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ECONOMIC ANALYSIS OF LAND TREATMENT OF MUNICIPAL WASTEWATERS

By

C. Edwin Young
Research Assistant

and

Gerald A. Carlson
Associate Professor
Department of Economics
Agricultural Experiment Station
North Carolina State University at Raleigh

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ABSTRACT

The 1972 Water Pollution Control Act Amendments are requiring increased treatment of municipal wastewaters. One method to obtain a high quality effluent at relatively low cost compared to other techniques is land treatment. This study compares and evaluates conventional in-plant treatment and land treatment in a cost framework and in a production efficiency framework. The major objective is to explain why more municipalities have not chosen land treatment in the past.

Regression analysis was used to estimate cost functions for 125 municipal treatment plants across the southern portion of the United States. Comparison of the two types of cost curves -- one including land treatment and one excluding land treatment -- indicates that inclusion of land treatment permits higher levels of treatment per dollar of expenditure. The advantages of land treatment are greater for smaller plants. A .5 mgd plant will save $.07 per 1000 gallons (treated to 85 percent BOD_5 removal) if it uses land treatment, while a 10 mgd plant will save $.05 per 1000 gallons. Cost differentials are greater for treatment to 95 percent BOD_5 removal. Savings could be increased by 7-15 cents more from sale of by-products from the land site depending upon site characteristics and product prices.

Production efficiency analysis was used to investigate labor, capital and other input mixes utilized compared with relative prices of these inputs. Inclusion of land treatment raises the efficiency indicies and marginal productivities per dollar. This analysis indicated that municipalities with conventional treatment systems tend to have larger quantities of unused capital inputs than did land treatment facilities.

The decision regarding the use of land treatment was examined through a probability of adoption function. It was found that the use of land treatment increases as maximum final BOD_5 requirements are lowered, irrigation prices rise, and as stream flow and rainfall become smaller. Land purchase prices were not found to be significant in explaining adoption of land spreading of wastes since only about 40 percent of the land treatment sites purchased land for the purpose of spreading effluent and sludge. The remainder used other public lands or sold or gave the wastes to farmers.

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ECONOMIC ANALYSIS OF LAND TREATMENT OF MUNICIPAL WASTEWATERS

C. Edwin Young and Gerald A. Carlson

I. Summary and Conclusions

The treatment of municipal wastewater is increasing throughout the United States. Federal law (1972 Water Pollution Control Act Amendments) is requiring that more wastes be treated and that the level of existing treatment be increased. If required levels of wastewater treatment are increased, how will the quantities of materials used change? Depending upon relative prices of materials and technological constraints, plants may move toward more capital or chemical intensive procedures such as high level secondary and tertiary treatment. On the other hand, they may move toward more land intensive techniques if land use prices are relatively low. An analysis of relative quantities and prices of materials should be performed to determine if wastewater treatment officials respond to economic incentives in selecting treatment technologies.

The present research investigates the production of sewage treatment services. Cost minimization, production function analysis, and derived demand analysis of a specific technique, land treatment, are employed. Particular emphasis is placed on evaluating the land treatment alternative since it has been receiving recent interest from technical and government personnel.

The analysis is restricted to evaluating waste services after the wastes have entered the treatment facility. This limitation is imposed to keep the scope of the analysis manageable. It is recognized that techniques and costs of collection affect the size and location of the sewage treatment plant.

It is also acknowledged that both the quantity and the quality of the incoming wastes can be altered through the use of regulations and/or prices. Ethridge (1970), Elliott and Seagraves (1972), Howe and Linaweaver (1967), and Hanke and Davis (1971) show that sewer surcharges and water rates do affect the quantity and the quality of the wastes entering the wastewater treatment plants.

The research is undertaken with several objectives in mind. These objectives are:

1) to develop a model for the production of municipal wastewater treatment services to include a quantity and quality measure of output;

2) to determine if relative factor prices can explain the factor mix, especially for the use of land;

3) to examine the returns to scale of both the quantity and quality aspects of the waste treatment services in order to establish whether or not land treatment can substitute for conventional in-plant treatment methods such as secondary treatment and tertiary treatment; and

4) to compare the capital requirements of land and non-land treatment and its effect on economic efficiency in wastewater treatment.

Background

Land treatment is the application of sewage effluents and/or sludges to land for purposes of water purification and crop production. Land application of sewage is an old practice. It was introduced to the United States in the late nineteenth century. A portion of these facilities are still in operation. An examination of an Environmental Protection Agency survey of land treatment facilities indicates that most are located in the Southwestern part of the United States. The majority serve fewer than 5000 individuals.

Potential health problems exist with the use of land treatment. These problems can be minimized if adequate precautions are taken. These precautions include prohibiting direct human consumption of crops, chlorination of effluent prior to land application, and the use of buffer zones.

Land treatment of sewage effluents produces salable by-products ranging from agricultural crops to golf course and landscape irrigation. The value of these crops has increased dramatically over the last two years. For example, the returns to irrigating forages with a 1 1/2 inches per week application rate has increased from an estimated 6.6¢ per 1000 gallons in 1972 to 16.8¢ per 1000 gallons in 1974. As a result of the valuable by-products from irrigation with sewage effluent, municipalities can either sell or give the effluent to others.

Cost Analysis Conclusions

The costs of wastewater treatment were studied by estimating annual cost functions from a survey of 125 treatment plants. The cost functions were estimated including land treatment and excluding land treatment. The results from the cost analysis indicate that there are returns to scale to increasing the flow through the plant. Costs decreased as allowable BOD in the effluent increased. Some evidence was found which indicated that there may be diseconomies associated with increasing the level of BOD_5 removal.

Tests on relative price differences were performed in the cost analysis. The prices of labor and capital influence costs signficantly. For high level BOD removal facilities, electricity prices are directly related to total costs. Analysis of input use indicated that wastewater treatment plants could produce the same levels of output with less capital than they are now using. In the cost analysis it was found that if excess capacity were reduced by 10 percent that total costs would fall by about 3 percent.

Production and Efficiency Conclusions

Conventional treatment plants are designed and built with flow capacity exceeding average daily flow for several reasons: to meet peak flow periods, to plan for population growth, and to avoid costly additions. A comparison between land and non-land treatment systems indicated that the latter had more excess capital than the former as measured by marginal products per dollar of capital.

The land sites were more price efficient than the conventional plants with high degree of statistical significance (t = 17.0). That is, the land treatment managers were able to vary labor-land-capital combinations as prices changed more readily than those using conventional treatment technology.

Land Treatment Results

The cost and efficiency analyses indicated that there are pricing and capacity advantages to using land treatment. As a result the analysis was extended to investigate the decision of municipalities to adopt or not adopt land treatment. The economic model is developed as a probability of adoption function.[1]

The significant variables in explaining the probability of adoption were the opportunity price[2] of the major by-product-irrigation water, a variable representing natural ability to meet ambient environmental standards river flow, and the required level of BOD_5 removal. High land prices did not decrease adoption of land treatment, since many of the cities did not purchase the land used for treatment services and they applied wastes to high priced land (parks, golf courses).

Predicted Adoption Costs

The demand results were used in an example for a 1 mgd plant with 40 percent BOD_5 removal. It was assumed that the plant was under federal and state order to increase BOD_5 removal to 95 percent. The estimated probability that the plant would use land treatment was 0.48 when the opportunity cost of not using land treatment was assumed to be $5 per acre foot of water. Using the estimated cost equations the costs for two ways to reach 95 percent removal were estimated. The annual costs of building and operating a new plant are $610,742 per year. If a land treatment site is built the costs are $462,400 per year. By similar evaluation for other sizes of plants it was found that land treatment is especially advantageous for smaller facilities. Using in-plant treatment as opposed to land treatment

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[1] The model was developed as derived demand for an input from a profit maximization framework.

[2] Opportunity price refers to the price which a farmer would have to pay for the next best alternative to the effluent (i.e. irrigation water).

costs a 0.5 mgd plant $0.40 per 1000 gallons extra. For a 10 mgd plant the savings from using land treatment are much lower ($0.14/1000 gallons).

Major Conclusions and Implications

From the analysis in this study it can be concluded that there are economic advantages to using land treatment. Land treatment is not the least cost treatment technique in all instances. However, as Sullivan et. al, 1973 noted, over fifty percent of the municipal land treatment facilities have been operating for more than fifteen years. There are more uncertainties surrounding land treatment, especially in new geographical areas. However, from an economic efficiency viewpoint, wastewater service customers should request that it be considered whenever treatment investment decisions are made.

This study collaborates others which find lower average treatment costs as the flow per day increases. This must not be interpreted as favoring regional treatment systems, since this study does not examine collection costs. Contrarily, the large savings for land over conventional treatment in small cities suggests land treatment in many small towns, rather than regional land or non-land treatment.

It is well known that municipal land treatment is highly concentrated in the Southwest. Irrigation productivities are higher there than in other portions of the country. However, this study indicates that increases in required levels of treatment and nonavailability of streams for dilution can also encourage land treatment.

II. Economic Description of Land Spreading of Municipal Wastewaters

Prior to proceeding with the analysis a description of the biological, engineering, and economic aspects of land treatment is necessary. This section will proceed by first providing a description of the output produced. Following the description of the output will be a discussion of land treatment. The remainder of the section will deal with the determination of initial plant size and alterations in existing plants for conventional and land treatment.

Description of the Output

The product produced is "cleaner" water. Water is neither created or destroyed during the treatment process. The wastes entering the sewage treatment plant may be characterized as a given quantity of water, usually measured in millions of gallons of water per day, with specific concentrations of biological and chemical elements. Common components of municipal sewage are BOD_5[1], nitrogen, phosphorous, heavy metals, suspended solids, and pathogenic elements. The treatment process separates, removes and/or alters the composition of the waste components. The final product is again measured in gallons of water and in concentrations of the biological and chemical elements emitted.

Different treatment processes produce different final concentrations. Thus the output or product of a wastewater treatment plant has two components:

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[1] Biochemical oxygen demand measures the number of pounds of oxygen utilized in five days of decomposition under aerobic conditions of the organic matter contained in the plant effluent. Although better measures for various purposes are available it was the most often quoted and readily available measure of changes in contamination and thus is adopted for this study.

a quality component describing the concentrations of various wastes parameters and a quantity component describing the volume of flow through the plant. The output can be specified as a given number of pounds or milligrams of the elements removed per period of time, or it can be specified through the use of two output measures: one for quantity of wastes discharged and one for quality of wastes discharged. A simple example will illustrate why the second specification of output is preferable. Assume that measurement of one element such as BOD_5 describes all quality aspects. Thus a hypothetical plant could produce an output of 1530 pounds of BOD_5 removal per day. Two entirely different plants could produce this output. A plant treating one million gallons of wastes per day and removing 90% of BOD_5, results in the removal of 1530 pounds of BOD_5 per day. A plant treating two million gallons of wastes per day removing only 45 percent of all BOD_5 would also have a BOD_5 removal of 1530 pounds per day. These two plants would have different factor mixes. In order to distinguish between these two types of plants this analysis will measure the output of a sewage treatment plant using at least two measures of output: a concentration of remaining wastes and a volume of flow measure. Note that when land treatment is assumed to follow secondary in-plant treatment, a measure of BOD_5 before land treatment will be made and a measure after treatment will be approximated.

Land Treatment

Land treatment is the application of sewage effluents and/or sludges to land for purposes of water purification and crop production. This is an old method of treatment dating back to early Athens. Early sewage farms applied raw sewage directly to the land. Using the nutrients contained in the sewage, they then grew agricultural crops for human consumption.[2] From the sixteenth to the end of the nineteenth century sewage farming was practiced throughout continental Europe and in England. The practice of sewage farming spread to their colonies in South Africa, Australia, and Mexico where it continues today.

Land application of sewage began in the United States in the late nineteenth century. In 1899 land disposal sites existed in 20 states from Massachusetts to California. A portion of these treatments sites have ceased operation. Pound and Crites (1973) list population increases, increased land values, odors, soil toxicity from over application of wastes, and the loss of plant operators as reasons for abandonment. Table 1 shows the distribution of land treatment sites by state in 1968. Most of the less than 500 existing land treatment sites are located in the Southwestern part of the United States. This may be attributed to the increased land values and population in the East and the high value of water in the Southwest. These and other cross-sectional differences will be examined in detail in subsequent chapters.

The validity of the data in Table 1 as an indicator of the use of land spreading can be questioned. For example, 14 sites are listed for North Carolina. None of these sites could be located. Therefore, it is most likely that the number of sites listed in Table 1 may not correspond with the actual number of sites using extensive land treatment in any one state. Plant scales are smaller for land treatment. Nevertheless, Table 1 does provide an indication of the overall use of land treatment in the United States.

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[2] The use of sewage for beneficial purposes was reported to have started in the sixteenth century [Pound and Crites, 1973].

Table 1. Distribution of municipal land treatment sites in the United States by states[a]

State	Number of land sites	Number of treatment plants	Percent land
California	259	534	48.5
Texas	106	918	11.5
New Mexico	28	82	29.3
Arizona	17	79	21.5
Nevada	12	36	30.0
Oklahoma	3	374	0.8
Maryland	11	154	14.0
New Jersey	2	380	0.5
North Carolina	14	384	3.6
West Virginia	3	101	3.0
Florida	5	535	0.9
Alabama	1	267	0.4
Virginia	1	301	0.3
Colorado	2	154	1.3
Wyoming	4	82	4.9
Washington	10	140	7.1
Oregon	6	178	3.4
Nebraska	1	434	0.2
Massachusetts	1	192	0.5
Kansas	1	477	0.2
Wisconsin	4	499	0.8
New Hampshire	2	79	2.5
	493		

[a] Environmental Protection Agency, 1968.

The sites used to construct Table 1 were examined to determine the effect of city size on the use of land treatment. This stratification is presented in Table 2. Table 2 shows that land treatment is more prevalent in smaller cities. In fact, over 50 percent of the cities using land treatment serve less than 5000 people. The advantages of land treatment for smaller cities will be investigated by separating the effects of lower land prices, and flow scale economies.

Table 2. Percentage of municipal land treatment sites by size of population served[a]

Population served	Percentage
200,000	.7
80,000 - 200,000	1.8
40,000 - 79,999	2.7
25,000 - 39,999	4.9
15,000 - 24,999	5.8
8,000 - 14,999	10.7
5,000 - 7,999	12.9
1,000 - 4,999	38.9
< 1,000	21.8
	100.0

[a] Environmental Protection Agency, 1968.

Land application of sewage is subject to health concern and legal constraints. "Consumption of fresh vegetables irrigated with sewage or polluted water has caused many disease outbreaks. Epidemics of typhoid fever and parasite infestations traceable to this cause has occurred in the United States, Europe, and other parts of the world," (Sepp, 1971, p. 1). Because of the potential health hazards those states and foreign countries which have laws relating to land application usually require disinfection of the sewage, and prohibit the application of sewage on root crops which may be directly consumed by humans.[3] Additional health hazards result if the wastes are sprayed on the land. Spray irrigation is one of the most common irrigation techniques. However, it can increase the dispersion of organisms by raising small droplets into wind streams. To avoid this problem the wastes should be chlorinated to kill the organisms prior to disposal. It is often suggested that a buffer zone be established to prevent wind loss.[4] The Army Corps of Engineers (Reed, et. al., 1972) assert that if adequate precautions are taken the health hazards are minimal.

When the sewage products are applied to the land the micro-organisms in the soil use the wastes for food thereby decomposing the wastes into more stable substances. Land treatment removes from 90 to 98 percent of the BOD_5 contained in the wastewater prior to application. Nitrogen removal runs from 75 to 85 percent, while phosphorous removal ranges from 95 to 99 percent (Reed, et. al. 1972). The actual removals are determined by the biological activity in

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[3] Sepp, 1971, Reed et. al., 1972, and Stevens, 1972 provide summaries of existing statues relating to land application of sewage.

[4] Sepp [1971], p. 11] reported on a study at the University of Southern California "on the travel of airborne bacteria by spraying of settled, undisinfected sewage." All results testing for coliform bacteria were negative outside the detectable mist zone. With a 5 to 10 mph wind, the maximum limit of the mist zone extended 105 feet downward from a sprinkler which had a normal spray radius of 30 feet.

the soil, the application rate, and the type of soil. Soil type determines the rate the water can flow through the soil. If the water moves at too rapid or slow of a rate, lower treatment levels occur.

Application rates should be mainly determined by infiltration rates, percolation rates, costs, and revenue considerations (Seitz and Swanson, 1973). Application rates may be stated in terms of inches of water per week. Experiments at the Pennsylvania State University indicate that two inches of water per week provides an adequate level of treatment (Kardos, 1972). The application rate has an influence on land costs if treatment rights are obtained by land purchase. For example an application rate of 1 1/2 inches per week as opposed to a rate of 2 inches per week requires approximately 33 percent more land cost.

There is more nutrient removal and biological activity in soil which is supporting growing plants. Therefore, it is better to grow some type of vegetative matter on the treatment site. Plants provide the major vehicle of nutrient removal. Plants which are often mentioned with land treatment are trees, grasses, corn, alfalfa, cotton, etc.

Land treatment of sewage effluents produces salable by-products. The by-products range from agricultural crops to golf course and landscape irrigation. Table 3 presents a summary of the uses of land treatment in California. The most popular recipient of the effluent is pasture and fodder crops which make up 37% of the total. An interesting feature of Table 3 is that 30 municipalities use sewage effluent to irrigate golf courses and landscape. The land receiving the effluent is used daily by the general public. The only precautions taken are chlorination and spraying at times when the facilities are not being used.

Table 3. Land treatment crops and activities in California[a]

Use	Number of sites	Percentage of total
Pasture and fodder crops	50	37.3
Agricultural crops	40	29.8
Golf course and landscape	30	22.4
Recreational lakes	6	4.5
Combinations	8	6.0
TOTAL	134	

[a] Source: David G. Deaner, 1971.

The revenues from the sale of agricultural crops can be used to offset the costs of operating the system. The effect of irrigation with sewage effluent on revenue was calculated for two application rates (1 1/2"/week and 2"/week), based on yield effects estimated by Kardos [1972]. The expected total and marginal revenues in cents per thousand gallons of effluent are presented in Table 4.[5] The important conceptual point to note is that both marginal and total revenues diminish as application rates rise at these application rates. As Seitz and Swanson, 1973, show, operation on the negative portion of the total revenue curve may be optimal if costs of alternative methods of treatment are high relative to land treatment cost and crop revenues.

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[5] Note that this pertains to the Pennsylvania evapotranspiration and soil conditions and will not hold for warmer climates and more sandy soils.

Table 4. Expected total and marginal revenues from effluent applications on various activities[a]

	Marginal		Total	
	1 1/2"	2"	1 1/2"	2"
White pine	1.1[b]	--	7.0	--
Corn for grain	3.6	2.7	10.2	7.6
Corn for silage	2.7	1.8	9.9	7.1
Red clover and other fodder	2.7	1.8	5.6	4.0
Grass - pasture, fodder	3.3	2.9	6.6	5.2
Golf	12-14	--	--	--

[a] Source: Based on yield effects given by Kardos [1972] except for golf.

[b] Cents per 1000 gallons.

The prices of the components of municipal wastewaters have varied substantially in recent years. The price increases can be attributed to increasing nutrient prices and final product prices. In the past two years the prices of nitrogen, phosphorus and potassium have risen by 170, 100, and 140 percent. The price per ton of grass has doubled due to increased nutrient prices in addition to other influences on the supply and demand for feed. Thus, if the price increases are included in Table 4 the marginal value of grass increases from 3.3 cents per 1000 gallons for 1 1/2" per week to 6.6 cents per 1000 gallons and from 2.9 cents per 1000 gallons for 2" per week to 5.8 cents per 1000 gallons. Total values increase to 16.8 cents per 1000 gallons and 13.6 cents per 1000 gallons for 1 1/2" per week and 2" per week, respectively.

Operation of a land treatment site is not limited to municipal employees. Because of the valuable by-products from irrigation with sewage effluent, municipalities can either sell or give the effluent to others. Table 5 shows that most of the municipalities surveyed in this study permit others to operate the land treatment site. Of the 50 municipalities using land treatment in the sample, only 18 own and operate their own system.

When attempting to induce a farmer to purchase the effluent or operate the land treatment system, marginal revenues should be considered. The recipient of the effluent is interested in the extra yield he can obtain by using the effluent. A farmer will be willing to pay up to the full value of the marginal increase in revenue to obtain the effluent so long as there is no risk

Table 5. Institutional arrangements for effluent disposal[a]

Municipal owned land:	
Purchased for waste treatment and operated by municipality	13
Purchased for waste treatment and leased to farmers	8
Land purchased for other purposes	5
Privately owned land:	
Effluent sold to farmers or others	10
Effluent given to farmers or others	14

[a] 1973 Survey results by C. Edwin Young. The survey procedure will be described in section 3.

involved. If the farmer anticipates that the effluent will harm his land he will require additional revenue to offset this risk. This explains why some municipalities own the land and lease it to farmers or give it to the farmers as shown in Table 5.

The cost of constructing and operating a land treatment site will vary from site to site. See Sullivan et.al., 1973, Reed et. al., 1972, and Pound and Crites, 1973, for operating and capital costs of land treatment facilities. If the irrigation process can not be operated continuously throughout the year, additional costs will be incurred. The effluent will have to be stored during periods of freezing weather and during periods of high rainfall. In order to store the effluent it must receive at least secondary treatment to avoid odors. Rainfall increases the land area needed for irrigation since there is a limit to the amount of water which can be applied to the land. Land costs will also increase when buffer zones are required. The application rate can be increased thus reducing the land area if the concentration of the limiting constituent of the wastes prior to disposal is reduced. Thus a tradeoff can be made between the land area costs and pretreatment costs.

Plant Size

The type and size of a municipal wastewater treatment plant are a function of the population served and the economic, physical, and environmental constraints facing the plant. Whether or not more than one treatment plant is required in an area depends upon a comparison of the economies of scale in treatment versus the diseconomies of collection. Once the plant site is determined, the plant size is calculated. The capital requirements are determined by comparing the expected flow of sewage over the life of the plant, the required level of treatment, the initial cost of capital, the difficulty of obtaining future capital, and the variability of flow.

The use of Federal funds for construction may lead to a high use of capital. The availability of Federal subsidies only for construction purposes reduces the price of capital relative to variable inputs. If local government officials act in a rational manner in the face of subsidies, they will substitute fixed capital for variable inputs. From a societal allocation of resources viewpoint excess capacity is costly. The effect of the surplus is to add unnecessarily to the overhead burden and to tie the owners to a less manageable fixed cost base (EPA, 1971).

Planning and design procedures also tend to increase capital usage. Consulting engineers may bias their recommendations toward capital intensive projects since design fees are usually based on a percentage of the construction costs. Local government officials may be inclined to accept these biases if DeAlessi's (1969) analysis is correct. He found that because of government workers' concepts of property rights they have a preference for capital intensive production processes.

