100%	----
2391	0.3	0.0	paper 43%, trash 41%, textiles 16%	----
2392	0.9	0.0	paper 60%, trash 22%, wood 18%	----
2393	0.5	0.0	trash 93%, textiles 7%	----
2394	0.2	0.0	trash 86%, textiles 9%	----
2395	0.3	0.0	trash 100%	----
2396	1.7	0.0	trash 100%	----
2399	0.1	0.0	textiles 50%, paper 50%	----
Sector 17				
2431	14.2	1.4	wood 99%	solvents 100%
2432	232.2	72.3	wood 100%	organic chemicals 100%
2433	24.7	0.0	wood 100%	----
2441	11.9	0.0	wood 100%	----
2442	31.4	0.0	wood 100%	----
2443	4.7	0.0	wood 89%, rubble 11%	----
2445	4.1	0.0	paper 85%	----
2491	29.5	0.0	wood 99%	----
2499	56.4	0.0	wood 100%	----
2511	4.2	1.5	wood 99%	organic chemicals 100%
2514	0.7	8.0	paper 27%, ferrous metals 21%, plastic 42%	solvents 100%
2515	0.3	0.0	trash 56%, paper 19%, textiles 13%	----
2519	0.8	0.0	wood 63%, textiles 24%	----
2521	2.0	0.0	wood 99%	----
2522	3.2	0.0	ferrous metals 95%	----
2531	1.0	0.0	wood 43%, ferrous metals 42%, paper 11%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
2541	3.4	0.0	trash 48%, wood 45%	----
2542	0.1	0.0	paper 50%, ferrous metals 50%	----
2591	0.7	0.0	trash 52%, paper 18%, wood 15%	----
2599	0.7	0.0	ferrous metals 75%, wood 21%	----
2621	11.7	0.0	rubble 53%, sludge 23%, paper 15%	----
2631	14.6	0.0	trash 94%	----
2641	2.5	0.0	paper 53%, plastic 43%	----
2642	4.0	0.0	paper 56%, trash 44%	----
2643	2.5	27.7	paper 87%	inorganic chemicals 100%
2645	2.5	0.0	paper 99%	----
2646	5.2	0.0	trash 98%	----
2649	4.3	0.0	paper 96%	----
2651	15.4	0.0	paper 89%, trash 9%	----
2653	46.9	0.0	wood 76%, paper 18%	----
2654	17.2	0.0	plastic 76%, wood 18%	----
2655	1.5	0.0	paper 89%, wood 11%	----
Sector 18				
2711	1.0	0.0	paper 97%	----
2721	0.1	0.0	paper 100%	----
2731	10.2	0.0	paper 100%	----
2732	0.3	0.0	paper 73%, trash 27%	----
2741	0.1	0.0	plastic 56%, paper 44%	----
2751	1.5	0.1	paper 79%, trash 17%	solvents 100%
2752	1.8	6.1	paper 81%, trash 18%	inorganic chemicals 100%
2753	0.2	16.9	paper 82%, ferrous metals 18%	organic chemicals 100%
2761	4.9	0.4	paper 76%, trash 24%	solvents 100%
2771	1.2	0.0	paper 100%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
2782	3.8	0.0	paper 100%	----
2789	3.0	0.0	paper 33%, trash 67%	----
2791	0.3	0.0	ferrous metals 42%, trash 37%, paper 21%	----
2793	1.9	315.7	ferrous metals 61%, paper 33%	inorganic chemicals 100%
2794	0.3	0.0	ferrous metals 63%, paper 37%	----
2799	7.2	0.0	textiles 93%	----
Sector 21				
3224	10.6	774.7	glass 94%	sludge 100%
3229	49.1	0.0	paper 100%	----
3231	2.0	0.0	glass 67%, trash 33%	----
3251	32.4	0.0	rubble 100%	----
3253	5.6	0.0	rubble 60%, ceramics 40%	----
3255	1.6	0.0	ferrous metals 71%, trash 21%	----
3259	0.6	27.3	plastic 61%, paper 22%	acids 92%, organic chemicals 8%
3261	1.2	0.0	ceramics 91%	----
3264	0.9	0.0	rubble 54%, ceramics 40%	----
3269	0.8	0.0	rubble 48%, paper 44%	----
3275	12.3	0.0	organic chemicals 53%, paper 34%, wood 14%	----
3281	1.9	0.0	rubble 55%, trash 45%	----
3291	0.3	0.0	rubble 67%, trash 33%	----
3292	14.2	0.0	ceramics 59%, rubble 39%	----
3293	1.5	0.0	rubble 83%	----
3295	3.3	0.0	trash 50%, rubble 44%	----
3296	3.1	0.0	ceramics 59%, rubble 37%	----
3297	0.6	0.0	paper 100%	----
3299	0.2	0.0	paper 50%, ferrous metals 33%, ceramics 17%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
Sector 22				
3241	4.7	0.0	rubble 85%, ferrous metals 13%	----
3271	30.8	0.0	rubble 100%	----
3272	153.8	0.0	rubble 99%	----
3273	3.6	0.0	rubble 96%	----
Sector 23				
3321	13.7	1.9	rubble 100%	oils and hydrocarbons 100%
3322	8.9	0.0	rubble 98%	----
3323	31.1	0.0	rubble 99%	----
3331	2.3	0.0	non-ferrous metals 83%, trash 13%	----
3333	0.1	0.0	rubble 46%, wood 31%, paper 23%	----
3334	58.4	0.0	rubble 98%	----
3339	4.0	0.0	ferrous metals 83%, trash 17%	----
3341	43.7	108.0	rubber 86%	sludge 100%
3352	1.6	0.0	non-ferrous metals 99%	----
3357	0.3	0.0	plastic 69%, non-ferrous metals 11%, paper 11%	----
3361	1.3	21.2	non-ferrous metals 44%, rubble 52%	solvents 100%
3362	3.9	0.0	non-ferrous metals 78%, rubber 15%	----
3369	2.9	0.0	non-ferrous metals 49%, ferrous metals 32%	----
3391	2.0	0.0	ferrous metals 50%, non-ferrous metals 25%, rubble 21%	----
3392	4.2	0.0	rubber 32%, wood 27%, paper 10%, rubble 10%	----
3399	0.5	0.0	ferrous metals 67%, rubble 17%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
Sector 24				
3411	9.0	152.4	non-ferrous metals 87%	organic chemicals 100%
3423	1.1	0.0	paper 75%, ferrous metals 25%	----
3425	0.3	0.0	non-ferrous metals 40%, ferrous metals 30%, paper 30%	----
3429	9.0	0.0	rubble 100%	----
3431	0.1	40,000.0	paper 60%, wood 40%	sludge 100%
3432	16.5	0.0	rubble 99%	----
3433	5.7	2.0	paper 75%, ferrous metals 14%, rubble 10%	organic chemicals 100%
3441	2.2	36,787.9	ferrous metals 70%, non-ferrous metals 12%	sludge 100%
3442	1.4	5.5	glass 81%	sludge 100%
3443	4.6	14.1	ferrous metals 38%, trash 38%, rubble 17%	inorganic chemicals 49%, organic chemicals 24%, sludge 24%
3444	1.1	0.0	ferrous metals 71%, non-ferrous metals 22%	----
3446	1.0	0.0	non-ferrous metals 100%	----
3449	0.3	0.0	trash 89%	----
3451	1.8	17.0	ferrous metals 59%, non-ferrous metals 25%	oils and hydrocarbons 100%
3452	2.8	74.2	ferrous metals 95%	acids 52%, oils and hydrocarbons 49%
3461	0.2	0.0	wood 52%, paper 31%, ferrous metals 11%	----
3471	0.4	2,284.5	paper 45%, trash 30%, wood 25%	inorganic chemicals 99%
3479	1.2	0.0	ferrous metals 30%, trash 29%, rubble 27%	----
3481	11.3	1.2	ferrous metals 94%	oils and hydrocarbons 100%
3491	8.1	0.0	ferrous metals 86%	----
3493	0.2	0.0	ferrous metals 100%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
3494	3.1	44.9	ferrous metals 94%	oils and hydrocarbons 100%
3498	1.2	0.0	rubble 65%, ferrous metals 14%, non-ferrous metals 12%	----
3499	2.0	0.0	ferrous metals 72%, trash 24%	----
Sector 25				
3522	0.8	0.0	ferrous metals 31%, paper 26%, rubble 25%	----
3531	0.9	0.0	ferrous metals 55%, trash 42%	----
3532	2.8	23.8	ferrous metals 86%, trash 14%	oils and hydrocarbons 100%
3533	4.0	38.4	ferrous metals 45%, rubble 41%	oils and hydrocarbons 91%, solvents 5%, sludge 4%
3534	0.3	0.0	ferrous metals 60%, paper 26%, wood 13%	----
3535	1.2	0.0	trash 60%, ferrous metals 40%	----
3536	5.8	90.9	rubble 73%, ferrous metals 26%	sludge 100%
3541	1.1	2.8	non-ferrous metals 62%, trash 31%	solvents 100%
3544	1.6	20.4	non-ferrous metals 35%, ferrous metals 29%, trash 18%, paper 18%	inorganic chemicals 77%, oils and hydrocarbons 23%
3545	11.8	0.0	ferrous metals 97%	----
3548	2.7	0.0	ferrous metals 33%, non-ferrous metals 33%	----
3553	0.6	2.2	ferrous metals 41%, wood 33%, trash 22%	solvents 100%
3554	0.6	0.0	ferrous metals 40%, wood 40%, paper 20%	----
3555	0.2	9.0	paper 40%, ferrous metals 38%	solvents 100%
3559	0.8	113.3	ferrous metals 66%, trash 27%	oils and hydrocarbons 100%
3561	1.5	7.7	ferrous metals 66%, trash 26%	oils and hydrocarbons 80%, solvents 11%

