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AN ENGINEERING, ECONOMIC, AND FINANCIAL FEASIBILITY ANALYSIS OF WASTEWATER REUSE IN EASTERN PALM BEACH COUNTY, FLORIDA

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And finally, none of this could be done without the assistance of my wife Laura, who provided the "cut-and-paste" artistry and moral support.

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Two different cost allocation methods were used to allocate the costs to individual potential users, a simple method based on flow and the game theory method. Of a total demand for reused water of 83 MGD, 7.5 MGD was found to be cost effective using the simple "added-pipe" rule allocation method, 15.2 MGD using the game theory method, and pooling all the benefits and costs, 38.3 MGD. It is expected that the true cost effective system size will lie somewhere between these values.

James P. Heaney

Dr. James P. Heaney, Chairman

CHAPTER 1: INTRODUCTION

This report presents the wastewater reuse feasibility study, a comprehensive economic, engineering, and financial feasibility analysis of wastewater reuse in eastern Palm Beach County. The area was chosen out of all the counties in the South Florida Water Management District (SFWMD) because of the large amount of potential irrigation sites. Involved in this task are surveying the SFWMD for potential users and suppliers, selecting a test area in which the analysis will be performed in order to evaluate wastewater reuse as a potential water supply option, costing the proposed networks, allocating the costs to the users. The users will be ranked in order of cost, and this information will be used to find the total size of a net zero cost system.

The thesis presents these details in basically this order. In Chapter 2, the study area is introduced, and the wastewater reuse problem is presented. Chapter 3 reviews other approaches to similar types of problems. The methodology of the study is presented in Chapter 4, and its application to Palm Beach County in Chapter 5. Chapter 6 presents the conclusions that can be drawn from the wastewater feasibility study, and recommends where further research can begin.