Legitimate reasons exist for building plants capable of handling larger than average flows of wastes. Variations in flow necessitates larger capacities. Sewage flow throughout the day will vary as water usage varies. Sewage flows will vary throughout the year. More water is used during the summer for baths, air conditioning, some industrial operations, clothes cleaning and various other uses. Wastewater flows are higher during period of rainfall if the storm drainage system is connected to the sewer system. Thus the treatment plants must be large enough to handle the flow variations. From a small sample Downing (1969) estimates that hourly peak flow can be from 150 to 200 percent of average hourly flow.

When building a new plant or expanding an old plant, care must be taken to limit excess flow and BOD_5 removal capacity. From the local viewpoint excess capacity causes increased costs in two ways: increased interest payments and increased operating costs. The interest cost of excess capacity is the annual interest payments on the capacity. Allowing for a 25 percent rate of growth in demand over the life of the plant and taking into consideration the economies of scale that exist in the cost to size relationship observed for waste treatment plant construction, the Environmental Protection Agency estimated that there was $670 million of excess capacity in 1968. Excess capacity was determined only for those plants operating at less than 80 percent of designed capacity. A portion of this excess capacity may be attributed to expected growth in some municipalities and to population decreases in others.

It costs more to operate a plant if excess capacity exists. Table 6 illustrates the operating and maintenance cost penalties of excess capacity at a point in time. As the percentage of capacity utilization increases the penalty associated with the operation of a plant decreases at a decreasing rate.

Thus, there are many economic considerations in the selection of the technology, size and operating characteristics of a treatment system. In the past, treatment

Table 6. Incidence of operating and maintenance cost penalties by utilization classes in 1968[a]

	Utilization range			
	0 - .2	.2 - 4	.4 - 6	.6 - .8
Penalty as a percentage of operating and maintenance costs	59.8	32.8	14.6	4.4
Percentage of all plants	5.6	15.1	24.3	24.0

[a] EPA, 1971, p. 98, where utilization is defined as average daily flow divided by designed flow.

technology, input combinations and by-product production were relatively standardized. In light of the more stringent regulations and changing relative costs of land, labor and capital, land treatment technology seems to warrant closer scrutiny.

III. Economic Analysis

The purpose of this section is to develop and estimate an economic model of the treatment of municipal wastewater. The analysis will be directed to examining the conditions surrounding the use of land treatment. Related hypotheses concerning the effect of relative price differences on factor usage will be tested. Specific emphasis will be placed on the price of capital and the use of capital. Do federal subsidies for construction bias the plants toward over capitalization?

The use of economic and statistical techniques to examine land treatment of municipal wastewater enables the discovery of details which would not be immediately obvious from a case study approach. Using large numbers of observations the effects of variations in prices, biological and demographic variables on production techniques, materials used, and costs can be determined. Multiple regression permits the effects of one variable to be analyzed individually while holding the effects of the remaining variables constant. The result is a general approach to evaluate cross-sectional differences.

There are seven assumptions underlying the analysis: (1) The underlying production function is assumed to be a generalized Cobb-Douglas (power) production function. (2) The output of municipal wastewater treatment is not a single product. Instead there are three basic outputs: a flow of treated wastes, a concentration measure of the treatment level in terms of BOD_5, and reusable water and suspended by-products which can be sold. (3) The outputs are exogenously determined but not in fixed proportions. (4) The quantity of reusable water is exogenously determined and its value is reflected by its opportunity price (the local irrigation price). (5) Land treatment is viewed as an additive, separable component of the production function (6). The sample and the returned questionnaires are assumed to be random within the strata. (7) It is assumed that technological change over the life of the plants in the sample has been neutral in land, labor, and capital. All variables written in lower case letters are the natural logarithms of that variable.

The analysis starts with a description of the data necessary for the study and its sources. A model for the production of wastewater treatment with multiple measures of output is developed. The analysis proceeds by developing and estimating cost curves, efficiency indexes, marginal conditions, and the demand for the use of land treatment. The estimated cost curves will provide vehicles to examine the costs of conventional treatment plants and the effects on costs of introducing the land treatment alternative. The efficiency and marginal analysis will permit examination of the effects of relative factor price differences on the use of land treatment and on the use of different factor inputs. The demand for land treatment will draw together the results concerning land treatment from the cost, efficiency and marginal analyses. The final section will draw on the regression results and outside information to examine the use of land treatment in the Southeastern United States.

Data Collection

Factors which influence municipal wastewater treatment can be expressed in equations of observable variables. Data corresponding to these variables were collected through the use of questionnaire and secondary sources.

A portion of the data was obtained using a mail survey. Questionnaire data were pursued due to a scarcity of data on wastewater treatment plants. This lack of data was especially evident with regard to land treatment plants although some of the data duplicated that collected by Sullivan et al, 1973. Appendix A includes a letter of introduction, a follow-up letter to non-respondents, a basic questionnaire, an additional questionnaire sent to sites identified as using land treatment, and a list of the data used in the analysis.[6] The questionnaire was sent to a stratified random sample of 500 cities in the southern half of the United States of which 25% responded. The 1968 Inventory of Municipal Waste Facilities [EPA, 1968] provided a list of facilities. The list was divided into four groups: Eastern land treatment sites, Eastern non-land treatment sites, Western land treatment sites and Western non-land treatment sites. The Mississippi River was used to divide East from West. The stratification of the data was done to insure that some variation existed in the land treatment response since most land treatment sites are located in the southwest.

The questionnaire data were supplemented with data from secondary sources. Price data, climatic data, and geographic data were obtained from secondary

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[6] All of the questionnaire data is not reported. Responses to many of the questions were incomplete. Only the data used in this study is reported.

sources. Price data was converted into 1972 dollars with the use of the Wholesale Price Index (U. S. Department of Commerce, 1973 b). Capital cost data were converted to 1972 dollars with the EPA Sewage Treatment Construction Cost Index.[7]

Price data were obtained from several sources. Labor prices were derived from County Business Patterns for 1972[8] (U. S. Department of Commerce 1973a). Federal Power Commission [1971] provided regional electrical rates. Capital prices were calculated from the EPA Sewage Treatment Construction Cost Index[9] and municipal interest rates from the questionnaire. Agricultural land prices were obtained from the 1969 Census of Agriculture. Heady and Agrawal [1972] furnished irrigation prices.

Average temperature and rainfall data were available from the U. S. Department of Commerce [1972a]. The United States Department of Interior [1973] data were used for river flows. Population density data were collected from the United States Department of Commerce [1972c].

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[7] Environmental Protection Agency, Office of Water Programs Operation, 1973, Sewage treatment plant and sewer construction cost indexes, unpublished.

[8] To determine the hourly wage rate it was assumed that the workers worked for 40 hours per week and that there are 13 weeks in the months of January, February and March.

[9] Environmental Protection Agency, Office of Water Programs Operation, 1973, Sewage treatment plants and sewer construction cost indexes, unpublished.

Wastewater Treatment Production Function

A production function relates the maximum output obtainable from a given set of inputs in a given time period. Following Young [1974] the production function can be written as:

$$O_1 = f(O_2, I_o, I_L, S_o, S_L) \qquad (1)$$

where: O_1 = quantity of wastes treated

O_2 = vector of changes in the physical components of the product (i.e., the quality of the treatment)

I_o = factor inputs excluding those inputs used for land treatment

I_L = factor inputs used for land treatments

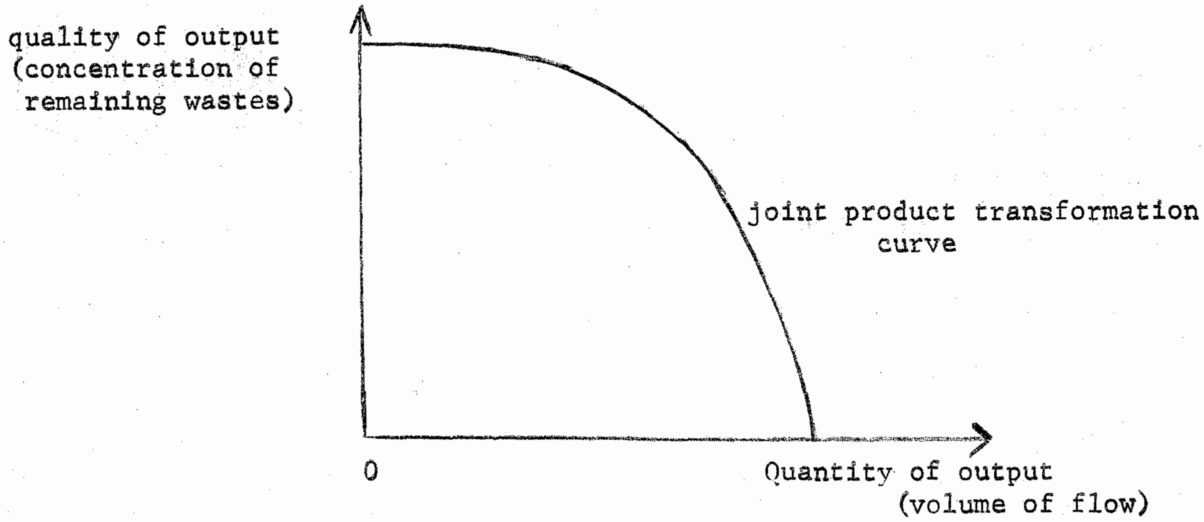
S_o = conditions affecting the treatment process excluding those conditions affecting land treatment

S_L = conditions affecting the land treatment process.

Factor inputs (I_o and I_L) refer to factors of production such as land, labor and capital. Conditions affecting input requirements (S_o and S_L) refer to outside influences on the production process. The distinction between factor inputs (I) and outside conditions (S) is that the decision maker has a degree of control over factor inputs while the outside conditions (S) are assumed to be uncontrollable. Examples of outside conditions are climate, legal constraints, location, etc.

As equation 1 is written it contains two measures of output: a quantity of wastes (O_1) and a quality of wastes (O_2). The production of the two outputs can be traded off against each other. The quantity and quality (level of treatment) dimensions of output need not be produced in fixed proportions. Holding input usage constant, a higher volume can be substituted for a lower final BOD_5 level of output. Figure 1. illustrates the potential substitutes of quantity for quality holding all inputs at a fixed level.

Figure 1. Wastewater treatment output as joint products



Inputs and outside conditions relating to land treatment are separated from their inputs and outside conditions to test hypotheses relating to the flexibility of land treatment. It is hypothesized that land treatment is a more flexible process with respect to input price differences. That is, as relative input prices change, land treatment managers can adjust at a faster rate than conventional treatment managers. It is hypothesized that economies to scale for increasing flow (Q_1) are smaller when land treatment is utilized. The diseconomies to increasing the level of treatment (Q_2) are also believed to be smaller with land treatment than with conventional facilities.

Cost of Wastewater Treatment

The predetermined nature of the output of the sewage treatment industry suggests cost minimization as a plausible model of economic behavior. Estimation of cost curves permits the effects of relative price differences and output differences on costs to be analyzed. A function relating cost to the quantity of output and input prices, can be derived from the production function and the marginal productivity conditions.[10] Estimation of cost curves is more convenient since accounting data is in nominal money terms.

Previous Wastewater Treatment Cost Studies

There are a number of studies dealing with the cost of treating sewage. These studies can be divided into engineering studies and economic studies. Although many of these studies are titled "The Economics of Sewage Treatment," they are accounting studies of the engineering aspects of sewage treatment. These engineering studies start with engineering production relationships to determine the quantities of inputs necessary to produce a given output. The production costs are the sum of the average input prices multiplied times the quantity of the inputs used. Thus, relative price differences and other cross-sectional differences are assumed not to influence costs (i.e., the results pertain to particular circumstances). These studies, also, present results in terms of parts of the treatment process, rather than as total costs of a given level of treatment. It is left to the reader to add the various portions together. In order to add the portions it must be assumed that no economies or diseconomies exist for combining processes. This may not necessarily be true, especially with respect to management and administrative costs.

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[10] These conditions indicate optimum quantities of each input to use to minimize costs such that the ratio of input prices just equals the ratio of the incremental contributions to output of each input (Young, 1974).

Two of the most comprehensive engineering studies were performed by Smith [1968] and Smith and McMichael [1969]. Smith's approach was to review and evaluate the major studies on the cost of sewage treatment. Table 7 presents Smith's estimates for primary, secondary, and tertiary treatment costs. Plant size is measured in millions of gallons per day (mgd) of wastes flowing through the plant. Note that as plant size (mgd) increases the average treatment costs fall, indicating economies to increasing the sewage flow. Engineering studies conclude that average costs increase at an increasing rate as the level of treatment increases. Examination of Table 7 reveals that the marginal costs (or the rate of change of costs) increases as the level of treatment increases.

A thorough search of the literature on the costs of sewage treatment revealed one attempt to determine the average and marginal costs of sewage treatment. This is a study published by P. Downing in [1969]. Downing's approach was to divide total costs into capital costs (or fixed costs) and variable costs. He then estimated two cost equations for each of four types of treatment: Imhoff tank, primary, trickling filters, and activated sludge plants. Downing could have made his results more useful to economists by using multiple regression techniques. By introducing a variable showing percent removal of wastes he would have only had to estimate one fourth as many equations. In addition the equations could be used to better evaluate such problems as, what is the optimum quantity and degree of treatment for a river basin?

Examination of the previous costs studies for wastewater treatment reveals two hypotheses concerning economies of scale. There are economies of scale with

Table 7. Cost of wastewater treatment (1972 dollars)

				Secondary Treatment						Tertiary Treatment										
	Primary Treatment[a]			Trickling Filter[a]			Activated Sludge[a]			Lime Clarification[b]			Granular Carbon Adsorption[b]			Ammonia Stripping[b]			Land Treatment[c]
Design Capacity (mgd)	1	10	100	1	10	100	1	10	100	1	10	100	1	10	100	1	10	100	1
Operating and Maintenance Cost (cents/1000 gal.)	5.8	3.5	2.2	6.9	4.4	1.6	9.5	6.0	3.4	12.2	6.9	4.2	25.7	7.7	5.1	5.3	2.4	1.9	9.3
Debt Service [4 1/2%, 25 yrs.] (cents/1000 gal.)	7.9	4.1	2.0	11.0	6.7	4.1	11.9	7.1	4.3	2.9	1.5	1.0	8.9	3.7	2.7	2.0	1.6	1.2	9.7
Total Cost (cents/1000 gal.)	13.7	7.6	4.2	17.9	10.1	5.7	21.4	13.1	7.7	15.1	8.4	5.2	34.6	11.4	7.8	7.3	4.0	3.1	19.0

[a] Source: Smith (1968)

[b] Source: Smith and McMichael (1969)

[c] Source: Pound and Crites (1973)

increasing flow as indicated in Table 7. Table 7 also indicates that increasing the level of treatment causes total costs to increase at an increasing rate. The hypothesis regarding percent BOD_5 removal can be stated that there are diseconomies to increasing the level of treatment. Both of these hypotheses will be tested in the empirical analysis.

Theoretical Cost Function

A cost function of the form shown in equation (2) can be derived from equation 1 by assuming the use of the optimum mix of inputs by meeting required levels of Q_1 and Q_2, and by including an index of plant size [Young, 1974].

$$C = K\, Q_1^{a_1}\, Q_2^{a_2}\, P_1^{a_3}\, P_5^{a_4}\, P_3^{a_5}\, S^{a_6}\, W^{a_7} \qquad (2)$$

where:

C = total annual cost of construction and operation

K = constant

a_i = estimated parameters

$Q_1 = X_1$ = quantity of wastes

$Q_2 = X_{10}$ = quality of wastes

P_1 = price of labor

P_5 = price of electricity

$S = X_4$ = outside conditions

$W = X_3$ = index of plant size.

Specification of Variables and Expected Results

The independent variables in the analysis are quantity of wastes treated (Q_1), quality of wastes treated (Q_2), exogenous conditions (S), an index of plant size (W), and factor prices (P_i). The dependent variable is the cost of wastewater treatment (C_o).

There are two measures of plant output: Q_1 and Q_2. A commonly used measure of the quantity of wastes treated is the average daily flow of wastes, X_1 through the plant in millions of gallons (mgd). Based on the evidence produced by Smith in Table 7, the coefficient of flow is expected to be positive but less than one. If the coefficient is less than one, it can be concluded that there are returns to scale in increasing the quantity of wastes treated. If the coefficient is less than one, a one percent increase in flow will cause costs to increase by less than one percent.

Measurement of Q_2, the quality or per unit level of the waste treatment services, is more difficult to quantify. In section two, the variety of the quality aspects were examined. Removal of BOD_5, nitrogen, phosphorous, and pathogens are types of increases in the quality of waste treatment services generated. Inclusion of all of these measures would not add significantly to the results. Significant nutrient removal does not occur until high levels of treatment are reached. The most commonly used and readily available variable is BOD_5. BOD_5 will be used to measure changes in the quality of the output. Costs should increase as the amount of BOD_5 removal increases. Engineers commonly use the percent of BOD_5 removal. X_2 will be defined as the percent of BOD_5 removed inside the plant. It has been established that percent BOD_5

removal may not be the best measure. A better measure of the level of treatment is the final concentration[11] of BOD_5. X_{10} will measure the BOD_5 concentration after in-plant treatment. X_{12} will measure the BOD_5 concentration after land treatment.

Land treatment does not provide total removal of the pollutants in the effluent. The degree of treatment is a function of the types of pretreatment, the operation of the land treatment site, and the physical characteristics of the site. The land treatment sites in the sample were unable to provide observations on the degree of treatment resulting from the land treatment site.[12]

The specification of final BOD_5 concentration before and after land treatment implies that they should have negative coefficients. Table 7 demonstrated that as percent BOD_5 removed increases, costs increase at an increasing rate. This hypothesis can be tested by testing whether or not the coefficient of x_2 is greater than one. The final hypothesis to be tested with regard to BOD_5 removal is whether or not land treatment provides BOD_5 removal at a lower cost than conventional treatment. If the coefficient of x_{12} is less than the coefficient of x_{10} in comparable equations, land treatment can be said to provide the desired treatment level at a lower cost.

In the discussion of previous research on wastewater treatment it was observed that stronger influent concentrations cause costs to increase. To adjust for strength of incoming wastes on costs, a variable, X_5, will be included

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[11] The concentration of BOD_5 will be measured in milligrams of BOD_5 per liter of water.

[12] BOD_5 removals from land treatment were estimated using published data by Reed, et. al., [1972], Sepp [1972] and Kardos [1972] and the characteristics of each of the sites. The BOD_5 removals are presented in Young [1974], Appendix I.

as a measure of industrial wastes. Industrial wastes are stronger and more toxic, therefore costs are expected to increase as the quantity of industrial wastes increase.

The age of capital, x_4, is included to adjust for increased maintenance costs associated with older plants and to test the formulation of the capital service flow. The coefficient may be negative if the formulation of the capital service flow is biasing the results. This can be tested by comparing the coefficient of age when the capital service flow is assumed to be constant versus when it is assumed to be declining. If the coefficient of age assuming a constant service flow becomes positive the formulation of the service flow can be assumed to be at fault.

The index of plant size, W, will be specified as the porportion of engineering design flow capacity utilized (X_3). x_3 will be defined as average flow divided by the designed flow capacity of the plant. In addition to assuring that the estimated regression is the long run cost curve, x_3, provides a test of the effect of excess capacity at a point in time. If the coefficient is significantly less than one, excess capacity can be said to cause annual costs to increase.

Factor prices influence production costs. For sewage treatment the most important price variable is the price of capital. Total expenditures on capital can exceed fifty percent of total costs. One measure of the price of capital goods is the regional cost of constructing similar sized plants. This information is available for each of the twenty Environmental Protection Agency districts. Actual construction costs in constant 1957-1959 dollars for each region were published in FWPCA [1968]. These costs were used to develop an index of construction costs. Current index values were obtained from the Environmental Protection Agency in unpublished form. Since the focal point is cross-sectional price differences, the regional index values can be used as the cost of capital facilities P_2, to each firm. P_2 may not be the best proxy for the price of capital. Capital expenditures are financed for long periods of time. The price of capital should account for interest differentials. Thus, an alternative measure of the price of the capital flow is P_5, where P_5 is defined as the interest rate paid to finance the capital investment multiplied by the regional index value (P_2).

In earlier chapters it was pointed out that local municipalities do not have to pay the full construction costs for wastewater treatment plants. Federal subsidies pay for a portion of the construction. To obtain a true local price of capital, P_6, multiply the percent of the total construction costs paid by the municipality times P_5. The local share is equal to one minus the federal share for the year of the last major capital improvement.

Labor costs are the second most important expenditure in terms of magnitude. The price of labor, P_1, is based on the concept of opportunity cost. A good measure of the wage rate of sewage treatment plant operators is what their wage would have been in their next best alternative. Since plant operators are skilled workers, it is felt that the wages of individuals employed in manufacturing industries are a good proxy for the opeartors' wages.

The remaining factors of production are chemicals, electricity, and maintenance. Maintenance costs are composed of labor and construction goods. Since the price of labor and the price of construction are included in the analysis, the inclusion of a price of maintenance would not improve the results. In fact it would probably decrease the predictive power since the price of maintenance would be highly correlated with the price of capital and labor. Although the production of electricity is regulated, there are cross-sectional variations in electrical rates. For a measure of electricity rates (P_3) the kilowatt hour rate for commercial firms using similar quantities of electricity will be used. The last factor of production to consider is chemicals. Although there may be some price differentials, it is felt that it will not be significant. There are relatively few producers of chemicals. Also chemicals are transported in concentrated forms, thereby reducing transportation costs.

The final variable to be defined is the dependent variable-cost. Costs for in-plant treatment (C_1) are defined as all costs of in-plant wastewater treatment including the service flow of capital as developed in Young [1974]. Costs including land treatment (C_2) are equal to C_1 plus all costs associated with land treatment, including capital flows.

Cost Regression Results

Empirical cost curves of the form developed in equation 2 are estimated by single-equation, least squares. The estimated cost functions may be divided into two groups: cost curves without land treatment and cost curves with land treatment.

Examination of cost curves will provide tests of hypotheses on returns to scale for increasing flow and for improving final quality. Comparison of cost curves when land treatment is excluded versus when it is included can be used to test the flexibility of land treatment. Based on Table 7 it is hypothesized that a higher quality of output measured as higher BOD_5 removal, can be produced at a lower cost when land treatment is included. It is also expected that the returns to increasing flow will be lower when land treatment is included. If the price variables have significant coefficients they should be accounted for in the allocative decision. Further examination of the waste treatment process will require a closer examination of the allocative and technical decisions.

Estimates of the cost equations are presented in Table 8 and Appendix B. Table 8 presents five of the estimated cost equations. Appendix B presents all of the cost regressions. Equations 1-4 in Table 8 are equations B1, B14a, and b, B6 and B17 respectively in Appendix B.

The estimation procedure for the land treatment regressions (equation 4 in Table 8) included land treatment as an alternative. The regression included land treatment sites and conventional plants as observations points. Costs for land treatment sites included only those costs incurred by the municipality (C_2). If the effluent was given away or sold, the costs incurred by the recipient were not included. Revenue from the sale of crops or the effluent was not deducted from the costs. Therefore, the cost curves which were estimated are probably a high estimate of the <u>net costs</u> of building and operating a land treatment site. The estimated cost curves give an indication of the direction of the influence on costs from using land treatment.