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
3562	2.3	0.0	ferrous metals 98%	----
3564	2.0	1.7	ferrous metals 61%, non-ferrous metals 18%, paper 18%	sludge 100%
3564	0.0	0.0	trash 100%	----
3566	32.9	0.0	ferrous metals 90%	----
3567	0.2	3.9	rubble 38%, ferrous metals 31%, paper 27%	solvents 100%
3569	3.2	0.0	ferrous metals 48%, wood 29%, trash 12%, paper 11%	----
3573	0.2	0.0	paper 96%	----
3576	0.6	0.0	ferrous metals 100%	----
3581	0.1	0.0	paper 83%	----
3582	0.5	0.0	paper 100%	----
3585	3.7	0.0	rubble 74%, paper 12%	----
3586	0.8	0.0	ferrous metals 75%, trash 17%	----
3589	0.4	18.1	trash 63%, ferrous metals 21%	organic chemicals 100%
3599	1.2	46.0	ferrous metals 61%, wood 15%, paper 14%	oils and hydrocarbons 61%, solvents 25%, sludge 14%
Sector 26				
3611	0.2	0.0	paper 100%	----
3612	0.2	1,224.4	wood 40%, non-ferrous metals 33%, trash 10%, rubber 10%	inorganic chemicals 100%
3613	1.4	0.0	ferrous metals 83%	----
3621	1.3	0.0	trash 60%, ferrous metals 40%	----
3622	0.1	0.0	trash 66%, non-ferrous metals 34%	----
3624	0.2	0.0	inorganic chemicals 43%, trash 43%, paper 13%	----
3629	0.2	0.5	paper 42%, trash 39%	oils and hydrocarbons 100%
3631	0.5	0.0	ferrous metals 83%, paper 11%	----
3632	1.4	0.0	trash 100%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
3634	1.3	3.8	ferrous metals 88%	solvents 100%
3636	0.8	0.0	paper 100%	----
3639	29.2	0.0	non-ferrous metals 92%	----
3641	0.7	0.0	ceramics 56%, paper 30%	----
3642	1.4	0.0	ferrous metals 84%	----
3644	7.2	0.0	ferrous metals 53%, non-ferrous metals 39%	----
3651	0.8	0.0	ferrous metals 47%, trash 53%	----
3652	0.8	50.6	trash 76%, plastic 18%	organic chemicals 100%
3662	0.0	0.0	paper 100%	----
3671	0.2	0.0	paper 100%	----
3672	2.3	0.0	trash 100%	----
3674	1.0	0.0	trash 62%, paper 19%, non-ferrous metals 19%	----
3679	0.5	5.7	trash 74%, plastic 15%	inorganic chemicals 100%
3691	1.3	0.0	rubble 80%, paper 20%	----
3693	0.7	0.0	trash 100%	----
3694	1.2	0.0	ferrous metals 82%, non0ferrous metals 10%	----
3699	0.5	0.0	wood 43%, paper 43%, trash 13%	----
Sector 27				
3711	1.2	0.0	paper 77%	----
3713	1.2	0.0	trash 58%, ferrous metals 41%	----
3714	5.3	19.0	ferrous metals 89%	solvents 96%, oils and hydrocarbons 4%
3715	1.7	0.0	wood 54%, ferrous metals 30%, paper 11%	----
3721	0.9	52.7	non-ferrous metals 50%, paper 34%, ferrous metals 13%	inorganic chemicals 77%,
3722	0.5	16.9	trash 99%	inorganic chemicals 100%
3723	2.6	0.0	wood 50%, ferrous metals 46%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
3729	0.7	0.0	ferrous metals 57%, trash 43%	----
3731	10.8	3,458.2	rubble 76%, ferrous metals 20%	oils and hydrocarbons 100%
3732	0.8	0.0	trash 48%, plastic 26%, glass 11%	----
3741	6.2	0.0	rubble 77%, non-ferrous metals 18%	----
3742	0.7	0.0	non-ferrous metals 100%	----
3791	3.9	0.0	wood 61%, paper 23%	----
3799	1.1	0.0	rubble 59%, ferrous metals 24%	----
Sector 28				
3069	1.7	1,420.5	rubber 62%, trash 36%	sludge 100%
3079	1.0	3.2	rubber 52%, trash 27%, paper 13%	oils and hydrocarbons 65%, inorganic chemicals 16%, solvents 19%
3111	3.8	0.0	animal remains 100%	----
3121	0.8	0.0	leather 42%, rubber 33%, ferrous metals 17%	----
3141	0.2	0.0	leather 66%, paper 23%, rubber 11%	----
3142	0.1	0.0	leather 70%, paper 30%	----
3151	1.3	0.0	leather 92%	----
3161	0.6	0.0	trash 100%	----
3171	0.5	0.0	wood 70%, trash 21%	----
3172	0.2	0.0	leather 98%	----
3199	0.5	0.0	leather 82%, paper 16%	----
3211	0.7	0.0	glass 54%, paper 44%	----
3811	0.1	0.0	trash 36%, paper 30%, ferrous metals 18%, non-ferrous metals 12%	----
3821	0.2	0.0	paper 67%, wood 22%, non-ferrous metals 11%	----
3831	0.6	85.9	trash 52%, glass 29%, ferrous metals 10%	organic chemicals 100%