The cost equations were estimated from cross-sectional survey data. When cross-sectional data are used, there exists a tendency for the error term to be heteroscedastic (i.e., a non-constant variance). A test to determine if

Table 8. Estimated cost equations[a]

Independent variables		Total cost				
		Without land				With land
		C_1	C_1	C_1	C_1	C_2
Equation number		1	2a[b]	2b[b]	3	4
Constant		7.7533	10.1153	4.3511	7.8962	7.8661
		(5.0217)	(4.6820)	(2.1278)	(4.4998)	(4.9570)
Flow	x_1	0.8304	0.8968	0.7073	0.7242	0.8302
		(18.8529)	(15.8338)	(9.9579)	(12.7344)	(18.3206)
Internal percent BOD_5 removal	x_2				0.2120	
					(1.3607)	
Proportion of capacity utilized	x_3	-0.3465	-0.2982	-0.5018	-0.1928	-0.3392
		(-2.2952)	(-1.3024)	(-2.8594)	(-1.2498)	(-2.2258)
Age of capital	x_4				-0.1067	
					(-1.6305	
Industrial wastes	x_5				0.0824	
					(1.6137)	
Final inplant BOD	x_{10}	-0.1478	-0.1527	-0.3077		
		(-2.1597)	(-1.1593)	(-1.6630)		
Final BOD after land treatment	x_{12}					-0.0906
						(-1.5127)
Price of labor	P_1	0.6664	0.4041	1.1658	0.8264	0.6600
		(2.4417)	(1.0114)	(3.3617)	(2.9421)	(2.3954)
Price of electricity	P_3	0.2362	-0.5144	0.9846	0.1606	0.1105
		(0.5236)	(-0.7608)	(1.8218)	(0.1594)	(0.2420)
Price of capital (excluding subsidy)	P_5	0.4144	0.2260	0.7674	0.4078	0.3880
		(1.8249	(0.6964)	(2.7063)	(1.6869)	(1.6782)
Sample size		125	73	52	125	125
R^2		0.7818	0.7608	0.7505	0.7684	0.7772

[a] Values in parenthesis are t values for test of significance from zero.

[b] Equation 2a was estimated using only those observations with less than 90 percent inplant BOD_5 removal. Equation 2b was estimated using only those observations with greater than or equal to 90 percent inplant BOD_5 removal.

the data exhibit heteroscedasticity was made by plotting the estimated residuals against the predicted values of the dependent variable for equation 1 in Table 8. The plot is presented as Figure 1 in Appendix C. Since no systematic increase in scatter occurred as size increased, heteroscedasticity was assumed not to exist.

Examination of Table 8 shows that all variables have the expected signs except for x_4. It was hypothesized that capital age would have a positive coefficient. The negative coefficient may be a result of the specification of the time distribution of capital service flow. This hypothesis was tested by estimating an equation B12 assuming a constant service flow of capital over the life of the facility. The coefficient of x_4 in B12 was -0.0569 (t = 1.09). Therefore, it is concluded that regardless of assumptions about the rate of obsolescense and physical depreciation, older capital, in and of itself, does not increase costs.

In each of the five equations in Table 8 the coefficient of flow, x_1, is positive and significantly greater than zero. The economies of scale hypothesis was tested for equation 1. The t value for the test that the coefficient, 0.8304, is significantly less than one was t = 3.8514. The coefficient is significantly less than one at the 1 percent level of significance. Therefore, it can be concluded that economies of scale exist for increasing the flow through the plant. A 10 percent increase in flow results in an 8.304 percent increase in cost. This result concurs with the engineering estimates presented in Table 7. Note that returns to scale are higher for high BOD removal facilities than low ones in 2b and 2a, respectively.

The final concentration of wastes is preferred as the quality measure. Of the BOD_5 variables representing the level or quality of treatment, the coefficient of the final concentration of BOD_5 after in-plant and land treatment (x_{10} and x_{12}) proved significantly different from zero. Final concentrations of wastes are preferred since they provide a more concise description of the effect on the environment.

The coefficient of percent BOD_5 removal was hypothesized to be greater than one. The low value of the coefficient of x_2 in equation 3, 0.2120, may have resulted from the limited portion of the data which had a high percent removal. The hypothesis of decreasing returns to increasing x_2 was tested by dividing the data into two groups: $X_2 \geq .9$ and $X_2 < .9$. These results are presented in Appendix B equation B13. The coefficient of x_2 when $X_2 < .9$ was 0.1464 and the coefficient of X_2 when $X_2 \geq .9$ was 1.2400. Although neither coefficient was significant, the results do indicate that costs may increase at an increasing rate as the percent BOD removed increases.

The effect of land treatment on costs can be examined by comparing equations 1 and 4. The coefficients of the final concentration of BOD_5 (x_{10} and x_{12}) appear to be the only differences between the non-land and land treatment cost curves.

The coefficient of the final BOD_5 concentration after in-plant treatment (x_{10}) in equation 1 is -0.1478 and the coefficient of x_{12} the final BOD_5 concentration including land treatment (x_{12}) in equation 4 is -0.0906. Although no statistical test of the differences was made it does appear that reducing the final concentration of BOD_5 using land treatment causes costs to increase less. For example a 10 percent decrease of BOD_5 causes costs to increase 0.906 percent using land treatment versus a 1.478 percent increase using conventional treatment.

The coefficient of the capacity utilization variable, x_3, was negative and significantly different from zero at the five percent level in equations 1, 2b and 4. Unused capacity is costly in terms of total costs. A 10 percent decrease in capacity utilization results in a 3.5 percent increase in costs.

The effect of industrial wastes was small. The coefficient of x_5 in equation 3 was 0.0824 which was not significantly different from zero at the five percent level.

The coefficients of the prices of labor and capital had the expected signs. The sign of the coefficient of the price of electricity, p_3, fluctuated from positive to negative among regressions and was not significantly different from zero except for high levels of BOD_5 removal in equation 2b. The coefficient of p_1, the price of labor, was significant at the 5 percent level. The coefficient of the price of capital is significant at the .1 percent level or higher in each of the equations except for low level BOD removal facilities (equation 2a).

Five major conclusions can be drawn from the empirical cost analysis. Prices do influence treatment costs. Excess capacity increases costs. There are returns to scale to increasing flow. Increasing the level of BOD_5 removal causes costs to increase at an increasing rate. Finally, costs of removing BOD_5 are decreased by using land treatment versus conventional in-plant treatment.

Production and Efficiency

The production of wastewater treatment services can be examined by direct estimation of the production function. A "production function ... presupposes technical efficiency and states the maximum output obtainable from every possible input combination" for a given time period. The best utilization of any input combination is a technical problem not an economic problem. The selection of the best input combination for the production of a particular output level depends upon input and output prices and is the subject of economic analysis. [Henderson and Quandt, 1958, p. 44].

There are two ways to estimate the production function as it appears in equation (1). The most obvious way is to use ordinary least squares. A second way is presented in the next section on measuring efficiency. The technique is to estimate a "frontier" production function. The remainder of this section on production and efficiency will examine the first order conditions for optimizing output per dollar of the inputs used.

Measuring Efficiency

Much of economic theory is concerned with the efficient allocation and transformation of scarce resources. Most analysis concentrates on the value of the marginal products of factors not being equal to their marginal factor costs. If they are unequal, the allocative decision is said to be inefficient. The second type of failure is the failure to produce the greatest possible output with the set of inputs used. A firm is said to be technically efficient if it operates on the production function, where the production function is defined as the maximum product which can be produced with the combinations of factors used.

The goal of this portion of the analysis is to examine the internal decisions of the plants. Are resources being used inefficiently in either an allocative or a technical sense? Because of the high initial costs and the slow rate of technical change it is felt that most of the inefficiency will result from allocative sources rather than from technical sources. A comparison of the relative efficiencies will provide a test of this hypothesis. The effect of federal subsidies on the allocative efficiency can be tested. A comparison of the allocative efficiency measures when the price of capital is adjusted for federal subsidies versus when the price of capital is unadjusted will provide a test of the hypothesis. The effect of land treatment can be analyzed by comparing efficiency ratings when the production function includes land treatment and when it does not. Because of the increased flexibility of land treatment it is hypothesized that efficiency ratings will be higher when land treatment is included. This is expected to be especially true for allocative efficiency.

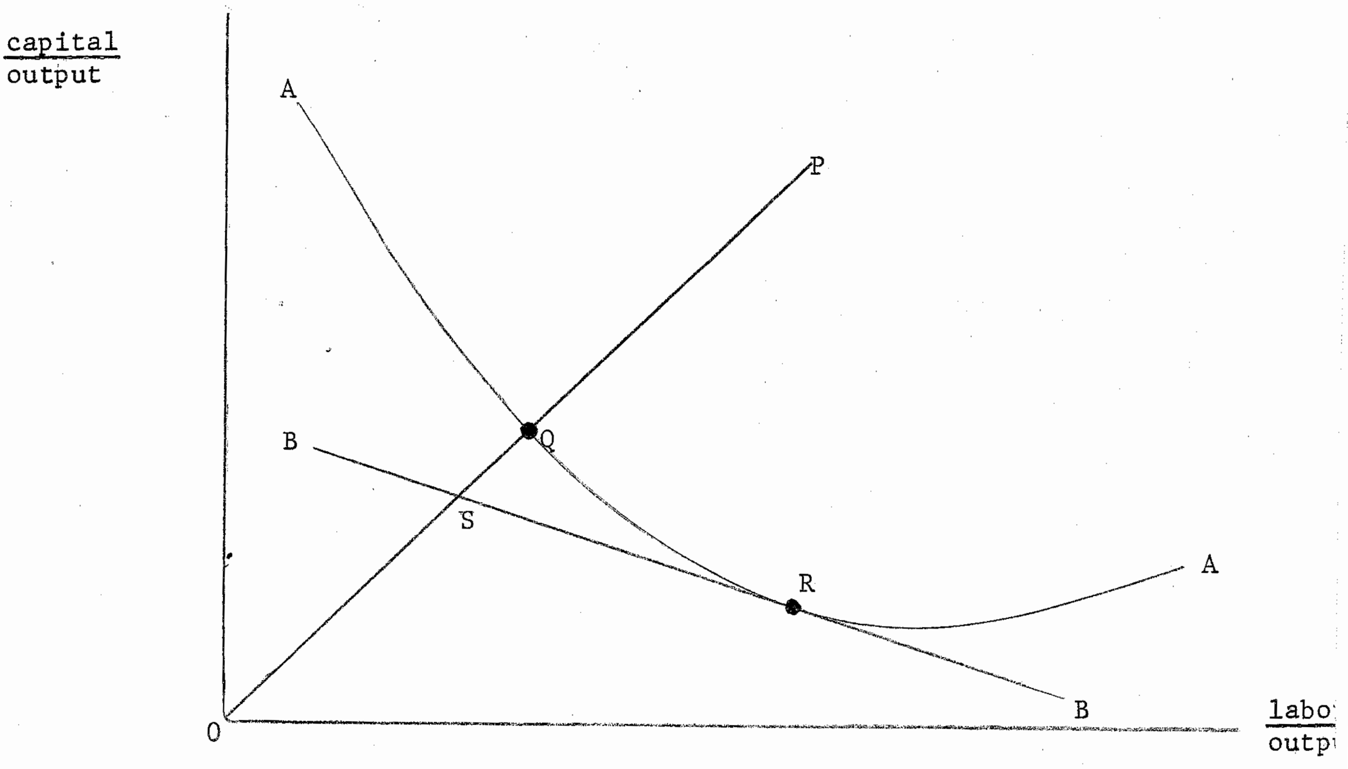
Efficiency Model

This section reviews and slightly modified a model developed by Farrell [1957] and extended by Farrell and Fieldhouse [1962], Seitz [1970], and Timmer

[1971, 1970]. Following Farrell [1957] for the moment, assume that the production function is linear homogenous. This production function can be expressed in the form of a "unit" isoquant. A unit isoquant is a locus of points indicating the minimum quantities of factors of production necessary to produce one unit of output as factor proportions change.

Let the curve AA in Figure 2 be the unit isoquant. Any firm operating on curve AA is said to be technically efficient (TE). Any firm using more than the minimum quantities of factors necessary per unit of output is inefficient. Both firm Q and firm R are 100 percent technically efficient. Firm P is inefficient and the ratio $\frac{OQ}{OP}$ measures the degree of technical inefficiency.

Figure 2. Measurement of efficiency with a unit isoquant



To obtain a measure of price efficiency (PE), let BB represent the relative factor price line facing the firms. Note that only a firm operating at point R is both price and technically efficient. Although firm Q is technically efficient it is not price efficient. The degree of its inefficiency is measured by the ratio $\frac{OS}{OQ}$. Similarly firm P's price inefficiency is measured by the ratio $\frac{OS}{OQ}$. Both firm Q and firm P have the same price efficiency. Firm Q is more efficient in an overall sense since it is more technically efficient. A measure of the overall allocative or economic efficiency (EE) of firm P is $\frac{OS}{OP}$. Firm Q's EE is measured by $\frac{OS}{OQ}$. Economic efficiency which is the ratio of minimum to actual unit costs is the product of technical and price efficiency [$EE_P = \frac{OS}{OP} = TE_P \cdot PE_P = \frac{OQ}{OP} \cdot \frac{OS}{OQ}$]. Thus, by using Farrell's technique it is possible to go beyond the simple cost comparisons of the previous section.

It is not necessary to assume linear homogenous production functions to apply this model. The cost of relaxing the assumption of linear homogeneity is that the functional form must be specified. For the analysis the production function will be specified as a generalized, Cobb-Douglas production function:

$$Q_1 = \alpha_o Q_2^{\alpha_1} \prod_{i=0}^{n} I_i^{\beta_i} \qquad (3)$$

It is easier to estimate this function in input-output space rather than in input-input space as Farrell did. The frontier production fucntion can be estimated with a linear programming model. For a description of the technique used see Timmer [1970, 1971] and Young [1974].

Production Variables

A production function is a relationship between output and inputs. A production function of the form developed in equation 3 will be estimated. The outputs Q_1 and Q_2 will be measured in the same manner in which they were measured for the cost analysis. The quantity measure will be X_1. Measurement of quality, Q_2, will be limited to final concentration after inplant treatment (X_{10}) and final concentration allowing for land treatment (X_{12}) depending upon whether or not land treatment is to be included in the analysis. It will be assumed that there are three inputs used in the production process: labor, capital, and other. Labor, L, will be defined as annual labor expenditures divided by the price of labor. Capital, C, will be defined as the annual service flow of capital divided by the price of capital, P_5. All other expenditures will be lumped into one variable called other, O_2, with a relative price of one.

Efficiency Results

The Timmer model shown in Young [1974], Appendix C was used to estimate frontier production functions. Equations 1 and 2 in Table 9 are the frontier production functions. Equation 1 is for in-plant treatment only while equation 2 includes inputs used for land treatment. Equations 3 and 4 are least squares production functions which will be used for comparison purposes in the following section. From the production functions, efficiency ratings can be calculated.

The efficiency ratings were computed by the procedure developed in Young [1974]. To calculate price and economic efficiency indicies, P_1

Table 9. Estimated production functions[a]

	Estimation procedure			
	Frontier		Least squares	
	Alternatives included			
	Without land treatment	With land treatment	Without land treatment	With land treatment
Independent variables	x_1	x_1	x_1	x_1
	1	2	3[b]	4
Constant	-6.219	-6.808	-7.339 (-13.963)	-7.113 (-14.090)
Labor	0.299	0.433	0.603 (5.945)	0.578 (5.629)
Capital	0.105	0.130	0.093 (3.347)	0.090 (3.246)
Other	0.480	0.359	0.189 (2.058)	0.214 (2.326)
BOD_5 concentration after inplant treatment	0.094		0.198 (2.653)	
BOD_5 concentration allowing for land treatment		0.233		0.141 (2.200)
$\bar{R}^2$			0.746	0.744

[a] Values in parentheses are t values for the test of significance from zero. Statistical tests cannot be performed on the frontier production functions because of the estimation technique.

[b] The t value for 5 percent level of significance and 125 d.g. is 1.98.

was used as the price of labor, and $P_0 = 1$ was used in the price of other. Two sets of efficiency indexes were calculated to examine the effect of capital subsidies. The price of capital not adjusted for federal subsidies, P_5, and the price of capital adjusted for federal subsidies, P_6, were used.

To test the difference between the efficiency ratings, tests of paired differences were used. The pairings was done within plants. Table 10 presents the t values for inter-production function comparisons. In all cases both PE and TE are significantly greater than EE. A comparison between technical and price efficiency will help to identify the cause of the apparent low level of economic efficiency. When land treatment is not included the difference between TE and PE is significant at the 5 percent level. When land treatment is included the differences are not significant. This indicates that land treatment plants may have adjusted their input use for relative price differences.

Table 11 presents the intra-production function comparisons. Technical efficiency ratings do not change significantly when land treatment is used. When land treatment is used the price efficiency ratings are significantly different from when it is not used ($t_{(PE_2 - PE_1)} = 16.5781$ and $t_{(PE_4 - PE_3)} = 17.0085$). Therefore, it can be concluded that the use of land treatment increased the plant's ability to respond to relative price changes. Land treatment processes can alter their factor mixes easier than conventional wastewater treatment plants. Since the TE rating differences are not significant the PE rating differences can be said to account for the EE differences, because by definition EE = PE x TE.

The efficiency ratings were calculated using the price of capital adjusted for federal subsidies to see if the specifications of the price of capital

Table 10. T values of the differences between inter-production function efficiency estimates[a]

	Price of capital	TE - PE	TE - EE	PE - EE
Non-land	P_5	3.1811	10.7998	11.4480
With land	P_5	1.8496	7.3921	11.4879
Non-land	P_6	2.4501	10.4499	11.9584
With land	P_6	1.2171	7.0826	11.8902

[a] t value for 5 percent level of significance and 125 d.f. is 1.98.

Table 11. T values of the differences between intra-production function efficiency estimates[a]

	Price of capital	TE	PE	EE
With land - Non-land	P_5	1.0800	16.5781	6.0208
With land - Non-land	P_6	1.0800	17.0085	6.0277
Non-land - Non-land	$P_6 - P_5$	0	10.6501	7.8382
With land - With land	$P_6 - P_5$	0	10.5551	7.7133

[a] t value for 5 percent level of significance and 125 d.f. is 1.98.

caused the apparent price inefficiency. The t value of the test for PE differences when the price of capital is P_6 versus P_5 is approximately 10.6. Price efficiency does increase significantly when P_6 is used as the price of capital. Note that when land treatment is not used that TE - PE is still significantly different in Table 10. Adjustment for the subsidized price of capital does not eliminate the difference between TE and PE for conventional waste water treatment.

Marginal Conditions

Based on the results of the efficiency analysis it can be concluded that there is some evidence of allocative inefficiency in wastewater treatment. If a plant is described as economically inefficient by the definitions and estimates of the previous section, how can input usage be altered to improve its efficiency? Economic theory argues that all rational firm operations will alter input usage until all ratios of marginal productivities divided by input prices are equal. If $\frac{MP_1}{P_1} > \frac{MP_2}{P_2}$, more of the first input and less of the second input should be used. This should continue until the marginal contribution to output of the last dollar expended on each input is equal.

The hypothesis concerning utilization of capital for land and non-land treatment systems can be explicitly tested by comparing the marginal productivity of capital per dollar of capital for the two systems. The influence of federal subsidies on local decisions of type of treatment system adopted can be tested by comparing the marginal product per dollar of capital when the price of capital is adjusted for the subsidy versus when it is not.

Empirical Evaluation of the Marginal Conditions

To investigate the cause of the inefficiency the marginal productivities per dollar of each input were estimated for equations 1, 2, 3 and 4 in Table 9. A brief investigation of the marginal productivities per dollar shows that the marginal products per dollar of the capital input are less than the marginal products per dollar of the other two inputs (labor and other) for each plant. This supports the earlier hypothesis that wastewater treatment plants have excess capital.

The significance of the differences between the marginal conditions was tested using t tests of paired differences. Table 12 presents the results of the t tests. In all of the equations the marginal productivities per dollar of capital were significantly less at the 1 percent level than the marginal productivities per dollar of either labor or other inputs. This conclusion holds even when the adjusted price of capital (P_6) is used. The differences between the marginal products per dollar of labor and the marginal products per dollar of the other inputs were also tested. When the ordinary least squares equations (equations 3 and 4 in table 9) were used the marginal productivity per dollar of labor was significantly greater than the marginal productivities per dollar of other inputs. When the non-land, frontier production function (equation 1, table 9) was used the marginal productivity per dollar of other inputs was significantly greater than the marginal productivity per dollar of labor. When the land treatment frontier production function (equation 2, table 9) was used the difference between the marginal productivity per dollar of labor and the marginal productivity per dollar of other inputs was not significant.

Table 12. t tests of the differences between the marginal conditions for the equations in Table 9[a]

Differences	Equation 1	Equation 2	Equation 3	Equation 4
$\frac{MP_{Labor}}{P_1} - \frac{MP_{other}}{P_{other}}$	-5.2958	-1.1629	3.0723	3.0534
$\frac{MP_{Labor}}{P_1} - \frac{MP_{capital}}{P_5}$	4.8157	5.7244	5.0220	5.9058
$\frac{MP_{Labor}}{P_1} - \frac{MP_{capital}}{P_6}$	4.7340	5.6400	4.9868	5.8625
$\frac{MP_{other}}{P_{other}} - \frac{MP_{capital}}{P_5}$	10.6175	10.2912	10.1212	10.1991
$\frac{MP_{other}}{P_{other}} - \frac{MP_{capital}}{P_6}$	10.4371	10.1543	9.9295	10.0361
$\frac{MP_{capital}}{P_6} - \frac{MP_{capital}}{P_5}$	6.0915	5.9961	6.0915	5.9961

[a] t value for 5 percent level of significance and 125 d.f. is 1.98.

From the t tests on the marginal conditions, it can be concluded that the sampled wastewater treatment plants should increase the amounts of labor and other inputs used relative to the amount of capital used. No definite conclusions can be drawn regarding the labor-other input mix.

In an effort to determine if flow variation is the cause of the apparent overuse of capital the residual (predicted X_1 - actual X_1) from equation 1 in Table 8 was compared with a measure of the variability of flow. The measure of flow variability chosen was highest daily flow divided by average daily flow. Questionnaire data on high daily flow was available for 86 of the plants. Equation 4 presents results of this regression:

$$\text{Ln}\ (\hat{X}_1 - X_1) = \underset{(6.34456)}{1.7022} - \underset{(-0.1239)}{0.0662}\ \text{Ln}\ \frac{\text{high daily flow}}{\text{average daily flow}} . \qquad (4)$$

$$R^2 = 0.0002$$

These results do not support the hypothesis that designing for actual variation in flow is the cause of the overuse of capital. However, this is not a conclusive test of the effect of flow variability; it is conceivable that some of the excess capacity is to account for flow variations.

Demand for Land Treatment

The results from the cost and efficiency analysis indicate that land treatment is a viable alternative as a wastewater treatment technique. Since the major objective of this analysis is to examine land treatment as an alternative technique for sewage treatment, the analysis will be extended to examine the conditions under which municipalities are most likely to adopt land treatment.

Theoretical Demand Function

The derived demand for an input can be obtained by use of constrained minimization of costs. Young [1974] developes a derived demand for land treatment including by-product production of the form shown in equation 5.

$$I_L = HQ_1^{h_1} Q_2^{h_2} P_B^{h_3} P_I^{h_4} P_2^{h_5} S_L^{h_6} \tag{5}$$

where: H = constant

h_i = estimatable parameters

$X_1 = Q_1$ = quantity of wastes treated

$X_{12} = Q_2$ = vector of levels or quality of treatment

P_B = by-product price

P_I = price conventional treatment

P_2 = price of land treatment

S_L = outside influences on the use of land treatment

I_L can be thought of as a probability of a particular plant using land treatment. In the long run the probability of adoption can be explained by relative prices and environmental variables. It is expected that land treatment is not subject to the high degree of increasing returns to scale for increasing flow that in-plant processes are. Therefore, it is expected that the smaller the municipality, the more likely it is that land treatment will be used. If land treatment can obtain high levels of treatment at lower costs than in-plant treatment processes, higher quality constraint will induce adoption of land treatment. Also, as the output or by-product such as irrigation waters becomes more valuable the use of land treatment is expected to increase.

Specification of the Variables

The probability of land treatment services being adopted can be specified whether or not a plant uses land treatment. To do this a dummy variable model is used. When a dummy variable is used as a dependent variable, the predicted values from the regression equation are the estimated probabilities of the process being used. The dummy variable YDUM can be specified as:

$$\text{YDUM} = \begin{cases} 0 \text{ if the plant does not use land treatment} \\ 1 \text{ if the plant uses land treatment.} \end{cases}$$

An equation using a dummy variable as a dependent variable can be estimated as a log-linear probability function or as a non-linear probability function. Young [1974] discusses the merits of both forms. He concludes that the non-linear method is preferable since it limits the range of the probability estimates to the 0 - 1 range.

The functional form of the probability regressions for land treatment is shown in equation 5. The probability of using land treatment is a function of its price. The major input in land treatment is land. Therefore, as the price of land, PAG, increases the demand for land treatment should fall. The price of land will be measured as the average price of agricultural land in the county that the plant is located.[13]

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[13] It is felt that agricultural land represents the type of land that municipalities will have to compete for to construct land treatment sites. Land treatment sites will be built on the urban fringe. For large cities where agricultural interests must compete with industrial and development interests the county value will reflect the higher opportunity value of the land.

The measures of the quantity and quality of output and the prices of in-plant inputs will remain as previously defined. As flow through the plant, X_1, increases the probability of land treatment is expected to fall. This will reflect the lower degree of returns to scale to increasing the flow associated with land treatment. The measure of the treatment level will be the final concentration of BOD_5 after land treatment, X_{12}. It is anticipated that as the required level of treatment increases (i.e., X_{12} falls) the use for land treatment will increase. In-plant treatment is a substitute for land treatment, therefore, the higher the price of in-plant treatment (mainly capital) the higher the probability of use of land treatment. The price of labor and electricity are exceptions because land treatment is a relatively labor and electrical intensive process. Labor and electricity are expected to be complementary to land treatment.

When land treatment of wastewater is used, a salable by-product is generated. This salable by-produce is water for irrigation. As the demand for irrigation increases as reflected in its price (PIR), the probability of using land treatment is expected to increase.

There are four additional variables which are anticipated to influence the use of land treatment. These variables are river flow (RF), population density (PD), temperature (T), and rainfall (R). Required BOD_5 removal is not independent from the plant location. It is hypothesized that as amount of water available for dilution (RF) increases, the regulatory agency's determination of required level of BOD_5 removal falls.[14] Stream dilution

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[14] For those plants located near oceans river flows was assumed to equal 150,000 cfs. While oceans have extremely large quantities of water, they are relatively stagnant at points. An ocean discharge can cause pollution in portions of the ocean (see EPA, 1973).

and cleansing is a substitute for in-plant BOD_5 removal. Because of potential odors and health hazards, land treatment is expected to be less prevalent in densely populated areas (PD). The remaining influences on the demand for land treatment are climatic variables: annual rainfall, R, and average temperature, T. As annual rainfall increases the soil is more likely to contain a higher moisture content. As temperature increases the moisture content of the soil decreases and the productivity of land decomposition of wastes will increase. As the moisture content of the soil rises, less water can be applied on an annual basis.[15] This decreases the probability of using land application of wastewaters.

Empirical Probability Regressions

Two probability regressions for land treatment were estimated. The regression results are presented in Table 13. Equation 1 inTable 13 is a linear probability function not adjusted for heteroscedasticity. All of the variables have the hypothesized signs except for population density. The R^2 in equation 1 is low. The best estimate of the demand for land treatment is equation 2. Equation 2 was estimated using non-linear regression. The method used was developed by Gallant [1973].[16] Generalized least squares estimates of equations 1 and 2 were not reported because they produce high instability with this approach. The zero-one nature of the dependent variable caused some of the weights to become prohibitively high. Figures 2 and 3 in Appendix C show the residuals plotted

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[15] Also in those areas subject to severe freezing winter temperatures, winter storage of the effluent will be required.

[16] The parameters from equation 1 in Table 13 were used as the start values for the non-linear estimation procedure.

Table 13. Estimated probability regressions for land treatment[a]

Independent Variable		Use of Land Treatment Y DUM	
Equation Number		Log Linear	Non Linear
		1	2
Constant		-1.7222 (-0.6436)	-6.1398 (-0.6591)[-0.5053]
Flow	x_1	-0.0152 (-0.5447)	-0.0773 (-0.7872)[-0.6076]
Final BOD_5 level	x_{12}	-0.0824 (-2.2942)	-0.4995 (-3.0519)[-2.5114]
Price of labor	P_1	-0.1758 (-0.8866)	-0.8921 (-1.2731)[-1.0061]
Price of capital	P_5	+0.1541 (1.0890)	0.4368 (0.7622)[0.6035]
Price of electricity	P_3	-0.3871 (-1.3162)	
Price of land	pag	-0.0493 (-0.8940)	-0.0227 (-0.1403)[0.1084]
Price of irrigation	pir	0.0226 (2.0854)	0.0897 (1.8041)[1.4922]
Population density	pd	0.0450 (1.0235)	
Average July temp.	t	0.6098 (1.1286)	$1.\overset{8}{\cancel{7}}147$ (0.9322)[0.7220]
Annual rainfall	r	-0.1634 (-2.4411)	-0.5488 (-2.3910)[-1.8656]
River flow	rf	-0.0200 (2.5333)	-0.0612 (-1.9780)[-1.6399]
R^2		0.3708	
SSE		18.7462	(18.5534)
Variance		0.1659	(0.1472)
Sample size		125	125

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[a] Values in parenthesis are Z values. The bracketed values for the non-linear equation are Z statistics computed by using standard errors corrected for heterocedasticity.

against the predicted values for equation 1 and 2 in Table 13. The estimates not using generalized least squares will be accepted because of the unrealistic nature of the generalized least squares estimates.

All coefficients in the non-linear model had the hypothesized signs. Equation 2 is a better fit than equation 1. The SSE of equation 2 is lower. The non-linear results are preferred because the probability estimates are bounded by zero and one. The coefficients of the level of treatment, x_{12}, average rainfall, r, price of irrigation, pir, and river flow, rf, are significantly different from zero at the .05 or lower level of probability.

The most important result from the empirical estimation is that as the restriction on final emissions increases, the demand for land treatment increases. A 10% decrease in allowable emissions will increase the standardized cumulative normal variate for land treatment by almost 5 percent.

The conclusion that land prices do not affect the use of land treatment was unexpected. The results from equation 2 indicate that the price of land exerts no significant influence on the use of land treatment. A possible explanation of this result is that park land, greenways, and golf courses can be used for wastewater irrigation. These are high valued pieces of land which tend to have their value increases as a result of the irrigation. In addition, land need not be purchased to obtain rights to use of it for treating sewerage effluents (see Table 3).

The prices of labor and the salable by-product performed better than the two other prices. As the irrigation price increases in value, the advantages for recycling are greater. The results from the non-linear model tend to support the hypotheses on conventional inputs at low significance levels. Labor and electricity are complementary to land, while capital is a substitute.

Environmental conditions appear to exert significant influences on the land treatment decision. The coefficients of average rainfall and river flow are significantly different from zero at the .05 level of significance. Areas with relatively more water (rainfall and/or river flow) are less likely to have land treatment sites.

The magnitudes of the various economic and environmental forces on land treatment adoption is examined by using estimated coefficients to predict land treatment adoption.

Predictions for Land Treatment in the Southeast

This section will proceed by examining the conditions surrounding the demand for land treatment in the Southeast and the costs associated with wastewater treatment. The purpose is to determine under what price conditions land treatment technology might be accepted. The analysis will be made for a small city serving approximately 10,000 people located in North Carolina. The analysis will assume that the city has a wastewater treatment plant capable of 40% BOD_5 removal. The city is under state and federal orders to increase BOD_5 removal to at least 95 percent. How will the city respond in light of the results presented in this analysis?

Demand for Land Treatment

The probability that the city will currently be using land treatment can be calculated using equation 2 from Table 13. A plant treating the wastes for 10,000 people is assumed to have an average flow of 1 mgd. A 40% BOD_5 removal rate indicates that the average daily emission level will be 90 mg/l. Assume that the city has a river with a flow of 1000 cfs available for disposal of its wastes. The remaining data for Wake County, North Carolina are:

Price of labor = \$3.80
Price of capital = \$1190
Price of land = \$500
Price of irrigation = \$0
Average July temperature = 88
Annual rainfall 43

Using the coefficient from equation 2 in Table 13 the estimated standard normal deviate of the plant using land treatment is:

$$-6.1398 - 0.0773\,[\ln(X_1 = 1)] - 0.4995\,[\ln(X_{12} = 90)] - 0.8921\,[\ln(p_1 = 3.80)] + 0.4386\,[\ln(p_5 = 1190)] - 0.0277\,[\ln(pag = 500)] + 0.0897\,[\ln(pir = 0)] + 1.7147\,(\ln(t = 88)] - 0.5488\,[\ln(r = 43)] - 0.0612\,[\ln(rf = 1000)] = YDUM = -\,2.04.$$

From a cumulative normal table, if the standard normal deviate is -2.04 the probability is 0.02; which is the estimated probability of the plant presently using land treatment.

Figure 3 shows how the estimated probability of using land treatment changes as the percentage of BOD_5 removal varies from 50 to 99 percent, and as irrigation price rises from $0 to $10 per acre foot. Figure 3 was developed from equation 2 in Table 13 using the assumptions for our 1 mgd plant in Wake County, North Carolina.

If the plant must increase the level of treatment to 90%, the probability that it will use land treatment (from Figure 3) rises to 0.21. Wastewater irrigation produces a salable by-product -- agricultural crops. Not irrigating with the wastewater has an opportunity cost in terms of lost revenue associated with it. This opportunity cost can be thought of as an increase in the price of irrigation. If it is assumed that the value in terms of increase crop yields of the water for irrigation is $5 per acre foot, the probability of the plant using land treatment rises to .48. Figure 3 illustrates that as the percent removal increases the probability of land treatment being used increases at an increasing rate. The probability of a plant using land treatment doubles as the value of irrigation goes from zero to five dollars per acre foot.

The effect of river flow also can be plotted. Figure 4 shows how the probability changes as river flow varies. Note that a large increase in river flow does not result in a large decrease in the probability of land treatment. The effect of river flow is considerably higher at extremely low river flows (< 1000). As river flow approaches low levels the probability of land treatment increases at an increasing rate.

This example has illustrated that as the degree of treatment and the value of the foregone alternative increases, the use of land treatment will increase in the Southern United States.

Figure 3. Probabilities of using land treatment for varying percentage BOD_5 removals for three irrigation prices

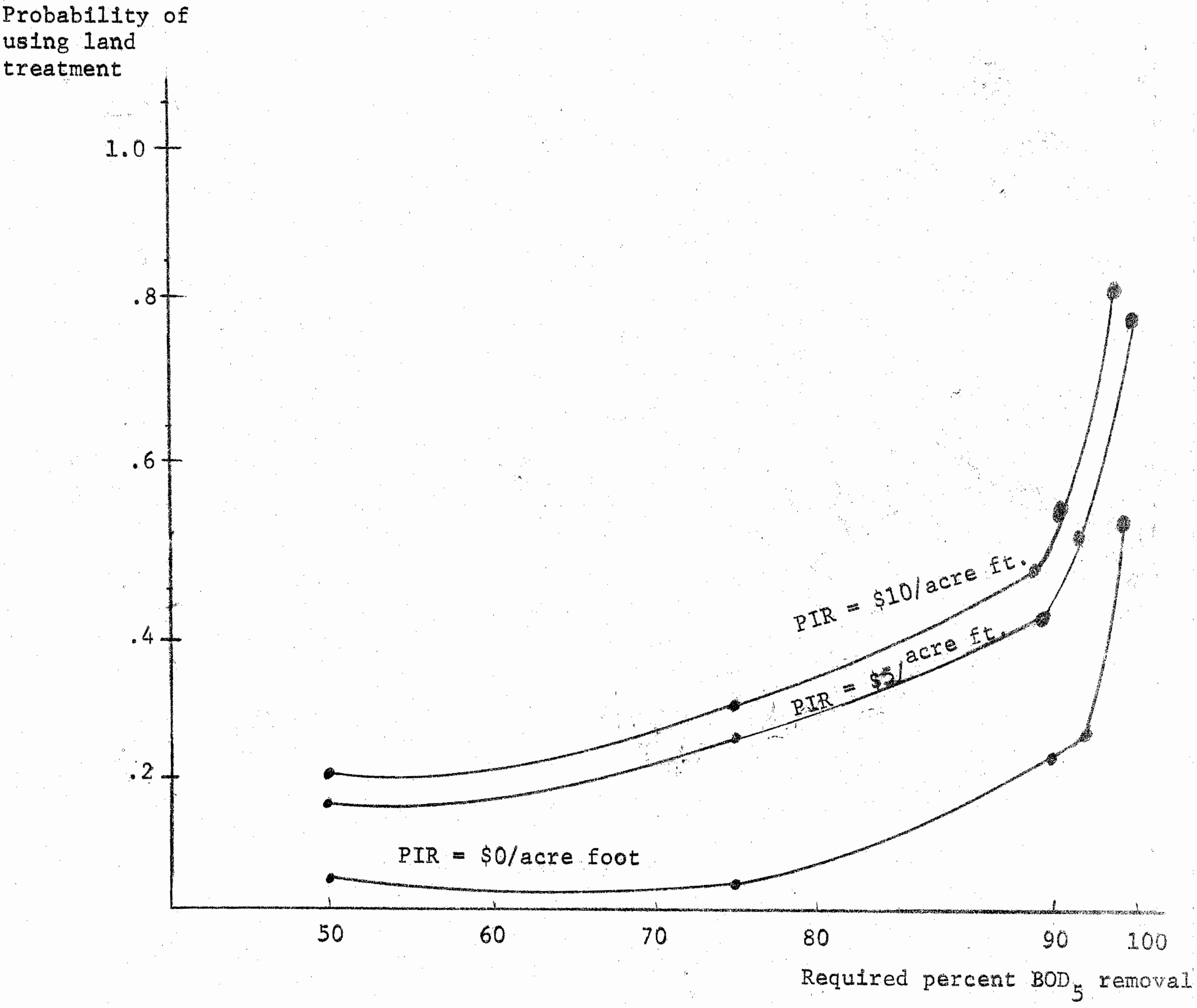
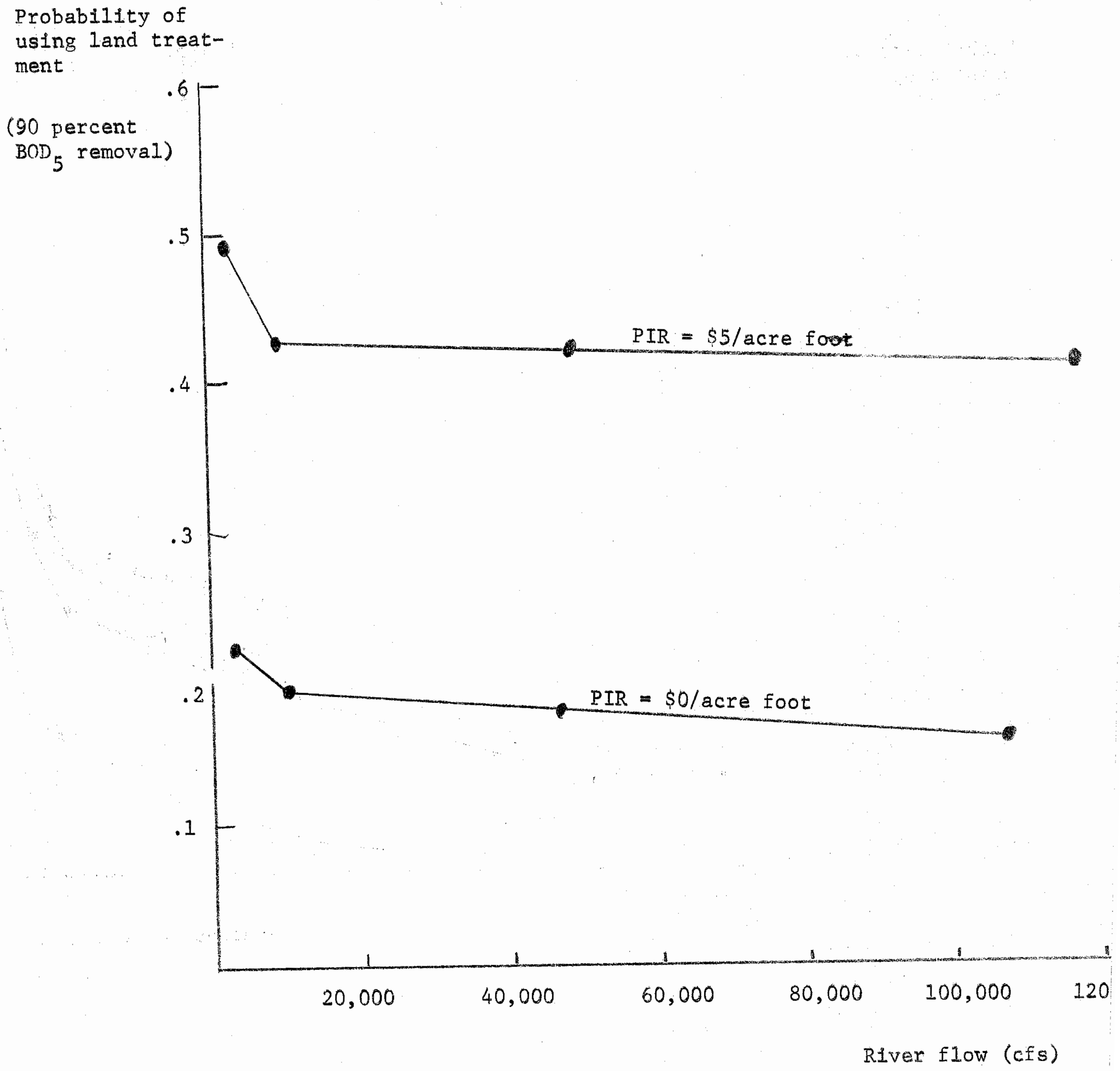


Figure 4. Probabilities of using land treatment for various river flows.



Cost of Land Treatment

The remainder of this section will examine the costs associated with operating a 1 mgd plant capable of attaining a required 95% level of treatment.

Estimated of the costs for the plant with and without land treatment to reach 95% BOD_5 removal can be obtained using equation 2b from Table 8 and equation B22b from Appendix B.[17] For Wake County, North Carolina the price of electricity is $12/750 kilowatt hours. Assume that the plant is operating at 90% of designed capacity, the excess capacity being saved for emergencies and population growth. To build a new conventional 1 mgd plant capable of 95% BOD removal would cost $610,742/year (based on equation 2b in Table 8). Equations 2b and B22b can be used to calculate the costs of building a new plant capable of 95% BOD_5 removal using inplant and land treatment respectively. The cost of the new plant including land treatment are $462,400 per year. The least expensive alternative open to the municipality is to build a land treatment site.[18]

Similar calculations have been made for a .5 mgd plant, a 5 mgd plant and 10 mgd plant at 75%, 85% and 95% BOD_5 removal. The results of these calculations are shown in Table 14 in terms of total and average costs. A better view of Table 14 can be obtained by plotting the average costs

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[17] The equations used in this analysis were chosen to account for the fact that costs increase at faster rate after 90% BOD_5 removal.

[18] This assumes that the land treatment is sufficient to preclude health hazards associated with land treatment.