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
3841	0.5	0.0	paper 100%	----
3842	0.2	0.0	trash 38%, paper 31%, organic chemicals 31%	----
3843	0.0	0.0	trash 100%	----
3851	2.3	122.4	trash 73%, sludge 26%	organic chemicals 79%, sludge 21%
3861	0.4	0.0	paper 62%, trash 23%, ferrous metals 15%	----
3871	0.6	14.1	trash 100%	organic chemicals 79%, sludge 21%
3911	0.3	0.0	paper 80%, wood 14%	----
3914	1.1	44.4	trash 84%, wood 11%	inorganic chemicals 100%
3931	0.6	0.0	trash 99%	----
3941	2.5	0.0	plastic 75%, paper 19%	----
3949	0.5	0.0	trash 54%, ferrous metals 23%, wood 14%	----
3953	0.3	0.0	trash 79%, paper 13%	----
3955	8.7	0.0	paper 100%	----
3962	0.4	0.0	plastic 47%, paper 35%, trash 18%	----
3963	0.3	0.0	trash 100%	----
3964	0.2	0.0	trash 100%	----
3991	3.0	0.0	crop wastes 71%, trash 29%	----
3993	1.5	0.0	wood 36%, paper 27%, ferrous metals 27%	----
3994	0.0	0.0	paper 45%, textiles 45%	----
3996	2.3	0.0	rubber 63%, ferrous metals 27%, trash 10%	----
3999	1.4	47.2	trash 65%, ferrous metals 25%	inorganic chemicals 91%, solvents 9%