Table 14. Total and average annual treatment costs for a city in Wake County, North Carolina

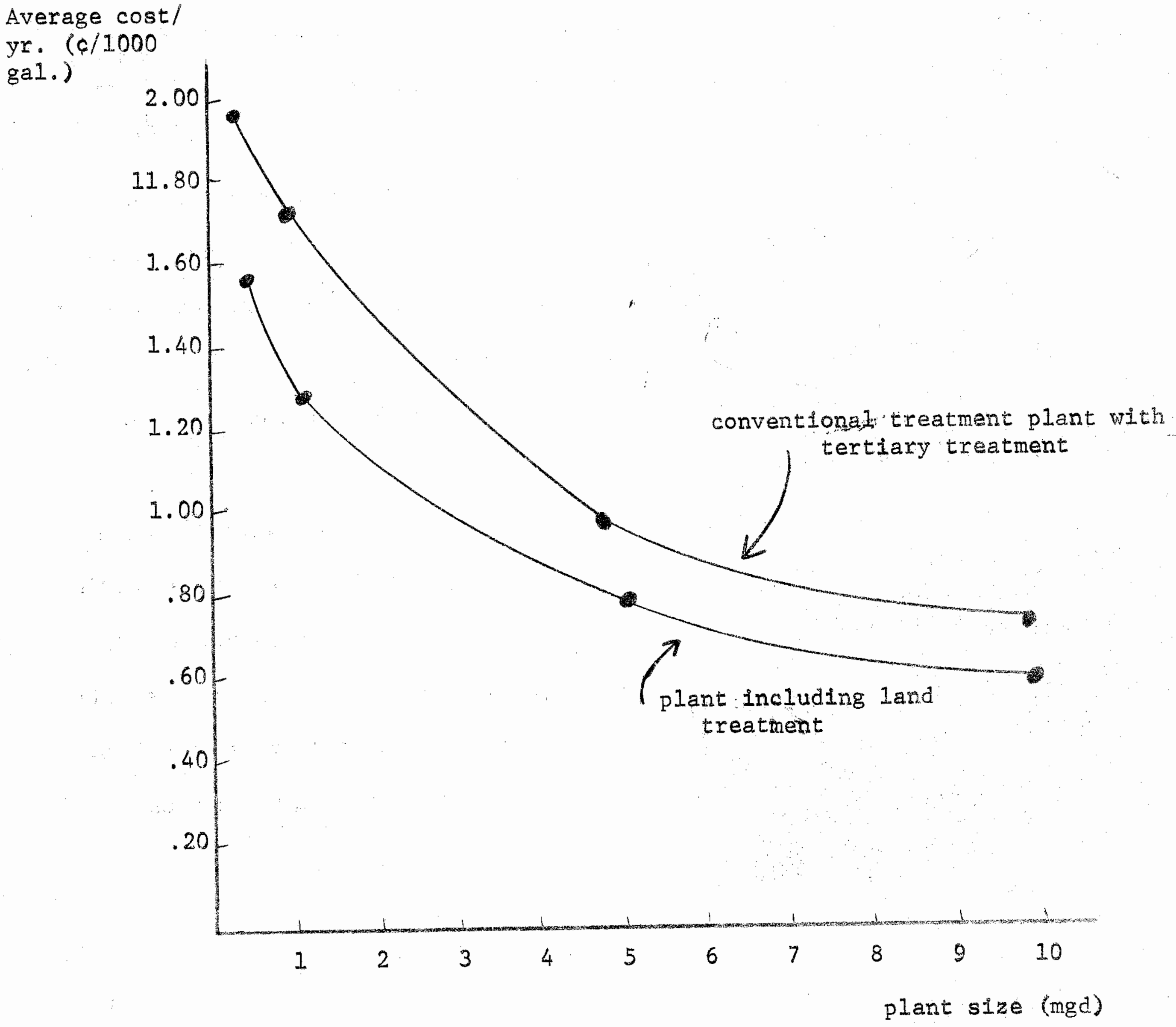
	New Conventional Plant			New Plant Including Land Treatment		
Plant size (mgd)	Percent BOD removal			Percent BOD removal		
	75	85	95	75	85	95
.5	$65,536 ($.36/1000 gal)	$70,225 ($.38/1000 gal)	$360,600 ($1.96/1000 gal)	$51,076 ($.28/1000 gal)	$57,121 ($.31/1000 gal)	$285,690 ($1.56/1000 gal)
1	$116,417 ($.32/1000 gal)	$125,670 ($.34/1000 gal)	$610,742 ($1.67/1000 gal)	$96,721 ($.26/1000 gal)	$100,489 ($.28/1000 gal)	$462,400 ($1.27/1000 gal)
5	$442,225 ($.24/1000 gal)	$477,481 ($.26/1000 gal)	$1,728,000 ($.95/1000 gal)	$367,236 ($.20/1000 gal)	$376,996 ($.21/1000 gal)	$1,412,486 ($.77/1000 gal)
10	$785,882 ($.22/1000 gal)	$850,084 ($.23/1000 gal)	$2,803,221 ($.77/1000 gal)	$652,864 ($.81/1000 gal)	$683,929 ($.19/1000 gal)	$2,299,968 ($.63/1000 gal)

versus plant size for 95% BOD_5 removal. To construct Table 14 and Figure 5 it was assumed that a 1 mgd plant has an annual flow of 365,000,000 gallons of wastes. In Table 14 and Figure 5 a land treatment plant is always the least expensive. For each of the cases there are increasing returns to increasing the plant size.

An interesting feature illustrated by Figure 5 is that the advantages of land treatment are greater for smaller plants. For 95% BOD_5 removal and a .5 mgd plant, the inclusion of a land treatment site as opposed to in-plant treatment saves $.40/1000 gallons. For a 10 mgd plant the savings is $.14/1000 gallons. This implies that land treatment is especially advantageous for smaller municipalities.

Federal subsidies for construction may alter these conclusions. Under the Federal Water Pollution Control Act Amendments of 1972, federal subsidies will be to reduce the cost of capital to the municipality, thus biasing the plants towards capital inputs as opposed to variable inputs. Subsidies will bias land treatment plants towards land purchase as opposed to leasing land or selling the effluent. The bias between high level in-plant treatment and land treatment cannot be determined from this study.

Figure 5. Average treatment costs per year without by-product sales (95% BOD_5 removal)



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APPENDICES

Appendix A. Questionnaire and Data

Cover Letter

Dear Sir:

The Water Resources Institute at North Carolina State University is sponsoring a study of alternative sewage disposal systems. Through a careful selection process your sewage disposal district has been chosen to participate in this study. We are examining the economic implications of sewage disposal. We are planning a comparison between conventional methods of treating and disposing of secondary effluents and sludges and the treatment and disposal through land application of the effluents and sludges. It is of extreme interest to us as to why your treatment facility is the most efficient given your local circumstances.

For our study to succeed we need your cooperation in filling out and returning the enclosed questionnaire. If you are unable to provide the exact information requested, please feel free to make an educated guess or consult others. You know enough about your operation to provide a reasonable estimate. Please feel free to provide additional comments on any part of the questionnaire as you fill it out.

The information given will be averaged with that of 500 other facilities. We will not reveal individual facility data or release this information to others. We thank you for your cooperation in filling out this questionnaire and returning it to us in the enclosed envelope. If you would like a copy of our report, we will send it to you free of charge when it is completed. Please indicate whether or not you want a copy of the questionnaire.

Sincerely,

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Some questions which we are particularly interested in your best estimates of are: number of employees (question b), BOD of influent and effluent (part of No. 19), average daily flow (No. 20), cost data (Nos. 21, 22 and 23) and the type of plant you have (questions 24, 25, 26 and 27). If you have misplaced the questionnaire, telephone us collect (919-737-2617, ask for Ed Young) and we will send you another copy.

We are seriously attempting to collect information from 500 municipal wastewater plants. Your cooperation is needed to produce a report which will explain the costs of conventional and land spreading wastewater treatment. Thank you for your participation.

Sincerely,

C. Edwin Young
Research Associate

Gerald A. Carlson
Assistant Professor

General Questionnaire

1. Name and address of sewage treatment facility
   (I would like a copy of the completed report: Yes___No___)

2. Number of people served_______________.

3. Number of industrial firms served_______________.

4. Approximate percentage of primary wastes resulting from industrial sources______%.

5. Future plans for the disposal of effluents. Please specify.

6. Number of persons employed in 1972:

   _____skilled _____% of payroll

   _____unskilled _____% of payroll

   _____supervisory _____% of payroll

7. Maximum storage capacity:

   sludge___mil. gal., entering wastes___mil. gal., and final treated effluent ___mil gal.

8. Transportation of sludge to disposal site: methods and distance transported (if more than one method is used specify the percentage of the sludge transported by each method).

9. Transportation of final effluent water to disposal site: methods and distance transported (if more than one method is used specify the percentage of the effluent transported by each method).

10. Name and average monthly flow of the water body which receives the final effluent.

Storm Drainage

11. Is your sewer system separate from your storm drainage system?

12. For every inch of rainfall your city receives in one day (24 hours) about how much does your total daily flow increase? ________mgd.

13. Please list your five highest volume days in 1972.

Date	Volume
1.__________	__________mgd.
2.__________	__________mgd.
3.__________	__________mgd.
4.__________	__________mgd.
5.__________	__________mgd.

Land Spreading

14. Was land spreading of sludge for the fertilizer of crops or trees considered during the planning of the current system?

_____Yes _____No

15. Was land spreading of the final effluent for the fertilization of crops or trees considered during the planning of the current system?

_____Yes _____No

16. Specify local legal restrictions on the land disposal of waste products.

17. Value of irrigation water in the vicinity \$____ per acre foot. If you cannot provide this data, please give us the name and address of someone who can.

18. Check the soil characteristics of the soils currently used for waste disposal. If none are used check the dominant characteristics of the soils within a five mile radius of your plant.

Approx. depth inches	Soil Characteristics	Drainage			Permeability		
		Well	Imperfect	Poor	Rapid	MOD.	Slow
	Sands, gravels, gr. sands						
	Loamy soils						
	Clayey soils (lean clays)						
	Clayey soils (fat clays)						
	Organic (Peats, Mucks)						

19. Chemical Composition of Wastes at Different Stages (average values)

	Composition of wastewater upon entering the treatment facility	Composition of water after secondary treatment	Composition of sludge prior to ultimate disposal	Composition of final effluent prior to ultimate disposal
BOD_5	mg/l	mg/l	%	mg/l
Total Nitrogen	mg/l	mg/l	%	mg/l
Total Phosphorous	mg/l	mg/l	%	mg/l
Total Potassium	mg/l	mg/l	%	mg/l
Heavy Metals	mg/l	mg/l	%	mg/l
Toxic Components	mg/l	mg/l	%	mg/l
Total Solids	mg/l	mg/l	%	mg/l
pH				
Residual Coliform Bacteria	organisms/ 100 ml	organisms/ 100 ml	organisms/ 100 ml	organisms/ 100 l
Special Characteristics				

20. Please indicate either the total annual flow <u>or</u> average daily flow in each of the following years and the designed capacity of your treatment facility:

Fiscal 1967-68 ______________ million gallons

Fiscal 1969-70 ______________ million gallons

Fiscal 1971-72 ______________ million gallons

Designed Capacity ______________ million gallons

21. Annual treatment costs of wastes after entering the treatment plant. Fill in the squares with your best estimates.

	Fuel and Chemical Cost	Maintenance	Transportation	Wages and Salaries*	Other
Fiscal 1971-72					
Fiscal 1969-70					
Fiscal 1967-68					

*Wages and salaries should include all costs such as social security, retirement, hospitalization, group insurance, etc.

22. Initial capital cost $______. This should include construction costs, land costs, and all other costs involved in developing the sewage plant. It should not include the costs of constructing your sewer lines.

23. Interest rate on sewage bonds at their date of issue ______%. You may have to consult your city manager or mayor to determine this rate.

24. Primary treatment: Date built__________________________________
Type:

25. Percent of total annual treatment costs going toward secondary treatment____%. Secondary effluent disposal: Date built_______. Type: a.____Activated sludge; b.____Aeriated lagoon; c.____Trickling filter; d.____Other (specify type).

26. Percent of total annual treatment costs going toward secondary treatment____%. Secondary effluent disposal: Date built______. Type: a.____Direct disposal into waterway; b.____Land disposal of effluent; c.____Tertiary treatment plant (specify details); d.____Other (specify type).

27. Percent of total annual treatment costs going toward secondary effluent treatment and disposal____%. Sludge disposal: Date built______________. Type: a.____Landfill; b.____Incineration; c.____Lagooning; d.____Land application of wet sludge; e._____ Land application of dried sludge; f.____Other (specify type).

Questionnaire. Appendix-Land Application

For those sewage districts which use land application for sludge and/or effluent water disposal.

Sludge	Effluent	
		1. Classification of disposal technique:
1.a.___	1.a.___	a. Spray irrigation.
b.___	b.___	b. Overland runoff.
c.___	c.___	c. Rapid infiltration.
d.___	d.___	d. Other (please specify details on a separate page).
		2. Does the district:
2.a.___	2.a.___	a. Operate its own disposal site.
b.___	b.___	b. Sell the sludge and/or effluent to someone.
c.___	c.___	c. Give the sludge and/or effluent to someone.
d.___	d.___	d. Permanent lease with someone or a group to take all of your sludge and/or effluent.
3. ___	3. ___	3. Designed capacity of disposal system (mgd.).
4. ___	4. ___	4. Number of years which the land disposal system has been in operation.
5. ___	5. ___	5. Purchase price of land.
6. ___	6. ___	6. Current market price of land.
7. ___	7. ___	7. Type of disinfection used prior to land disposal.
8. ___	8. ___	8. Quantity of disinfection added per gallon of sludge and/or effluent.

9. Type of effluent water used for the irrigation.

a.____primary b.____secondary c.____tertiary

13. Irrigation with Sludge

	Irrigation uses	Acres in 1971	Acres in 1972	Yield per acre if crops are grown	application rates			Months system operates each year
					per hr.	per wk.	per yr.	
	a. Landscape							
	b. Golf course							
	c. Forest							
corn	d. Pasture							
	e. Corn							
	f. Hay							
	g.							
	h.							

14. If the sludge is sold, leased, or given directly to farmers, give the details of the selling arrangements including the price of the sludge and the methods and costs of transporting the sludge to the disposal site.

15. Comments on the sludge disposal operation.

10. Irrigation with Effluent Water

Irrigation uses	Acres in 1971	Acres in 1972	Yield per acre if crops are grown	application rates per hr.	per wk.	per yr.	Months system operates each year
a. Land-scape							
b. Golf course							
c. Forest							
d. Pasture							
e. Corn							
f. Hay							
g.							
h.							

11. If the effluent water is sold, leased, or given directly to farmers, give the details of the selling arrangements including the price of the effluent and the method and costs of transporting the effluent to the disposal site.

12. Comments on the effluent disposal operation.

13. Irrigation with Sludge

Irrigation uses	Acres in 1971	Acres in 1972	Yield per acre if crops are grown	application rates per hr.	per wk.	per yr.	Months system operates each year
a. Land-scape							
b. Golf course							
c. Forest							
d. Pasture							
e. Corn							
f. Hay							
g.							
h.							

14. If the sludge is sold, leased, or given directly to farmers, give the details of the selling arrangements including the price of the sludge and the methods and costs of transporting the sludge to the disposal site.

15. Comments on the sludge disposal operation.

Variable Descriptions

ID = identification number

X_9 = BOD_5 concentration (mg/ℓ) of the influent

X_{10} = BOD_5 concentration (mg/ℓ) after conventional in-plant treatment

X_{13} = BOD_5 removal (mg/ℓ)

X_5 = mgd of industrial wastes

PD = county population density

T1 = average July temperature

R1 = annual rainfall (inches)

X_4 = age of initial plant

X_8 = number of years since the last major plant improvement

FLOW72 = average daily flow of wastes through the plant in millions of gallons

DFlow = designed flow capacity of the plant

FUEL = 1972 fuel and chemical costs

MAIN = 1972 maintenance costs

TRANS = 1972 transportation costs

WAGE = 1972 wages and salaries

Y1 = 1972 total costs

P_1 = price of labor

P_3 = price of electricity

P_5 = price of capital

PCTLOC = proportion of capital costs paid locally

PAG = county agricultural land prices

PS = population served

STATE = state identification number

Type = classification; 1 = no land treatment; Z = land treatment

Appendix B. Empirical Cost Equations

$$c_1 = \underset{(5.0217)}{7.7533} + \underset{(18.8529)}{0.8304x_1} - \underset{(-2.1597)}{0.1478x_{10}} - \underset{(-2.2952)}{0.3465x_3} + \underset{(2.4417)}{0.6664p_1} + \underset{(1.8249)}{0.4144p_5} + \underset{(0.5236)}{0.2362p_3} \qquad R^2 = 0.7818$$

$$c_1 = \underset{(6.6507)}{9.3528} + \underset{(18.7346)}{0.8340x_1} - \underset{(-2.2083)}{0.1529x_{10}} - \underset{(-2.5960)}{0.3904x_3} + \underset{(2.7095)}{0.7434p_1} + \underset{(0.7655)}{0.1576p_6} + \underset{(0.6584)}{0.2994p_3} \qquad R^2 = 0.7768$$

$$c_1 = \underset{(2.1383)}{4.4290} + \underset{(12.6477)}{0.7729x_1} + \underset{(0.1242)}{0.0263x_9} - \underset{(-2.4293)}{0.1784x_{10}} + \underset{(0.1409)}{0.0039x_5} + \underset{(1.2318)}{0.3712x_7} + \underset{(1.8130)}{0.5038p_1}$$

$$+ \underset{(3.5811)}{0.7797p_5} + \underset{(0.5281)}{0.2499p_3} \qquad R^2 = 0.7734$$

$$c_1 = \underset{(6.2710)}{9.2466} - \underset{(13.9943)}{0.8604x_1} - \underset{(-2.0259)}{0.1443x_{10}} - \underset{(-2.4894)}{0.3892x_3} - \underset{(-0.4869)}{0.0156x_4} - \underset{(-0.6007)}{0.0157x_5} + \underset{(2.5872)}{0.7206p_1}$$

$$+ \underset{(0.1782)}{0.8185p_6} + \underset{(0.5017)}{0.2355p_3} \qquad R^2 = 0.7778$$

$$c_1 = \underset{(3.3169)}{5.0656} + \underset{(12.5356)}{0.7722x_1} + \underset{(1.3446)}{0.2149x_2} + \underset{(0.1807)}{0.0048x_5} + \underset{(1.9076)}{0.5378p_1} + \underset{(3.6148)}{0.7960p_5} + \underset{(0.6998)}{0.3331p_3} \qquad R^2 = 0.7613$$

$$c_1 = \underset{(4.4998)}{7.8962} + \underset{(12.7344)}{0.7242x_1} + \underset{(1.3607)}{0.2120x_2} - \underset{(-1.2498)}{0.1928x_3} - \underset{(-1.6305)}{0.1067x_4} - \underset{(1.6137)}{0.0824x_5} + \underset{(2.9421)}{0.8264p_1}$$

$$+ \underset{(1.6869)}{.4078p_5} + \underset{(0.1594)}{0.1606p_3} \qquad R^2 = 0.7684$$

$$c_1 = \underset{(5.9296)}{8.6159} + \underset{(13.7175)}{0.8598x_1} + \underset{(1.1590)}{0.1852x_2} - \underset{(-2.4983)}{0.3970x_3} - \underset{(-0.8861)}{0.0281x_3} - \underset{(-0.7350)}{0.0194x_5} + \underset{(2.6285)}{0.7402p_1}$$

$$+ \underset{(0.8803)}{0.1938p_6} + \underset{(0.6442)}{0.3047p_3} \qquad R^2 = 0.7726$$

$$c_1 = \underset{(3.0828)}{13.2437} + \underset{(12.4019)}{0.7208x_1} + \underset{(1.3872)}{0.2189x_2} - \underset{(-1.5521)}{0.2448x_3} - \underset{(-1.7970)}{0.1181x_4} + \underset{(1.6968)}{0.8779x_5} - \underset{(3.3967)}{1.0579p_1}$$

$$- \underset{(-0.6251)}{0.5420p_2} + \underset{(0.0295)}{0.0299p_3} \qquad R^2 = 0.7633$$

$$c_1 = \underset{(9.2594)}{9.6425} + \underset{(16.7404)}{0.8436x_1} + \underset{(1.6213)}{0.2916x_1} - \underset{(-2.1875)}{0.3765x_3} + \underset{(1.59424)}{0.4174x_4} \qquad R^2 = 0.7101$$

$$c_1 = \underset{(1.8507)}{3.7105} + \underset{(12.2213)}{0.7614x_1} + \underset{(0.4870)}{0.0601x_6} + \underset{(1.0746)}{0.3311x_7} - \underset{(-1.2318)}{0.0332x_8} - \underset{(-0.0520)}{0.0014x_5} + \underset{(1.8369)}{0.5192p_1}$$

$$+ \underset{(3.5104)}{0.7847p_5} + \underset{(0.6772)}{0.3239p_3} \qquad R^2 = 0.7647$$

$$c_1 = \underset{(3.1593)}{15.1639} + \underset{(0.9078)}{0.5725b} - \underset{(-0.4478)}{0.777x_3} - \underset{(-1.6308)}{0.1203x_4} + \underset{(3.0240)}{0.1637x_5} + \underset{(3.6178)}{1.2560p_1} - \underset{(-0.7583)}{0.7356p_2}$$

$$- \underset{(-0.7723)}{0.8670p_3} \qquad R^2 = 0.6994)$$

$$c^*_1 = \underset{(1.8570)}{4.8885} + \underset{(8.8103)}{0.9623x_1} + \underset{(0.5506)}{0.1506x_2} + \underset{(-1.5876)}{0.4382x_3} - \underset{(-1.0944)}{0.0569x_4} - \underset{(-.3724)}{0.0169x_5} - \underset{(-0.8828)}{0.4234p_1}$$

$$+ \underset{(3.7815)}{1.4579p_1} + \underset{(0.7063)}{0.5738p_3} \qquad R^2 = 0.6106$$

$$\text{if } X_2 < .9 \text{ a) } c_1 = \underset{(4.5524)}{9.5261} + \underset{(15.6507)}{.8932x_1} + \underset{(0.7500)}{0.1464x_2} - \underset{(-1.2499)}{0.2885x_3} + \underset{(1.0254)}{0.4144p_1} + \underset{(0.7322)}{0.2388p_5}$$

$$- \underset{(-.8369)}{0.5670p_3} \qquad \begin{array}{r} R^2 = 0.8175 \\ \text{d.f.} = 72 \end{array}$$

$$\text{if } X_2 \leq .9 \text{ b) } c_1 = \underset{(1.7684)}{3.6949} + \underset{(9.6931)}{0.6686x_1} + \underset{(0.3311)}{1.2400x_2} - \underset{(-2.6192)}{0.4779x_3} + \underset{(2.9029)}{1.0266p_1} + \underset{(2.6159)}{0.7678p_5}$$

$$+ \underset{(2.0511)}{1.1282p_3} \qquad \begin{array}{r} R^2 = 0.7358 \\ \text{d.f.} = 51 \end{array}$$

$$\text{if } X_2 < .9 \text{ a) } c_1 = \underset{(4.6820)}{10.1153} + \underset{(15.8338)}{0.8968x_1} - \underset{(-1.1593)}{0.1527x_{10}} - \underset{(-1.3024)}{0.2982x_3} + \underset{(1.0114)}{0.4141p_1} + \underset{(0.6964)}{0.2260p_5}$$

$$- \underset{(-0.7608)}{0.5144p_3} \qquad \begin{array}{r} R^2 = 0.7608 \\ \text{d.f.} = 72 \end{array}$$

$$\text{if } X_2 \geq .9 \text{ b) } c_1 = \underset{(2.1278)}{4.3511} + \underset{(9.9579)}{0.7073x_1} - \underset{(-1.6630)}{0.3077x_{10}} - \underset{(-2.8594)}{0.5018x_3} + \underset{(3.3617)}{1.1658p_1} + \underset{(2.7063)}{0.7674p_5}$$

$$+ \underset{(1.8218)}{0.9846p_3} \qquad R^2 = 0.750 \quad \text{d.f.} = 51$$

$$\text{if } X_2 < .9 \text{ a) } c_1 = \underset{(5.6153)}{10.6424} + \underset{(15.8850)}{0.8990x_1} - \underset{(-1.1573)}{0.1531x_{10}} - \underset{(-1.4083)}{0.3179x_3} + \underset{(1.1153)}{0.4398p_1} + \underset{(0.5024)}{0.1420p_6}$$

$$- \underset{(-0.7398)}{0.5024p_3} \qquad R^2 = 0.8190 \quad \text{d.f.} = 72$$

$$\text{if } X_2 \geq .9 \text{ b) } c_1 = \underset{(3.3323)}{7.0822} + \underset{(9.3363)}{0.7072x_1} - \underset{(-1.6575)}{0.3256x_{10}} - \underset{(-3.1546)}{0.5815x_3} + \underset{(3.3015)}{1.2171p_1} + \underset{(1.1936)}{0.3489p_6}$$

$$+ \underset{(1.9090)}{1.1016p_3} \qquad R^2 = 0.718 \quad \text{d.f.} = 51$$

$$\text{if } X_3 \leq .95 \text{ a) } c_1 = \underset{(3.0611)}{18.4076} + \underset{(8.7771)}{0.7219x_1} + \underset{(0.9926)}{0.2708x_2} - \underset{(0.9990)}{0.2876x_3} - \underset{(-.7671)}{0.0649x_4} + \underset{(0.5829)}{0.0389x_5}$$

$$+ \underset{(3.0720)}{1.3423p_1} - \underset{(-1.4793)}{1.7840p_2} + \underset{(0.7096)}{1.0016p} \qquad R^2 = 0.6851 \quad \text{d.f.} = 88$$

$$\text{if } X_3 > .95 \text{ b) } c_1 = \underset{(0.4258)}{2.9836} + \underset{(10.2271)}{0.8944x_1} + \underset{(2.4111)}{0.5517x_2} - \underset{(-2.7073)}{1.6352x_3} - \underset{(-2.4305)}{0.3814x_4} - \underset{(-0.2235)}{0.0248x_5}$$

$$- \underset{(0.6783)}{0.3484p_1} + \underset{(1.5971)}{2.3082p_2} - \underset{(-1.7644)}{3.8553p} \qquad R^2 = 0.8810 \quad \text{d.f.} = 35$$

$$c_2 = \underset{(4.9570)}{7.8661} + \underset{(18.3206)}{0.8302x_1} - \underset{(-1.5127)}{0.0906x_{12}} - \underset{(-2.2258)}{0.3392x_3} + \underset{(2.3954)}{0.6600p_1} + \underset{(1.6782)}{0.3880p_5} + \underset{(0.2420)}{0.1105p3} \qquad R^2 = 0.7772$$

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Sincerely,

C. Edwin Young

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Dear Sir:

On May 22 we mailed to you a set of questions about your wastewater treatment system. To date we have not received your reply. Since your system was one drawn in a stratified sample of similar municipal plants, it is important for us to hear from you. The questionnaire may have asked for items which were difficult to compute or depend upon records that you do not have access to.

Some questions which we are particularly interested in your best estimates of are: number of employees (question b), BOD of influent and effluent (part of No. 19), average daily flow (No. 20), cost data (Nos. 21, 22 and 23) and the type of plant you have (questions 24, 25, 26 and 27). If you have misplaced the questionnaire, telephone us collect (919-737-2617, ask for Ed Young) and we will send you another copy..

We are seriously attempting to collect information from 500 municipal wastewater plants. Your cooperation is needed to produce a report which will explain the costs of conventional and land spreading wastewater treatment. Thank you for your participation.

Sincerely,

C. Edwin Young
Research Associate

Gerald A. Carlson
Assistant Professor

General Questionnaire

1. Name and address of sewage treatment facility
(I would like a copy of the completed report: Yes___No___)

2. Number of people served______________.

3. Number of industrial firms served______________.

4. Approximate percentage of primary wastes resulting from industrial sources_____%.

5. Future plans for the disposal of effluents. Please specify.

6. Number of persons employed in 1972:

_____skilled	_____% of payroll
_____unskilled	_____% of payroll
_____supervisory	_____% of payroll

7. Maximum storage capacity:

sludge___mil. gal., entering wastes___mil. gal., and final treated effluent ___mil gal.

8. Transportation of sludge to disposal site: methods and distance transported (if more than one method is used specify the percentage of the sludge transported by each method).

9. Transportation of final effluent water to disposal site: methods and distance transported (if more than one method is used specify the percentage of the effluent transported by each method).

10. Name and average monthly flow of the water body which receives the final effluent.

Storm Drainage

11. Is your sewer system separate from your storm drainage system?

12. For every inch of rainfall your city receives in one day (24 hours) about how much does your total daily flow increase? ________mgd.

13. Please list your five highest volume days in 1972.

Date	Volume
1.__________	__________mgd.
2.__________	__________mgd.
3.__________	__________mgd.
4.__________	__________mgd.
5.__________	__________mgd.

Land Spreading

14. Was land spreading of sludge for the fertilizer of crops or trees considered during the planning of the current system?

_____Yes _____No

15. Was land spreading of the final effluent for the fertilization of crops or trees considered during the planning of the current system?

_____Yes _____No

16. Specify local legal restrictions on the land disposal of waste products.

17. Value of irrigation water in the vicinity \$____ per acre foot. If you cannot provide this data, please give us the name and address of someone who can.

18. Check the soil characteristics of the soils currently used for waste disposal. If none are used check the dominant characteristics of the soils within a five mile radius of your plant.

Approx. depth inches	Soil Characteristics	Drainage			Permeability		
		Well	Im-perfect	Poor	Rapid	MOD.	Slow
	Sands,gravels,gr.sands						
	Loamy soils						
	Clayey soils (lean clays)						
	Clayey soils (fat clays)						
	Organic (Peats, Mucks)						

19. Chemical Composition of Wastes at Different Stages (average values)

	Composition of wastewater upon entering the treatment facility	Composition of water after secondary treatment	Composition of sludge prior to ultimate disposal	Composition of final effluent prior to ultimate disposal
BOD_5	mg/1	mg/1	%	mg/1
Total Nitrogen	mg/1	mg/1	%	mg/1
Total Phosphorous	mg/1	mg/1	%	mg/1
Total Potassium	mg/1	mg/1	%	mg/1
Heavy Metals	mg/1	mg/1	%	mg/1
Toxic Components	mg/1	mg/1	%	mg/1
Total Solids	mg/1	mg/1	%	mg/1
pH				
Residual Coliform Bacteria	organisms/ 100 ml	organisms/ 100 ml	organisms/ 100 ml	organisms/ 100 1
Special Characteristics				

20. Please indicate either the total annual flow or average daily flow in each of the following years and the designed capacity of your treatment facility:

Fiscal 1967-68 ______________________ million gallons
Fiscal 1969-70 ______________________ million gallons
Fiscal 1971-72 ______________________ million gallons
Designed Capacity ______________________ million gallons

21. Annual treatment costs of wastes after entering the treatment plant. Fill in the squares with your best estimates.

	Fuel and Chemical Cost	Maintenance	Transportation	Wages and Salaries*	Other
Fiscal 1971-72					
Fiscal 1969-70					
Fiscal 1967-68					

*Wages and salaries should include all costs such as social security, retirement, hospitalization, group insurance, etc.

22. Initial capital cost $______. This should include construction costs, land costs, and all other costs involved in developing the sewage plant. It should not include the costs of constructing your sewer lines.

23. Interest rate on sewage bonds at their date of issue ______%. You may have to consult your city manager or mayor to determine this rate.

24. Primary treatment: Date built________________________________
Type:

25. Percent of total annual treatment costs going toward secondary treatment____%. Secondary effluent disposal: Date built_______. Type: a.____Activated sludge; b.____Aerated lagoon; c.____Trickling filter; d.____Other (specify type).

26. Percent of total annual treatment costs going toward secondary treatment____%. Secondary effluent disposal: Date built______. Type: a.____Direct disposal into waterway; b.____Land disposal of effluent; c.____Tertiary treatment plant (specify details); d.____Other (specify type).

27. Percent of total annual treatment costs going toward secondary effluent treatment and disposal____%. Sludge disposal: Date built______________. Type: a.____Landfill; b.____Incineration; c.____Lagooning; d.____Land application of wet sludge; e._____ Land application of dried sludge; f.____Other (specify type).

Questionnaire. Appendix-Land Application

For those sewage districts which use land application for sludge and/or effluent water disposal.

Sludge	Effluent	
		1. Classification of disposal technique:
1.a.___	1.a.___	a. Spray irrigation.
b.___	b.___	b. Overland runoff.
c.___	c.___	c. Rapid infiltration.
d.___	d.___	d. Other (please specify details on a separate page).
		2. Does the district:
2.a.___	2.a.___	a. Operate its own disposal site.
b.___	b.___	b. Sell the sludge and/or effluent to someone.
c.___	c.___	c. Give the sludge and/or effluent to someone.
d.___	d.___	d. Permanent lease with someone or a group to take all of your sludge and/or effluent.
3. ___	3. ___	3. Designed capacity of disposal system (mgd.).
4. ___	4. ___	4. Number of years which the land disposal system has been in operation.
5. ___	5. ___	5. Purchase price of land.
6. ___	6. ___	6. Current market price of land.
7. ___	7. ___	7. Type of disinfection used prior to land disposal.
8. ___	8. ___	8. Quantity of disinfection added per gallon of sludge and/or effluent.

9. Type of effluent water used for the irrigation.

a.____primary b.____secondary c.____tertiary

13. Irrigation with Sludge

	Irrigation uses	Acres in 1971	Acres in 1972	Yield per acre if crops are grown	application rates			Months system operates each year
					per hr.	per wk.	per yr.	
	a. Land-scape							
	b. Golf course							
	c. Forest							
corn	d. Pasture							
	e. Corn							
	f. Hay							
	g.							
	h.							

14. If the sludge is sold, leased, or given directly to farmers, give the details of the selling arrangements including the price of the sludge and the methods and costs of transporting the sludge to the disposal site.

15. Comments on the sludge disposal operation.

10. Irrigation with Effluent Water

Irrigation uses	Acres in 1971	Acres in 1972	Yield per acre if crops are grown	application rates			Months system operates each year
				per hr.	per wk.	per yr.	
a. Land-scape							
b. Golf course							
c. Forest							
d. Pasture							
e. Corn							
f. Hay							
g.							
h.							

11. If the effluent water is sold, leased, or given directly to farmers, give the details of the selling arrangements including the price of the effluent and the method and costs of transporting the effluent to the disposal site.

12. Comments on the effluent disposal operation.

13. Irrigation with Sludge

Irrigation uses	Acres in 1971	Acres in 1972	Yield per acre if crops are grown	application rates			Months system operates each year
				per hr.	per wk.	per yr.	
a. Land-scape							
b. Golf course							
c. Forest							
d. Pasture							
e. Corn							
f. Hay							
g.							
h.							

14. If the sludge is sold, leased, or given directly to farmers, give the details of the selling arrangements including the price of the sludge and the methods and costs of transporting the sludge to the disposal site.

15. Comments on the sludge disposal operation.

Variable Descriptions

ID = identification number

X_9 = BOD_5 concentration (mg/ℓ) of the influent

X_{10} = BOD_5 concentration (mg/ℓ) after conventional in-plant treatment

X_{13} = BOD_5 removal (mg/ℓ)

X_5 = mgd of industrial wastes

PD = county population density

T1 = average July temperature

R1 = annual rainfall (inches)

X_4 = age of initial plant

X_8 = number of years since the last major plant improvement

FLOW72 = average daily flow of wastes through the plant in millions of gallons

DFlow = designed flow capacity of the plant

FUEL = 1972 fuel and chemical costs

MAIN = 1972 maintenance costs

TRANS = 1972 transportation costs

WAGE = 1972 wages and salaries

Y1 = 1972 total costs

P_1 = price of labor

P_3 = price of electricity

P_5 = price of capital

PCTLOC = proportion of capital costs paid locally

PAG = county agricultural land prices

PS = population served

STATE = state identification number

Type = classification; 1 = no land treatment; Z = land treatment

Appendix B. Empirical Cost Equations

$$c_1 = \underset{(5.0217)}{7.7533} + \underset{(18.8529)}{0.8304x_1} - \underset{(-2.1597)}{0.1478x_{10}} - \underset{(-2.2952)}{0.3465x_3} + \underset{(2.4417)}{0.6664p_1} + \underset{(1.8249)}{0.4144p_5} + \underset{(0.5236)}{0.2362p_3} \qquad R^2 = 0.7818$$

$$c_1 = \underset{(6.6507)}{9.3528} + \underset{(18.7346)}{0.8340x_1} - \underset{(-2.2083)}{0.1529x_{10}} - \underset{(-2.5960)}{0.3904x_3} + \underset{(2.7095)}{0.7434p_1} + \underset{(0.7655)}{0.1576p_6} + \underset{(0.6584)}{0.2994p_3} \qquad R^2 = 0.7768$$

$$c_1 = \underset{(2.1383)}{4.4290} + \underset{(12.6477)}{0.7729x_1} + \underset{(0.1242)}{0.0263x_9} - \underset{(-2.4293)}{0.1784x_{10}} + \underset{(0.1409)}{0.0039x_5} + \underset{(1.2318)}{0.3712x_7} + \underset{(1.8130)}{0.5038p_1}$$
$$+ \underset{(3.5811)}{0.7797p_5} + \underset{(0.5281)}{0.2499p_3} \qquad R^2 = 0.7734$$

$$c_1 = \underset{(6.2710)}{9.2466} - \underset{(13.9943)}{0.8604x_1} - \underset{(-2.0259)}{0.1443x_{10}} - \underset{(-2.4894)}{0.3892x_3} - \underset{(-0.4869)}{0.0156x_4} - \underset{(-0.6007)}{0.0157x_5} + \underset{(2.5872)}{0.7206p_1}$$
$$+ \underset{(0.1782)}{0.8185p_6} + \underset{(0.5017)}{0.2355p_3} \qquad R^2 = 0.7778$$

$$c_1 = \underset{(3.3169)}{5.0656} + \underset{(12.5356)}{0.7722x_1} + \underset{(1.3446)}{0.2149x_2} + \underset{(0.1807)}{0.0048x_5} + \underset{(1.9076)}{0.5378p_1} + \underset{(3.6148)}{0.7960p_5} + \underset{(0.6998)}{0.3331p_3} \qquad R^2 = 0.7613$$

$$c_1 = \underset{(4.4998)}{7.8962} + \underset{(12.7344)}{0.7242x_1} + \underset{(1.3607)}{0.2120x_2} - \underset{(-1.2498)}{0.1928x_3} - \underset{(-1.6305)}{0.1067x_4} - \underset{(1.6137)}{0.0824x_5} + \underset{(2.9421)}{0.8264p_1}$$
$$+ \underset{(1.6869)}{.4078p_5} + \underset{(0.1594)}{0.1606p_3} \qquad R^2 = 0.7684$$

$$c_1 = \underset{(5.9296)}{8.6159} + \underset{(13.7175)}{0.8598x_1} + \underset{(1.1590)}{0.1852x_2} - \underset{(-2.4983)}{0.3970x_3} - \underset{(-0.8861)}{0.0281x_3} - \underset{(-0.7350)}{0.0194x_5} + \underset{(2.6285)}{0.7402p_1}$$
$$+ \underset{(0.8803)}{0.1938p_6} + \underset{(0.6442)}{0.3047p_3} \qquad R^2 = 0.7726$$

$$c_1 = \underset{(3.0828)}{13.2437} + \underset{(12.4019)}{0.7208x_1} + \underset{(1.3872)}{0.2189x_2} - \underset{(-1.5521)}{0.2448x_3} - \underset{(-1.7970)}{0.1181x_4} + \underset{(1.6968)}{0.8779x_5} - \underset{(3.3967)}{1.0579p_1}$$
$$- \underset{(-0.6251)}{0.5420p_2} + \underset{(0.0295)}{0.0299p_3} \qquad R^2 = 0.7633$$

$$c_1 = \underset{(9.2594)}{9.6425} + \underset{(16.7404)}{0.8436x_1} + \underset{(1.6213)}{0.2916x_1} - \underset{(-2.1875)}{0.3765x_3} + \underset{(1.59424)}{0.4174x_4} \qquad R^2 = 0.7101$$

$$c_1 = \underset{(1.8507)}{3.7105} + \underset{(12.2213)}{0.7614x_1} + \underset{(0.4870)}{0.0601x_6} + \underset{(1.0746)}{0.3311x_7} - \underset{(-1.2318)}{0.0332x_8} - \underset{(-0.0520)}{0.0014x_5} + \underset{(1.8369)}{0.5192p_1}$$

$$+ \underset{(3.5104)}{0.7847p_5} + \underset{(0.6772)}{0.3239p_3} \qquad R^2 = 0.7647$$

$$c_1 = \underset{(3.1593)}{15.1639} + \underset{(0.9078)}{0.5725b} - \underset{(-0.4478)}{0.777x_3} - \underset{(-1.6308)}{0.1203x_4} + \underset{(3.0240)}{0.1637x_5} + \underset{(3.6178)}{1.2560p_1} - \underset{(-0.7583)}{0.7356p_2}$$

$$- \underset{(-0.7723)}{0.8670p_3} \qquad R^2 = 0.6994)$$

$$c_1^* = \underset{(1.8570)}{4.8885} + \underset{(8.8103)}{0.9623x_1} + \underset{(0.5506)}{0.1506x_2} + \underset{(-1.5876)}{0.4382x_3} - \underset{(-1.0944)}{0.0569x_4} - \underset{(-.3724)}{0.0169x_5} - \underset{(-0.8828)}{0.4234p_1}$$

$$+ \underset{(3.7815)}{1.4579p_1} + \underset{(0.7063)}{0.5738p_3} \qquad R^2 = 0.6106$$

if $X_2 < .9$ a) $$c_1 = \underset{(4.5524)}{9.5261} + \underset{(15.6507)}{.8932x_1} + \underset{(0.7500)}{0.1464x_2} - \underset{(-1.2499)}{0.2885x_3} + \underset{(1.0254)}{0.4144p_1} + \underset{(0.7322)}{0.2388p_5}$$

$$- \underset{(-.8369)}{0.5670p_3} \qquad \begin{aligned} R^2 &= 0.8175 \\ \text{d.f.} &= 72 \end{aligned}$$

if $X_2 \leq .9$ b) $$c_1 = \underset{(1.7684)}{3.6949} + \underset{(9.6931)}{0.6686x_1} + \underset{(0.3311)}{1.2400x_2} - \underset{(-2.6192)}{0.4779x_3} + \underset{(2.9029)}{1.0266p_1} + \underset{(2.6159)}{0.7678p_5}$$

$$+ \underset{(2.0511)}{1.1282p_3} \qquad \begin{aligned} R^2 &= 0.7358 \\ \text{d.f.} &= 51 \end{aligned}$$

if $X_2 < .9$ a) $$c_1 = \underset{(4.6820)}{10.1153} + \underset{(15.8338)}{0.8968x_1} - \underset{(-1.1593)}{0.1527x_{10}} - \underset{(-1.3024)}{0.2982x_3} + \underset{(1.0114)}{0.4141p_1} + \underset{(0.6964)}{0.2260p_5}$$

$$- \underset{(-0.7608)}{0.5144p_3} \qquad \begin{aligned} R^2 &= 0.7608 \\ \text{d.f.} &= 72 \end{aligned}$$

$$\text{if } X_2 \geq .9 \text{ b) } c_1 = \underset{(2.1278)}{4.3511} + \underset{(9.9579)}{0.7073x_1} - \underset{(-1.6630)}{0.3077x_{10}} - \underset{(-2.8594)}{0.5018x_3} + \underset{(3.3617)}{1.1658p_1} + \underset{(2.7063)}{0.7674p_5}$$

$$+ \underset{(1.8218)}{0.9846p_3} \qquad R^2 = 0.750 \quad \text{d.f.} = 51$$

$$\text{if } X_2 < .9 \text{ a) } c_1 = \underset{(5.6153)}{10.6424} + \underset{(15.8850)}{0.8990x_1} - \underset{(-1.1573)}{0.1531x_{10}} - \underset{(-1.4083)}{0.3179x_3} + \underset{(1.1153)}{0.4398p_1} + \underset{(0.5024)}{0.1420p_6}$$

$$- \underset{(-0.7398)}{0.5024p_3} \qquad R^2 = 0.8190 \quad \text{d.f.} = 72$$

$$\text{if } X_2 \geq .9 \text{ b) } c_1 = \underset{(3.3323)}{7.0822} + \underset{(9.3363)}{0.7072x_1} - \underset{(-1.6575)}{0.3256x_{10}} - \underset{(-3.1546)}{0.5815x_3} + \underset{(3.3015)}{1.2171p_1} + \underset{(1.1936)}{0.3489p_6}$$

$$+ \underset{(1.9090)}{1.1016p_3} \qquad R^2 = 0.718 \quad \text{d.f.} = 51$$

$$\text{if } X_3 \leq .95 \text{ a) } c_1 = \underset{(3.0611)}{18.4076} + \underset{(8.7771)}{0.7219x_1} + \underset{(0.9926)}{0.2708x_2} - \underset{(0.9990)}{0.2876x_3} - \underset{(-.7671)}{0.0649x_4} + \underset{(0.5829)}{0.0389x_5}$$

$$+ \underset{(3.0720)}{1.3423p_1} - \underset{(-1.4793)}{1.7840p_2} + \underset{(0.7096)}{1.0016p} \qquad R^2 = 0.6851 \quad \text{d.f.} = 88$$

$$\text{if } X_3 > .95 \text{ b) } c_1 = \underset{(0.4258)}{2.9836} + \underset{(10.2271)}{0.8944x_1} + \underset{(2.4111)}{0.5517x_2} - \underset{(-2.7073)}{1.6352x_3} - \underset{(-2.4305)}{0.3814x_4} - \underset{(-0.2235)}{0.0248x_5}$$

$$- \underset{(0.6783)}{0.3484p_1} + \underset{(1.5971)}{2.3082p_2} - \underset{(-1.7644)}{3.8553p} \qquad R^2 = 0.8810 \quad \text{d.f.} = 35$$

$$c_2 = \underset{(4.9570)}{7.8661} + \underset{(18.3206)}{0.8302x_1} - \underset{(-1.5127)}{0.0906x_{12}} - \underset{(-2.2258)}{0.3392x_3} + \underset{(2.3954)}{0.6600p_1} + \underset{(1.6782)}{0.3880p_5} + \underset{(0.2420)}{0.1105p3} \qquad R^2 = 0.7772$$

$$c_2 = \underset{(6.2733)}{9.3902} + \underset{(13.7394)}{0.8634x_1} - \underset{(-1.5952)}{0.0972x_1} - \underset{(-2.3413)}{0.3696x_3} - \underset{(-0.6767)}{0.0215x_4} - \underset{(-0.6168)}{0.0162x_5} + \underset{(2.5409)}{0.7132p_1}$$

$$+ \underset{(0.7087)}{0.1560p_6} + \underset{(0.1961)}{0.0932p_3} \qquad R^2 = 0.7741$$

$$c_2 = \underset{(6.6698)}{9.5512} + \underset{(18.2879)}{0.8353x_1} - \underset{(-1.6994)}{0.1021x_{12}} - \underset{(-2.4887)}{0.3781x_{12}} + \underset{(2.6678)}{0.7380p_1} + \underset{(0.5852)}{0.1216p_6} + \underset{(0.3547)}{0.1632p_3} \qquad R^2 = 0.7726$$

$$c_2 = \underset{(4.4928)}{7.3337} + \underset{(18.4171)}{0.8113x_1} - \underset{(-0.2779)}{0.0337x_{13}} - \underset{(-2.4381)}{0.3806x_3} + \underset{(2.3826)}{0.6628p_1} + \underset{(1.8840)}{0.4360p_5} + \underset{(0.4547)}{0.2079p_3} \qquad R^2 = 0.7730$$

$$c_2 = \underset{(5.2124)}{7.9644} + \underset{(18.3924)}{0.8302x_1} - \underset{(-1.5650)}{0.0925x_{12}} - \underset{(-2.2236)}{0.3336x_3} + \underset{(2.4023)}{0.6592p_1} + \underset{(1.7170)}{0.3972p_5} \qquad R^2 = 0.7771$$

$$\text{if } X_2 < .9 \text{ a) } c_2 = \underset{(5.5721)}{10.5192} + \underset{(15.4821)}{0.9019x_1} - \underset{(-0.8666)}{0.0746x_{12}} - \underset{(-1.3050)}{0.2966x_3} + \underset{(0.9514)}{0.3768p_1}$$

$$+ \underset{(0.5122)}{0.1456p_6} - \underset{(-0.9488)}{0.6494p_3} \qquad \begin{array}{l} R^2 = 0.8165 \\ \text{d.f.} = 72 \end{array}$$

$$\text{if } X_2 > .9 \text{ b) } c_2 = \underset{(3{,}5054)}{7.6690} + \underset{(9.1130)}{0.6941x_1} - \underset{(-1.4544)}{0.2052x_{12}} - \underset{(-2.6826)}{0.5042x_3} + \underset{(-3.1608)}{1.1485p_1}$$

$$+ \underset{(0.8390)}{0.2525p_6} + \underset{(1.6300)}{0.9426p_3} \qquad \begin{array}{l} R^2 = 0.7081 \\ \text{d.f.} = 51 \end{array}$$

Where:

c_1^* = Total cost assuming a constant service flow of capital

X_7 = Excess flow capacity = Designed Flow - Actual Flow

X_8 = 1972 - year of last major capital improvement

X_9 = BOD in (mg/1)

B = Pounds of BOD removed (a combination of X_1 and X_{10})

P_2 = EPA regional construction cost index

X_{13} = BOD removal from land treatment = $X_{12} - X_{10}$

Appendix C. Residual Plots

Figure 1. Plot of residuals versus predicted for Table 8, Equation 1.