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
Sector 29				
4212	0.4	29.6	wood 31%, trash 26%, paper 25%, rubber 14%	oils and hydrocarbons 100%
4213	0.8	32.1	trash 43%, paper 24%, manure 11%, rubber 9%	oils and hydrocarbons 82%, sludge 16%
4214	1.6	20.9	trash 50%, paper 32%, wood 10%	sludge 91%, oils and hydrocarbons 9%
4221	5.6	0.0	crop wastes 72%, textiles 16%	----
4222	0.3	0.0	paper 79%	----
4223	208.4	0.0	animal remains 49%, food processing wastes 42%	----
4224	8.5	0.0	wood 59%, paper 39%	----
4225	3.8	0.0	trash 85%	----
4226	0.5	534.6	ferrous metals 59%, trash 29%	organic chemicals 100%
Sector 30				
4411	5.5	0.0	trash 100%	----
4454	0.1	0.0	trash 82%, ferrous metals 18%	----
4459	2.5	0.0	trash 100%	----
4463	0.7	0.0	trash 50%, ferrous metals 50%	----
4464	1.2	0.0	trash 100%	----
4469	0.9	0.1	paper 49%, wood 49%	oils and hydrocarbons 100%
Sector 31				
4511	1.9	4.6	garbage 74%, trash 26%	oils and hydrocarbons 100%
4521	0.7	13.4	trash 100%	oils and hydrocarbons 100%
4582	1.0	37.3	ferrous metals 50%, trash 29%, non-ferrous metals 14%	oils and hydrocarbons 72%, organic chemicals 23%, sludge 5%
4583	0.4	0.0	trash 100%	----