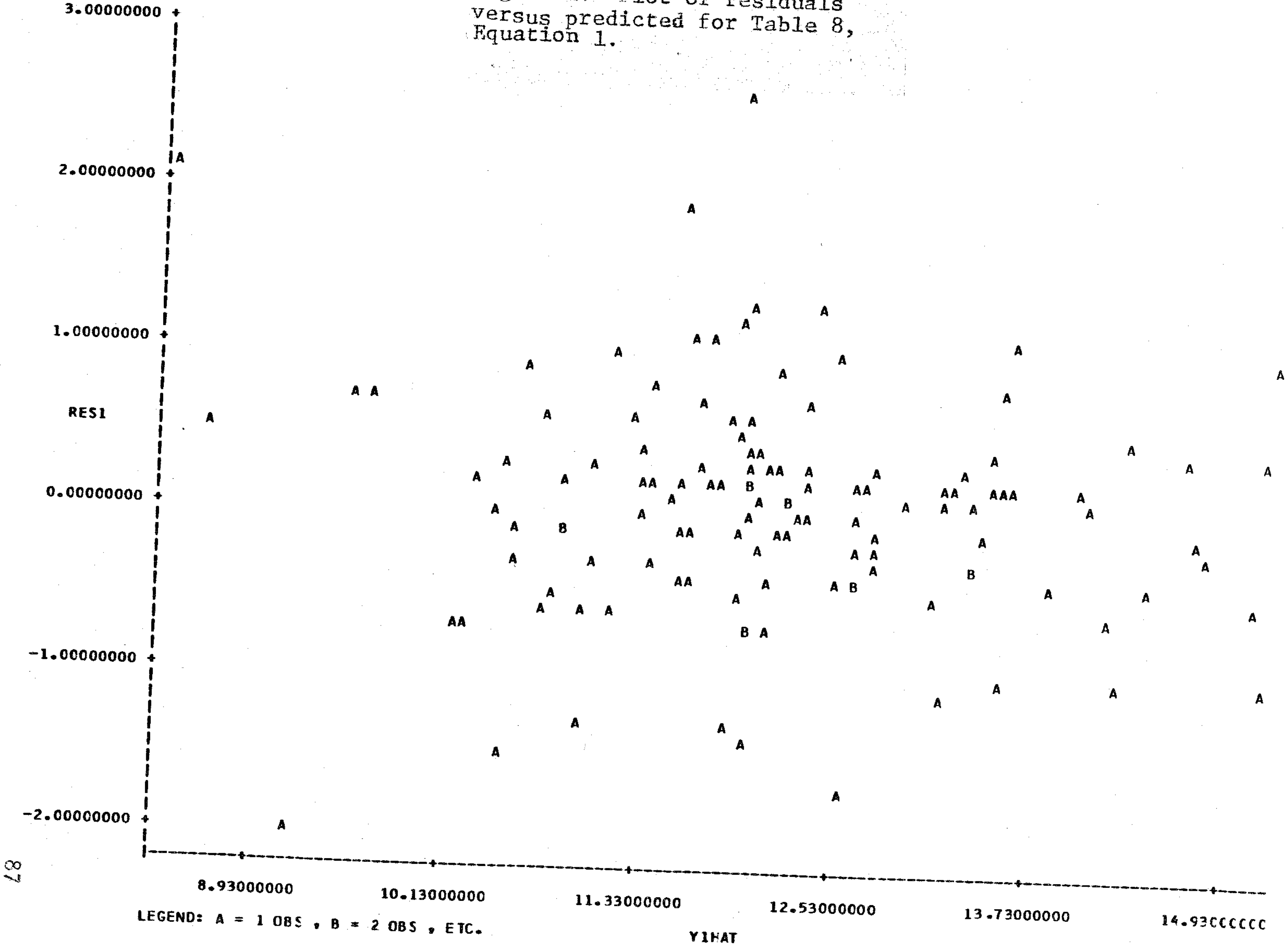


Figure 2. Plot of residuals versus predicted for Table 13, Equation 1.

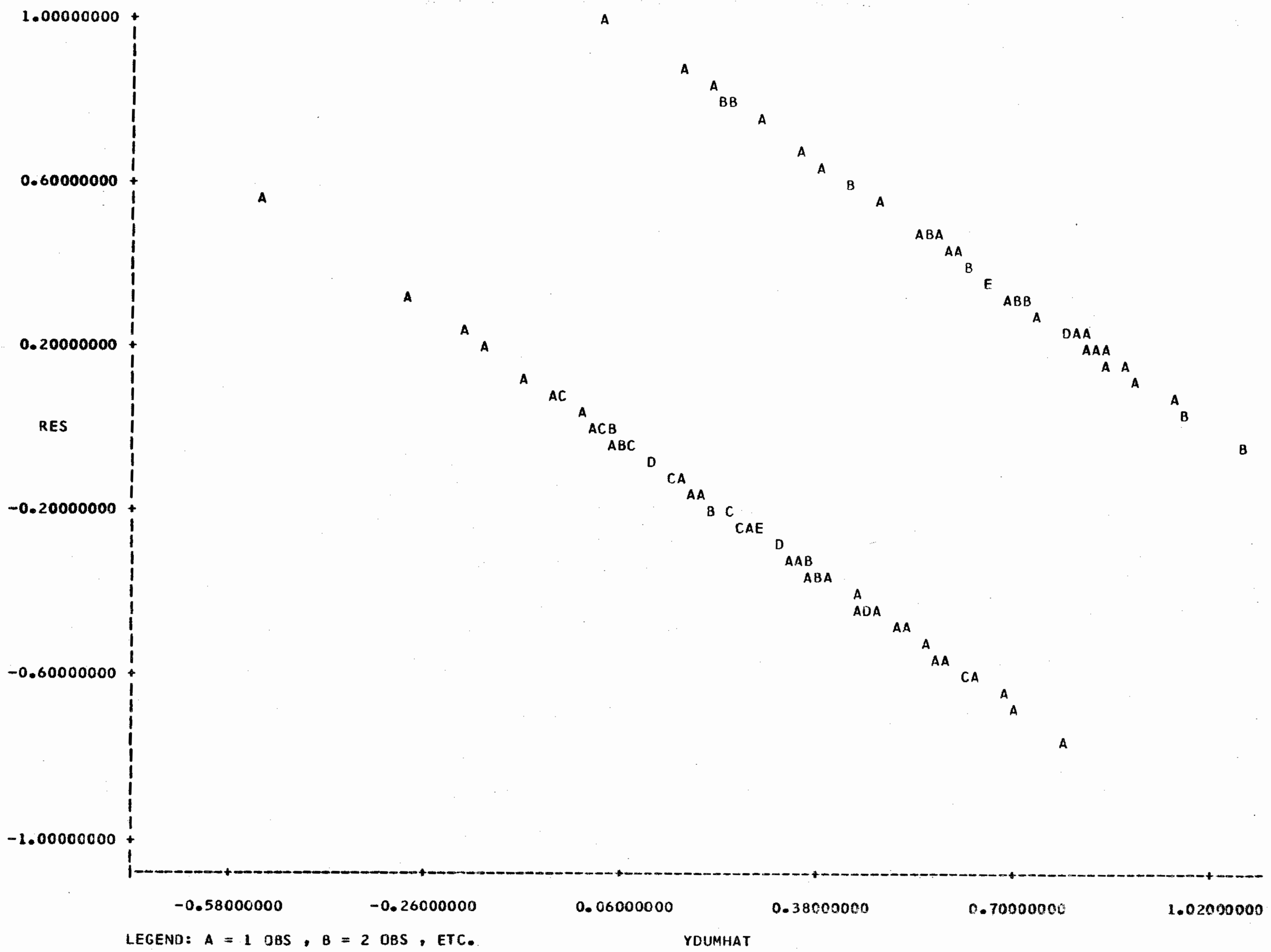
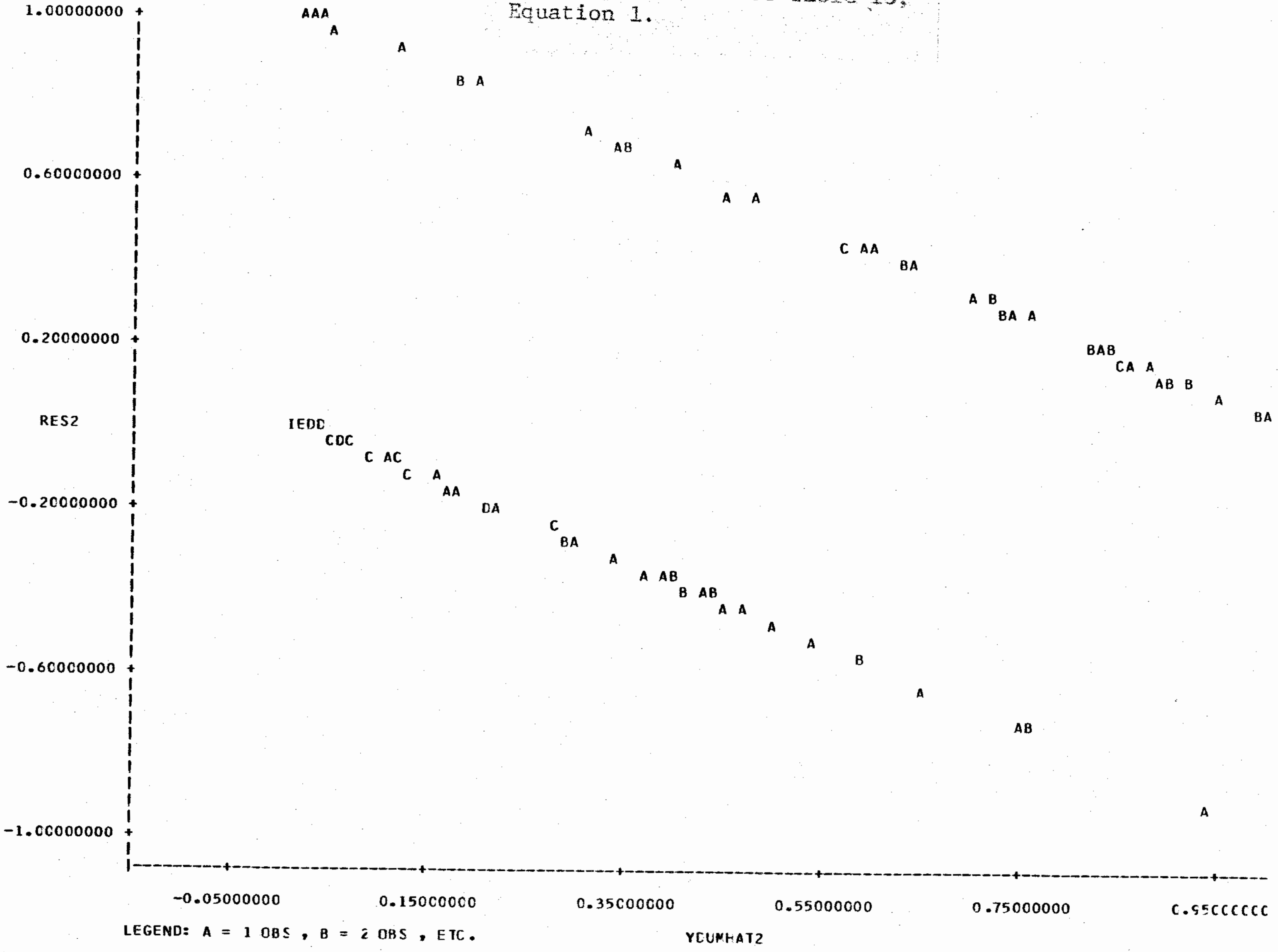


Figure 3. Plot of residuals versus predicted for Table 13, Equation 1.



Regression Date

OBS	ID	X9	X10	X13	X5	PD	T1	R1	RF	X4	X8
1	1	107.1	8.4	101.0	0.0000	690.4	92.0	53.4	150000	23	23
2	2	230.0	49.0	181.0	13.2000	1545.2	94.5	34.6	1480	32	20
3	3	73.0	5.0	68.0	0.0000	1971.1	89.7	51.6	150000	14	7
4	4	260.0	65.0	195.0	1.3170	1464.1	71.9	18.7	150000	24	6
5	5	180.0	160.0	20.0	0.6900	3012.5	90.6	53.9	150000	6	6
6	6	175.0	12.5	162.5	0.0000	7153.7	86.1	42.4	11	57	0
7	7	170.0	30.0	140.0	0.0000	1816.4	82.0	9.8	150000	0	0
8	8	256.0	73.0	183.0	0.8660	112.8	83.8	54.5	3215	10	10
9	9	253.0	165.0	88.0	33.3150	1853.5	88.5	41.3	110900	14	14
10	10	175.0	15.0	160.0	0.0577	122.3	90.5	51.4	136	14	14
11	11	305.0	40.5	264.5	2.4700	118.1	83.5	48.2	669	14	8
12	12	133.0	22.0	111.0	0.0000	1816.4	82.0	9.8	150000	13	13
13	13	240.0	12.0	228.0	0.0000	202.1	83.3	14.7	54	9	9
14	14	238.0	140.0	98.0	4.1980	15903.9	71.9	18.7	150000	20	20
15	15	211.0	14.0	197.0	0.0300	35.9	92.8	30.8	939	31	57
16	16	211.0	21.0	190.0	2.0500	53.4	95.4	13.4	779	22	3
17	17	200.0	15.0	185.0	0.0000	27.9	94.2	19.7	97	25	0
18	18	459.0	39.0	420.0	11.1386	128.7	95.4	13.4	1440	25	3
19	19	320.0	17.8	302.2	0.0600	1244.4	71.9	18.7	150000	19	4
20	20	293.5	23.3	270.2	0.0756	151.6	80.4	45.1	14	35	35
21	21	465.0	13.0	452.0	1.3700	378.4	92.0	51.4	5	1	1
22	22	288.0	52.0	236.0	0.0000	46.0	88.2	44.7	728	15	15
23	23	150.0	15.0	135.0	0.0000	2021.2	86.0	39.2	13	17	17
24	24	260.0	48.0	212.0	0.3195	70.6	90.7	45.1	1913	11	11
25	25	296.0	231.0	65.0	39.8500	1871.2	86.1	42.4	150000	14	14
26	26	203.0	129.0	74.0	0.0000	478.9	83.3	36.1	50000	13	13
27	27	180.0	30.0	150.0	0.0000	144.3	88.1	43.6	10	24	5
28	28	359.0	234.0	125.0	0.0000	10.5	92.8	30.8	10	16	16
29	29	263.0	39.0	251.0	0.0090	122.3	92.0	51.4	0	6	6
30	30	230.0	85.0	147.0	3.5220	205.6	88.8	43.4	44	11	11
31	31	190.0	16.0	174.0	0.0000	19.0	89.4	7.2	402	11	4
32	32	186.0	12.0	174.0	0.0000	227.5	92.0	51.4	150000	9	9
33	33	301.0	41.0	260.0	5.4270	440.6	87.7	42.2	2390	43	0
34	34	300.0	10.0	296.0	1.2000	64.0	82.0	9.8	83	22	22
35	35	350.0	100.0	250.0	0.0000	69.2	100.0	11.1	3	10	10
36	36	140.0	19.0	121.0	0.8436	127.7	71.9	18.7	17	20	20
37	37	341.0	39.1	301.9	24.7500	819.0	71.9	18.7	150000	16	8
38	38	222.0	19.2	202.8	2.1750	147.6	96.0	32.1	2351	1	1
39	39	226.0	23.3	202.7	4.1120	666.5	94.0	27.8	50	42	2
40	41	316.0	80.0	236.0	5.3850	266.3	88.1	43.6	885	17	6
41	42	210.0	103.0	107.0	3.4200	225.1	87.7	42.2	555	13	13
42	43	235.0	15.0	220.0	2.4700	232.3	92.4	48.7	50980	13	3
43	44	188.0	12.0	176.0	1.2000	89.5	83.8	54.5	150000	8	8
44	47	254.0	14.0	240.0	0.0000	61.0	88.1	43.6	1070	13	13
45	48	240.0	14.0	228.0	0.2500	57.2	91.2	51.0	513	33	11
46	49	140.0	90.0	50.0	0.0000	26.3	89.2	49.2	328	16	16
47	50	200.0	17.0	195.0	0.1500	205.5	95.4	13.4	4148	0	0
48	51	652.0	124.0	625.0	0.2000	69.2	100.0	11.1	2142	23	0
49	53	150.0	40.0	135.0	0.0580	39.1	100.0	11.1	2142	48	1
50	54	255.0	64.0	241.0	0.1600	7.1	95.4	11.6	197	25	25
51	55	350.0	20.0	346.0	0.1500	17.6	94.3	23.3	48	15	15
52	56	325.0	195.0	195.0	1.2250	47.4	96.9	18.0	4	14	14
53	57	196.0	14.0	182.0	0.0000	20.5	85.3	36.7	8374	6	6
54	58	200.0	20.0	185.0	0.0648	202.1	83.3	14.7	0	12	10
55	59	350.0	35.0	343.0	1.1120	220.6	79.5	42.4	398	2	2

10. Irrigation with Effluent Water

	Irrigation uses	Acres in 1971	Acres in 1972	Yield per acre if crops are grown	application rates			Months system operates each year
					per hr.	per wk.	per yr.	
	a. Landscape							
	b. Golf course							
	c. Forest							
crops	d. Pasture							
	e. Corn							
	f. Hay							
	g.							
	h.							

11. If the effluent water is sold, leased, or given directly to farmers, give the details of the selling arrangements including the price of the effluent and the method and costs of transporting the effluent to the disposal site.

12. Comments on the effluent disposal operation.

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OBS   ID     X9     X10     X13      X5       PD      T1     R1      RF   X4   X8

 56   60  550.0   250.0   300.0  0.7750     75.7    83.5   48.2     219    7    7
 57   61  128.0     8.0   120.0  0.0000     37.2    91.9   50.7     684   15   15
 58   62  200.0    50.0   168.0  0.5975     40.4   100.3    6.4    1935   33   20
 59   63  225.0     5.0   220.0  2.2400     96.6    71.6   13.4      20   37   19
 60   64  237.5    12.5   234.0  0.0000      6.1   104.6    7.2   12400    7    7
 61   65  225.0    30.0   201.0  0.0260    172.4    90.8   61.7     356   72   13
 62   66  226.0    15.0   221.0  0.0000     34.7   103.5    3.9       0   14   14
 63   67  211.0    17.0   207.0  2.9240     38.1    98.5   11.0      22   54    1
 64   68  275.0    50.0   266.0  0.0000    103.9    87.4   44.2      52    6    6
 65   69  300.0    15.0   296.0  0.7500    128.7    95.4   13.4     855    7    7
 66   70  270.0    60.0   257.0  0.0000      4.8    95.7    7.2     250   72   14
 67   71  194.0    27.0   172.0  0.0000     34.7   103.5    3.9       0   16   16
 68   72  316.0   111.0   304.0  4.4790    200.8    92.4   18.1      35   31    1
 69   73  250.0    30.0   229.0  0.4400     69.7    94.5    6.7       0   20   20
 70   74  240.0    20.0   229.0  0.3400   1464.1    95.4   13.4       0   15    5
 71   75  200.0    26.0   181.0  1.2915     89.3    93.4   10.3   10250    2    2
 72   76  169.0    42.0   158.0  0.0000    759.7    95.4   13.4    4148   32   32
 73   78  250.0    40.0   237.0  0.2250     34.0    82.0    9.8       0   10   10
 74   79  150.0    72.0   101.0  0.0000    198.2    91.0   53.1    3996   32   32
 75   80  220.0   143.0   157.0  0.0500     13.3    99.6   22.0   11970   11   11
 76   81  186.0    34.0   182.0  0.1000    318.7    76.8   10.4  150000    8    8
 77   82  208.0    69.9   163.0  0.0000     17.4    92.4   10.1       0    4    4
 78   84  270.0    15.0   255.0  0.2090     34.0    83.3   14.7      13   16    7
 79   85  250.0    50.0   218.0  0.0448     40.4   100.3    6.4    1935   25   16
 80   86  240.0    25.0   236.0  0.0000    140.7    91.2    8.1     670   21   21
 81   89  350.0    30.0   320.0  0.2440    965.1    85.2   41.3      14   42   12
 82   91  180.0    34.0   146.0  0.0000    134.8    89.0   51.3     112   31   18
 83   92  103.6     4.1    99.5  0.0040    142.4    87.4   44.2     200    0    0
 84   93  300.0    18.0   282.0  1.1925     36.6    89.2   62.9  150000    5    5
 85   94  154.0   100.0    54.0  0.0000    508.7    88.8   59.8  150000    2    2
 86   95  162.0    52.0   110.0  3.9074    620.9    88.8   59.8  150000   17   17
 87   96  100.0    22.0    78.0  0.1974     43.6    83.8   54.5    3515   18   18
 88   97  225.0    60.0   167.0  1.5000    270.1    91.2    8.1      50   34   10
 89   98  150.0    25.0   146.0  0.0000     62.0    85.3   36.7   11970   11   11
 90   99  210.0     5.5   204.5  0.0165     26.3    92.5   26.8  150000    2    2
 91  101  137.0    41.0    96.0  0.0000    701.0    92.9   37.1    6213   41   41
 92  102  275.0   130.0   145.0  0.0000   1244.4    71.9   18.7  150000   37    3
 93  104  129.0    20.0   109.0  0.0000      9.9    99.6   22.0   11470   20    8
 94  105  148.0    12.0   136.0  0.0000    257.4    91.0   53.1  150000   10   10
 95  106  252.0    13.0   239.0  0.0880    204.1    85.2   44.1    8046   21   21
 96  107  250.0    90.0   249.0  1.8400    109.4    84.2   13.2      12   36    2
 97  110  204.0    51.0   153.0  0.1250     62.5    83.5   48.2      10    8    8
 98  111  170.0    26.0   144.0  0.0000    119.5    92.0   68.1  150000   30   12
 99  112  313.0    35.1   277.9  0.0000      3.6    98.5   11.0     433    4    4
100  113  233.0    19.0   214.0  0.4565      6.1   106.9    3.0     870    2    2
101  115  320.0   270.0    50.0  0.0000   1853.5    88.5   41.3  110900   12   12
102  116  188.0     6.0   182.0  0.1300    228.9    88.5   45.8    1061   17   17
103  118  210.0    16.0   194.0  0.0000     71.4    90.3   41.4     346   22   22
104  119  213.0    27.0   207.0  0.0000    153.8    90.5   56.9    1733    6    6
105  120   62.0    34.0    38.0  0.0275     15.6    88.9    7.9  201800   16   11
106  121  201.0    20.0   181.0  1.6650    449.8    88.1   43.6     460   38   16
107  123  267.0    47.0   220.0  0.7380    174.2    87.7   42.2    2880   45   45
108  124  145.0     8.0   143.0  0.0000     19.0    89.4    9.8       0    2    2
109  125  200.0     6.0   194.0  2.1760     89.4    89.0   51.3    1308    0    0
110  126  400.3    69.0   333.0  1.8060     92.4    86.0   39.2    1535   12   12
```

ID	P1	P3	P5	PCTLOC	PAG	PIR	PS	STATE	TYPE
1	3.54	3.188	731.67	1.000	499.2	10.00	16000	17	2
2	3.76	3.447	1058.05	1.000	1256.0	8.28	935000	5	1
3	3.39	3.188	731.16	0.839	1759.9	28.00	9000	17	1
4	4.55	2.690	791.88	0.783	808.6	5.88	180000	3	1
5	3.50	2.929	945.05	0.783	25840.7	0.00	110000	11	1
6	4.05	3.840	1736.96	0.478	5274.3	0.00	15000	23	1
7	4.47	2.690	737.64	0.478	4393.5	57.96	31000	3	1
8	2.64	2.545	1093.58	0.879	685.6	0.00	30000	20	1
9	4.03	3.133	558.47	0.877	769.3	0.00	495000	14	1
10	3.11	3.188	737.49	0.877	726.3	28.00	60000	17	1
11	2.52	2.545	799.21	0.835	441.9	0.00	20000	20	1
12	4.47	2.690	1158.09	0.868	4393.5	57.96	7500	3	1
13	4.05	2.690	992.13	0.863	1954.2	30.28	23000	3	1
14	4.53	2.690	901.86	1.000	20733.9	5.88	200000	3	1
15	2.74	2.980	-12.22	1.000	357.6	11.58	12000	9	1
16	3.10	2.690	848.54	0.765	490.4	8.32	28000	3	1
17	5.51	3.447	738.90	0.478	114.7	8.28	15871	5	1
18	3.68	2.690	609.46	0.765	867.7	8.32	78000	3	1
19	4.44	2.690	1058.18	0.702	1034.6	5.88	21000	3	1
20	3.82	2.912	1127.75	1.000	234.8	0.00	22000	25	1
21	3.93	3.188	1240.76	0.644	1521.6	28.00	50000	17	1
22	3.29	3.133	626.96	0.892	218.0	0.00	6676	14	1
23	4.55	3.251	878.53	1.000	1231.9	0.00	14651	24	1
24	3.48	2.855	689.45	0.900	292.3	0.00	25000	15	1
25	4.30	3.840	964.56	0.877	3198.9	0.00	500000	23	1
26	4.63	2.912	954.96	0.868	487.2	0.00	26131	25	1
27	2.46	2.545	688.52	0.775	451.3	0.00	30000	20	1
28	2.15	2.980	388.66	1.000	198.0	8.28	2700	9	1
29	3.11	3.188	659.94	0.783	726.3	28.00	2800	17	2
30	2.15	2.545	677.35	0.900	415.1	0.00	22000	20	2
31	3.79	3.285	1438.83	0.702	140.9	2.47	16000	4	1
32	4.77	3.188	797.63	0.863	455.3	28.00	10452	17	1
33	3.07	2.545	513.12	0.478	666.9	0.00	55000	20	1
34	3.79	2.690	859.09	1.000	1268.9	8.32	22000	3	2
35	3.35	2.690	984.12	0.879	607.5	8.32	6000	3	1
36	3.34	2.690	835.27	1.000	669.7	1.91	60000	3	1
37	5.01	2.690	1380.55	0.835	1422.3	5.88	750000	3	1
38	3.20	3.447	1158.60	0.644	297.3	8.28	120000	5	1
39	2.82	3.447	1075.84	0.785	448.0	8.28	714390	5	1
41	3.62	2.545	803.13	0.783	642.8	0.00	130000	20	1
42	2.77	2.545	809.29	0.868	440.6	0.00	40000	20	1
43	3.84	3.081	761.86	0.765	470.8	0.00	135000	16	1
44	2.66	2.545	716.92	0.835	439.2	0.00	17000	20	1
47	2.42	2.545	799.93	0.868	314.7	0.00	7000	20	1
48	2.69	2.967	841.70	0.900	411.4	0.00	15000	18	2
49	2.14	3.027	788.86	1.000	276.8	0.00	4000	19	1
50	3.90	2.690	1247.91	0.478	888.4	8.32	16100	3	2
51	3.35	2.690	817.28	0.478	607.5	8.32	17000	3	2
53	3.22	2.690	1141.96	0.644	731.9	8.32	8400	3	2
54	2.66	3.786	715.26	1.000	66.7	2.20	40000	6	2
55	3.25	3.447	707.87	0.892	162.7	8.28	12000	5	2
56	2.48	3.447	911.80	0.877	148.0	8.28	75000	5	2
57	4.01	2.690	1032.17	0.783	178.3	8.32	18000	3	1
58	4.05	2.690	1274.27	0.879	1954.2	57.96	42500	3	2
59	3.88	1.750	932.78	0.785	1162.8	2.29	16600	1	2

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OBS    ID    X9   X10   X13        X5       PD     T1     R1       RF   X4   X8

111   127   170    12   158    0.0510     51.4   92.9   37.1      552    0   17
112   128   190   114    78    0.0000      9.9   98.5   11.0       62    4    4
113   129   250    55   195    0.3600    318.7   76.8   10.4        5   12   12
114   130   209    52   190    0.0000    128.7   95.4   13.4     1440   14   14
115   131   275    15   260    6.5000     96.2   90.4   49.5   530167    0    0
116   132   180    10   170    0.4800    394.5   85.9   42.5    11434    7    7
117   133   320    25   295    2.7250    832.0   95.9   31.3      377   50    5
118   134   244   190    56    7.6160    318.7   76.8   10.4   150000    9    9
119   135   150    80   141    0.0000     11.5   95.1   32.6        0    6    6
120   136   170    16   154    0.1050     17.3   95.9   31.3      893   22   22
121   138   226    52   176    0.2500    155.3   92.9   37.1      897    8    8
122   139   208   174    40   28.1940   1816.4   75.9   12.6   150000   20    1
123   140   220    10   212    0.1953   1728.2   75.9   12.6       17   11    6
124   141   163   132    31    2.7200    739.0   87.4   38.0   109800   18   18
125   142   188    33   155    0.1280    255.9   92.0   68.1   150000   14   14
126   143   232    23   224    0.2592     64.0   82.0    9.8        0   19   19
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  OBS    ID    FLOW72      DFLOW      FUEL      MAIN    TRANS      WAGE          Y1

    1     1      2.68       3.00      7562       590        0     14967      232875
    2     2    120.00      97.50         0     99367        0    428397     1379442
    3     3      1.90       1.33       729      1620        0     17031      145764
    4     4     13.17      21.50     79725     42804    10688    326486      817681
    5     5     23.00      23.00     41744     44323        0    290296     1600805
    6     6      2.67       4.20     10164     14081      578     36249      375838
    7     7      2.40       4.50      2333      1667     1000      8333      170716
    8     8      4.33       8.00     32272      3895     8798     73551      248700
    9     9     66.63     100.00     37280    193443    24676    296776     1168049
   10    10      5.77      10.00      5911      2099        0     32705      252747
   11    11      3.80       3.60     19111      3816        0     34803      474290
   12    12      0.65       1.00      3216     26968     1588     29555      131784
   13    13      1.40       3.00     10643      3844      452     32112      182902
   14    14     20.99      20.00    491233    187048    62942    748586     2342945
   15    15      1.00       1.20      2010      5246        0     24271       31527
   16    16      4.10      17.10     35013         0        0     53342      283400
   17    17      1.16       1.00     12278     13413      742     51736       97235
   18    18     18.26      60.00     68733     21375        0    116767      625939
   19    19      3.00       9.00     14561     41573     5050     67998      256364
   20    20      1.89       2.50      4892      7991        0     25713       38596
   21    21      5.48      12.00     33333      2667     2333     66667      625077
   22    22      0.90       0.95      4439       719        0     11429       58285
   23    23      1.36       1.20     15067     15304     3275     49981      155717
   24    24      6.39       2.60     25023      6811      574     55780      207767
   25    25     79.70      78.00    212183         0        0    250988     2028273
   26    26      1.75       4.00     16362      6980        0     93712     1936926
   27    27      2.80       4.50      2432      5929     1399     17121      159380
   28    28      0.15       0.15         0      1232        0      1389        8681
   29    29      0.90       1.45      5110     10139     1141     27142       77763
   30    30      5.87       6.00      2092      6932      308     64336      176465
   31    31      1.90       1.50      3021      4133     1877     54314      231490
   32    32      0.94       1.50     22306      6685        0     77882      313537
   33    33      8.10       8.00     40846         0        0    102055      691071
   34    34      2.40       2.40         0     32101        0     40030      110423
   35    35      0.75       2.20      1817       534        0      5344       35627
   36    36      7.03       5.00     17966     46782     3053     76261      253617
   37    37     82.50      94.00    369782    429095     5307    731187    11098152
   38    38     14.50      14.00     13667      3788     1474     37392      845410
   39    39    102.80     130.00    376915         0        0    446425     2110574
   40    41     17.95      16.00     43921     32294    40688    109676      638687
   41    42      5.70       6.00     11333     10000      500     20000      211152
   42    43     24.70      30.00     10688     25248    16385    165401     1328874
   43    44      2.40       4.00      5530      3992      524     17849      239531
   44    47      0.53       0.75      2467       716      400      3497       32738
   45    48      2.50       3.50      2525      2029     1069     17350       70612
   46    49      0.80       0.75       293      5099       96      5469       31915
   47    50      1.00       2.30     11671     35870        0     59928      342231
   48    51      2.00       3.00       517      3676      314     22777       66230
   49    53      1.16       1.45      2826         0     1523     10542       95759
   50    54      3.20       5.00      1400      1333      867     17333      173654
   51    55      1.00       2.00      3649         0        0     16952       61127
   52    56      4.90       5.30      1167      3000       67      6667      237057
   53    57      3.60       8.00     21672      4525     1815     37817      423253
   54    58      3.24       4.30      7353      9075     3027     63849      166064
   55    59      2.78       3.25     13724     14909      210     64839      125208
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 OBS    ID    FLOW72    DFLOW     FUEL      MAIN     TRANS      WAGE          Y1

  56    60      3.10     7.00     4348     14691         0     11808      570557
  57    61      2.40     2.10     1051      2930       473      6803       84424
  58    62     11.95    21.50     8491     33969         0    117062      261480
  59    63      4.48     6.50        0      5449      1119     67159      426089
  60    64      0.55     0.48     5947      3333      2667     11438       80163
  61    65      1.30     1.00     3064      7478       704     31678       65145
  62    66     26.98    30.00    84476    157366         0    170182      565759
  63    67     29.24    36.90    75591     35398     13311    308312      778720
  64    68      0.50     0.60     3133         0         0      9333       47471
  65    69      1.50     5.00     5596     20286         0     18632       81292
  66    70      0.82     1.75        0         0         0         0       41305
  67    71     12.50    12.00        0     97601         0    208375     1048038
  68    72     14.93    25.00    58660     18918         0    109708      560208
  69    73      4.40     8.00    11323     36802         0     81144      350072
  70    74      3.40     5.00    28243     34936      2239    146489      420895
  71    75      3.69    10.00     5000      7900         0      7071       46765
  72    76      0.28     0.85     1956       260         0     12122       14338
  73    78      2.50     3.00    14874      7434       597     47664      146905
  74    79      0.08     0.06        0       613       134       386        1133
  75    80      0.50     1.00      214       534       107       855        7403
  76    81      1.00     1.00        0         0         0     36096      175108
  77    82      1.38     1.50      473      2474       214      5212       28322
  78    84      2.09     4.00     6533         0         0     13333      169675
  79    85      2.24     3.00    11857     10388         0     84830      237842
  80    86      0.45     0.75     1760     19765       100      6711       92589
  81    89      1.22     1.40    12212      5618         0     28530       90586
  82    91      1.58     2.56     1525      3421      1200     15333      168599
  83    92      0.08     0.15      420         0         0      2000       25019
  84    93      7.95     9.00    45122     22574     21445     79434      565410
  85    94     16.78    34.00    15843     82814         0    124752      869058
  86    95     55.82    47.00        0    288649    433668    652634     2512645
  87    96      1.41     2.20     1005      4463       532     27970       79051
  88    97     30.00    44.00    32864    174573         0    334960     1297029
  89    98      2.30     2.50        0      2515       768     26308       83980
  90    99      0.55     1.00     1467       221         0      1666       23958
  91   101      5.40     4.00    11322      3859       859     63442       79482
  92   102     11.50    10.00        0     54598         0     74341      162236
  93   104      1.50     2.30    11837     41182         0     40302      227467
  94   105      1.87     2.20     4267      1200       333     16333      211632
  95   106      2.20     3.50        0    221887         0     83296      421952
  96   107     18.40    13.00     9350     38277         0      6167      801534
  97   110      0.25     0.45      773      4146       383      4229       29595
  98   111      4.20     4.00     7861     10493         0     39472      836731
  99   112      0.43     1.00      377         0         0       746       25582
 100   113      9.13    16.44    13947     11517         0     42362      282562
 101   115      1.80     1.35     6813     10526      1741     44759      113295
 102   116      6.50     7.35     4800         0       200     24000      184781
 103   118      2.00     1.00    13392      2833         0     45350       95131
 104   119      2.07     2.50     4915     31783      1116     17159      124547
 105   120      0.55     0.48     1345      2000         0      6800       33870
 106   121      6.66     9.00    13936     12481       191     80185      199787
 107   123      1.64     2.00     6450         0         0     36467       42917
 108   124      0.44     3.00        0         0         0         0      661669
 109   125      3.20     7.00     9333       667       133     10000      186438
 110   126      4.20     2.70     8255     11890      1149     41157      243271
```

ID	FLOW72	DFLOW	FUEL	MAIN	TRANS	WAGE	Y1
127	1.70	3.00	484	3594	107	4977	33634
128	0.75	0.52	2265	1216	0	6319	28937
129	3.60	4.00	41882	29107	1089	63525	293771
130	0.21	0.60	223	1040	0	1996	12077
131	13.00	20.00	46667	1500	0	34667	455935
132	1.60	2.00	8424	2578	605	32910	269396
133	54.50	75.00	47069	36654	0	243509	3468029
134	95.20	88.00	0	0	0	100685	2063127
135	0.34	0.52	0	0	0	0	13167
136	0.70	1.00	1260	886	478	5312	43196
138	5.00	3.50	6751	5730	0	42100	130410
139	140.97	184.00	224688	184134	119607	662029	5531150
140	2.79	5.00	23785	39346	5836	39576	273800
141	16.00	19.90	53255	21522	1894	228575	464337
142	6.40	16.00	31643	0	0	98846	594542
143	2.88	5.50	10000	1667	500	23000	221132

ID	FLOW72	DFLOW	FUEL	MAIN	TRANS	WAGE	Y1
127	1.70	3.00	484	3594	107	4977	33634
128	0.75	0.52	2265	1216	0	6319	28937
129	3.60	4.00	41882	29106	1089	63525	293771
130	0.21	0.60	223	1040	0	1996	12077
131	13.00	20.00	46667	1500	0	34667	455935
132	1.60	2.00	8424	2578	605	32910	269396
133	54.50	75.00	47069	36654	0	243509	3468029
134	95.20	88.00	0	0	0	100685	2063127
135	0.34	0.52	0	0	0	0	13167
136	0.70	1.00	1260	886	478	5312	43196
318	5.00	3.50	6751	5730	0	42100	130410
139	140.97	184.00	224688	184134	119607	662029	5531150
140	2.79	5.00	23785	39346	5836	39576	273800
141	16.00	19.90	53255	21522	1894	228575	464337
142	6.40	16.00	31643	0	0	98846	594542
143	2.88	5.50	10000	1667	500	23000	221132

```
ID       P1       P3          P5    PCTLOC        PAG      PIR        PS    STATE     TYPE

 1     3.54    3.188      731.67     1.000      499.2    10.00     16000       17        2
 2     3.76    3.447     1058.05     1.000     1256.0     8.28    935000        5        1
 3     3.39    3.188      731.16     0.839     1759.9    28.00      9000       17        1
 4     4.55    2.690      791.88     0.783      808.6     5.88    180000        3        1
 5     3.50    2.929      945.05     0.783    25840.7     0.00    110000       11        1
 6     4.05    3.840     1736.96     0.478     5274.3     0.00     15000       23        1
 7     4.47    2.690      737.64     0.478     4393.5    57.96     31000        3        1
 8     2.64    2.545     1093.58     0.879      685.6     0.00     30000       20        1
 9     4.03    3.133      558.47     0.877      769.3     0.00    495000       14        1
10     3.11    3.188      737.49     0.877      726.3    28.00     60000       17        1
11     2.52    2.545      799.21     0.835      441.9     0.00     20000       20        1
12     4.47    2.690     1158.09     0.868     4393.5    57.96      7500        3        1
13     4.05    2.690      992.13     0.863     1954.2    30.28     23000        3        1
14     4.53    2.690      901.86     1.000    20733.9     5.88    200000        3        1
15     2.74    2.980      -12.22     1.000      357.6    11.58     12000        9        1
16     3.10    2.690      848.54     0.765      490.4     8.32     28000        3        1
17     5.51    3.447      738.90     0.478      114.7     8.28     15871        5        1
18     3.68    2.690      609.46     0.765      867.7     8.32     78000        3        1
19     4.44    2.690     1058.18     0.702     1034.6     5.88     21000        3        1
20     3.82    2.912     1127.75     1.000      234.8     0.00     22000       25        1
21     3.93    3.188     1240.76     0.644     1521.6    28.00     50000       17        1
22     3.29    3.133      626.96     0.892      218.0     0.00      6676       14        1
23     4.55    3.251      878.53     1.000     1231.9     0.00     14651       24        1
24     3.48    2.855      689.45     0.900      292.3     0.00     25000       15        1
25     4.30    3.840      964.56     0.877     3198.9     0.00    500000       23        1
26     4.63    2.912      954.96     0.868      487.2     0.00     26131       25        1
27     2.46    2.545      688.52     0.775      451.3     0.00     30000       20        1
28     2.15    2.980      388.66     1.000      198.0     8.28      2700        9        1
29     3.11    3.188      659.94     0.783      726.3    28.00      2800       17        2
30     2.15    2.545      677.35     0.900      415.1     0.00     22000       20        2
31     3.79    3.285     1438.83     0.702      140.9     2.47     16000        4        1
32     4.77    3.188      797.63     0.863      455.3    28.00     10452       17        1
33     3.07    2.545      513.12     0.478      666.9     0.00     55000       20        1
34     3.79    2.690      859.09     1.000     1268.9     8.32     22000        3        2
35     3.35    2.690      984.12     0.879      607.5     8.32      6000        3        1
36     3.34    2.690      835.27     1.000      669.7     1.91     60000        3        1
37     5.01    2.690     1380.55     0.835     1422.3     5.88    750000        3        1
38     3.20    3.447     1158.60     0.644      297.3     8.28    120000        5        1
39     2.82    3.447     1075.84     0.785      448.0     8.28    714390        5        1
41     3.62    2.545      803.13     0.783      642.8     0.00    130000       20        1
42     2.77    2.545      809.29     0.868      440.6     0.00     40000       20        1
43     3.84    3.081      761.86     0.765      470.8     0.00    135000       16        1
44     2.66    2.545      716.92     0.835      439.2     0.00     17000       20        1
47     2.42    2.545      799.93     0.868      314.7     0.00      7000       20        1
48     2.69    2.967      841.70     0.900      411.4     0.00     15000       18        2
49     2.14    3.027      788.86     1.000      276.8     0.00      4000       19        1
50     3.90    2.690     1274.91     0.478      888.4     8.32     16100        3        2
51     3.35    2.690      817.28     0.478      607.5     8.32     17000        3        2
53     3.22    2.690     1141.96     0.644      731.9     8.32      8400        3        2
54     2.66    3.786      715.26     1.000       66.7     2.20     40000        6        2
55     3.25    3.447      707.87     0.892      162.7     8.28     12000        5        2
56     2.48    3.447      911.80     0.877      148.0     8.28     75000        5        2
57     4.01    2.690     1032.17     0.783      178.3     8.32     18000        3        1
58     4.05    2.690     1274.27     0.879     1954.2    57.96     42500        3        2
59     3.88    1.750      932.78     0.785     1162.8     2.29     16600        1        2
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ID	P1	P3	P5	PCTLOC	PAG	PIR	PS	STATE	TYPE
127	4.53	2.980	450.73	1.000	330.00	11.58	8561	9	1
128	3.96	3.447	1040.01	0.702	78.67	8.65	7000	5	1
129	4.48	2/690	962.15	0.863	995.23	57.26	44000	3	1
130	3.68	2.690	917.94	0.877	867.72	8.32	2150	3	2
131	2.79	3.098	819.10	0.478	445.93	0.00	50000	12	1
132	4.04	3.840	879.78	0.839	1176.56	0.00	16663	23	1
133	4.03	3.447	753.68	0.775	858.67	8.28	600000	5	1
134	4.48	2.690	931.27	0.863	995.23	57.26	999999	3	2
135	3.20	3.447	822.81	9.783	188.00	8.28	4000	5	2
136	3.20	3.447	537.92	1.000	141.33	8.28	8000	5	1
138	2.62	2.980	557.13	0.835	421.20	11.56	60000	9	2
139	4.47	2.690	682.32	0.644	4393.52	57.26	999999	3	2
140	4.28	2.690	1161.78	0.783	1134.15	57.26	36000	3	2
141	3.80	3.133	835.95	1.000	314.14	0.00	170000	14	1
142	3.86	3.081	1019.17	0.877	395.64	0.00	80000	16	1
143	3.79	2.690	888.74	1.000	1268.92	3.05	33000	3	2