SIC No.	Yearly Waste/Employee Tons	Gallons	Major Waste Components (percent) Tons	Gallons
Sector 32				
4712	0.1	0.0	paper 100%	----
4721	0.7	0.0	paper 67%, wood 32%	----
4731	40.6	0.0	manure 98%	----
4782	51.3	0.0	trash 100%	----
4783	4.4	0.0	wood 92%	
4784	1.2	0.0	trash 100%	----

APPENDIX E
INDUSTRIAL SOLID WASTE GENERATION FACTORS BY
ECONOMIC SECTOR

Sector	Tons/Employee/Year	SICs Included
10	3.94	1511, 1611, 1621, 1711, 1731, 1741, 1742, 1743, 1751, 1752, 1761, 1771, 1781, 1791, 1793, 1795, 1799
11	26.05	2013, 2015
12	0.55	2021, 2023, 2024, 2026
13	2.32	2031, 2033, 2035, 2036, 2037
14	0.86	2041, 2042, 2045, 2046, 2051, 2052, 2062, 2071, 2091, 2093, 2094, 2095, 2096, 2097, 2098, 2099
15	3.85	2082, 2084, 2086, 2087
16	1.04	2211, 2221, 2231, 2241, 2261, 2269, 2272, 2281, 2291, 2293, 2294, 2295, 2298, 2299, 2311, 2323, 2327, 2328, 2331, 2335, 2337, 2341, 2342, 2351, 2361, 2381, 2384, 2385, 2387, 2389, 2391, 2392, 2393, 2394, 2395, 2396, 2399
17	11.23	2431, 2433, 2441, 2442, 2443, 2445, 2491, 2499, 2511, 2515, 2519, 2521, 2531, 2541, 2591, 2599, 2641, 2642, 2643, 2645, 2646, 2649, 2651, 2653, 2654, 2655
18	2.36	2711, 2721, 2731, 2732, 2741, 2751, 2752, 2753, 2761, 2771, 2782, 2789, 2791, 2793, 2794, 2799

Sector	Tons/Employee/Year	SICs Included
21	5.46	3221, 3231, 3251, 3253, 3255, 3259, 3261, 3264, 3269, 3275, 3281, 3291, 3292, 3293, 3295, 3296, 3297
22	13.03	3241, 3271, 3273
23	8.6	3321, 3322, 3323, 3331, 3339, 3341, 3352, 3357, 3361, 3362, 3369, 3391, 3392, 3399
24	3.09	3411, 3423, 3425, 3429, 3433, 3441, 3442, 3443, 3444, 3446, 3449, 3451, 3452, 3461, 3471, 3479, 3481, 3491, 3493, 3494, 3498, 3499
25	1.92	3522, 3531, 3532, 3533, 3534, 3535, 3536, 3541, 3544, 3545, 3548, 3553, 3554, 3555, 3559, 3561, 3562, 3564, 3567, 3569, 3573, 3576, 3582, 3585, 3586 3589, 3599
26	1.13	3611, 3612, 3613, 3621, 3624, 3629, 3631, 3632, 3634, 3636, 3641, 3642, 3644, 3651, 3652, 3671, 3672, 3674, 3679, 3691, 3693, 3694, 3699
27	2.06	3711, 3713, 3714, 3715, 3721, 3722, 3723, 3729, 3732, 3741, 3742, 3791, 3799

Sector	Tons/Employee/Year	SICs Included
28	0.93	3069, 3079, 3111, 3121, 3141, 3142, 3151, 3161, 3171, 3172, 3199, 3211, 3821, 3831, 3841, 3842, 3851, 3861, 3871, 3911, 3914, 3931, 3941, 3949, 3953, 3962, 3963, 3964, 3991, 3993, 3994, 3996, 3999
29	2.69	4212, 4213, 4214, 4221, 4222, 4224, 4225, 4226
30	1.82	4411, 4454, 4459, 4463, 4464, 4469
31	1.00	4511, 4521, 4582, 4583
32	16.47	4712, 4721, 4781, 4782, 4783, 4784

SOURCE: Texas Water Quality Board

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