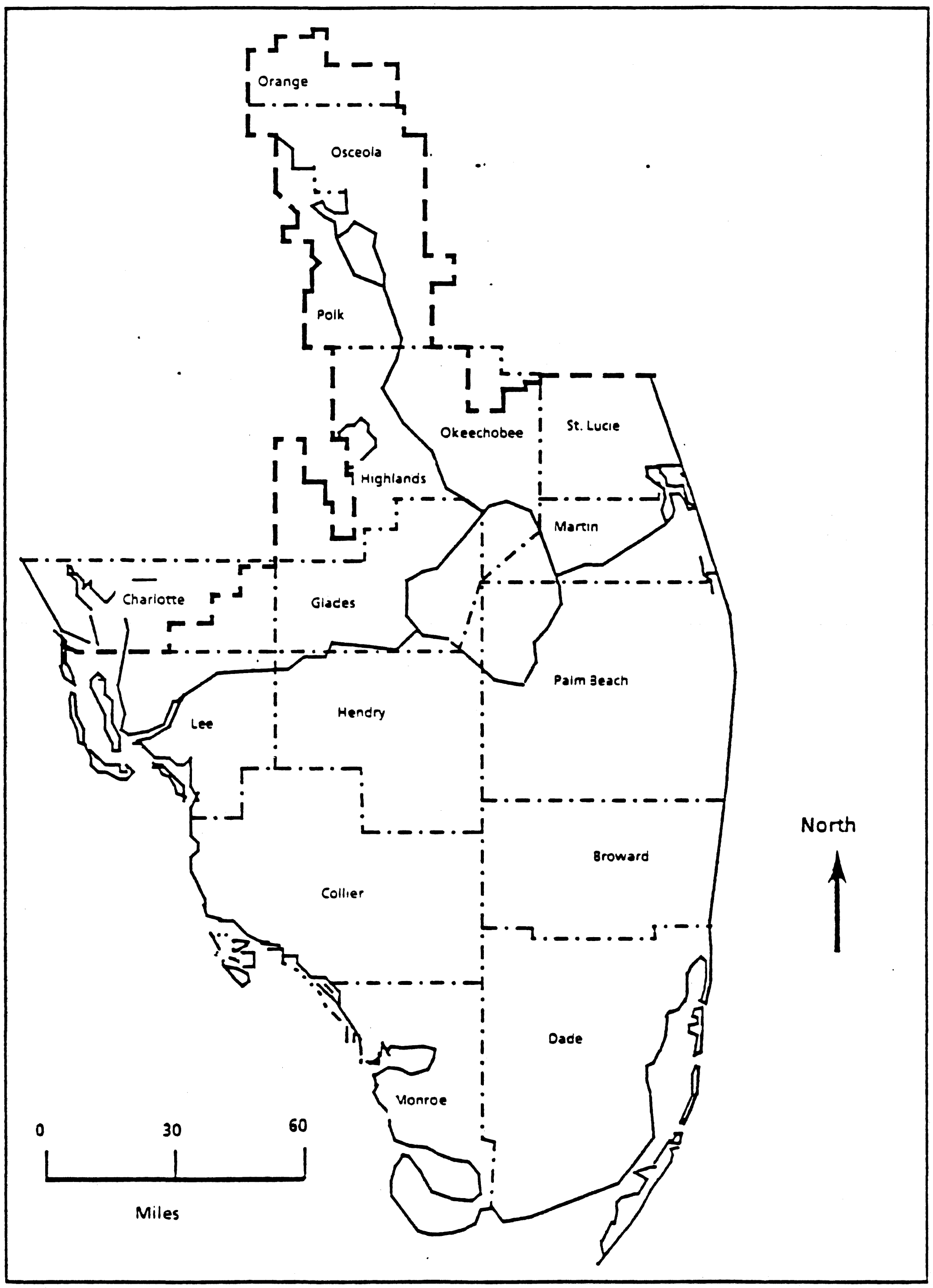


FIGURE 2-2: LOCATION OF STUDY AREA (PALM BEACH COUNTY) WITHIN THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

TABLE 2-1 INDICATORS OF WASTEWATER REUSE POTENTIAL WITHIN THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

	SUPPLY POTENTIAL		DEMAND POTENTIAL		SYSTEM POTENTIAL	
COUNTY	PRESENT APPROVED CAPACITY[a] (MGD)	ESTIMATED 1990 WASTEWATER FLOWS[b] (MGD)	PERMITTED URBAN LANDSCAPE ACRES[c]	POTENTIAL USE[d] (MGD)	MAXIMUM POTENTIAL SYSTEM[e] (MGD)	CO. SHARES OF MAXIMUM POTENTIAL SYSTEM (PERCENT)
Broward	200.45	114.39	10,289	79.8	79.8	32.2
Collier	33.90	8.95	4,425	34.3	8.9	3.6
Dade	302.78	158.31	6,145	47.7	47.7	19.2
Glades	0.00	0.00	195	1.5	0.0	0.0
Hendry	2.50	1.00	129	1.0	1.0	0.4
Highlands	0.00	0.00	0	0.0	0.0	0.0
Lee	70.13	19.88	5,607	43.5	19.9	8.0
Martin	9.50	4.38	2,654	20.6	4.4	1.8
Monroe	24.30	3.51	118	0.9	0.9	0.4
Okeechobee	4.00	0.00	0	0.0	0.0	0.0
Orange	17.00	7.61	976	7.6	7.6	3.1
Osceola	9.70	9.70	498	3.9	3.9	1.5
Palm Beach	94.60	66.60	14,378	111.5	66.6	26.8
Polk	0.00	0.00	205	1.6	0.0	0.0
St. Lucie	7.00	8.04	965	7.5	7.5	3.0
TOTAL	775.86	402.37	46,584	361.4	248.2	100.0

a. Covers plants with a capacity approved by DER of 1.0 MGD or more.
b. When flows were estimated to be less than 1.0 MGD, they were recorded as 0.0.
c. Covers SFWMD permit categories of golf courses, landscape and recreation areas.
d. Estimated from the acreages using an application rate of two inches per week.
e. Estimated as the smaller of the supply potential of 1990 flows (column 2) and the potential use (column 4).

All the counties within the District were inspected, to find the county which should be selected as a "test case" for the feasibility analysis. Then the county selected was subjected to a detailed feasibility study, involving the optimization and design of the networks, the estimation of various costs for coalitions, the selection of a "fair" charge for each coalition, and the evaluation of each member as to its relative economic benefits and costs.

Regulatory Requirements

The state of Florida, through the Florida Department of Environmental Regulation and the Florida Department of Health and Rehabilitative Services, has a complex set of regulatory requirements for wastewater reuse. Since DER's standards exceed those of the EPA, they will be used for the design.

The Florida DER classifies wastewater reuse schemes as slow-rate, high-rate, overland flow, and absorption bed (septic tank) systems (Florida, State of, DER, 1982). This reflects the influence of the EPA's classification scheme (U.S. EPA, 1978), in which wastewater reuse (unless it is linked in a closed loop to potable reuse), is defined as a land application scheme for disposal of wastewater; with the differentiation being that of the rate or method of application (e.g. overland flow, high-rate, slow rate). In Florida, slow-rate application of wastewater predominates, because of the shallow ground-water table, and the stringent regulatory requirements.

The following list summarizes the regulatory requirements having the greatest economic impact on the overall design (DER, 1982):

1. BOD-same as secondary requirements
2. TSS-less than 5 mg/l
3. no detectable fecal coliforms
4. alternative discharge systems
5. 3 day minimum storage requirement
6. buffer zones-500 feet minimum distance to potable wells.
7. buffer zones-public access-none required if irrigation is at night.
8. monitoring wells may or may not be required, depending on the hydrogeology of the site.
9. 2 inches per week maximum application rate for slow rate system (on an annual basis). This can be raised in specific instances if the hydrology permits.

In application these requirements may be individualized somewhat, as the enforcement of the regulations is left up to local DER officials, on a "case-by-case" basis. The treatment processes needed to meet these regulations are advanced secondary, followed by chlorination. Most treatment plants in South Florida currently treat wastewater to secondary standards. The inclusion of a tertiary filter (sized only for the flow to be used in the wastewater reuse system) and additional chlorination facilities would bring the wastewater up to these standards. The alternative disposal requirement probably has the greatest impact on costs, especially in cases in which the utility is at a decision point as to its disposal options. For example, the Loxahatchee River Environmental Control District 201 Region (ENCON), located in North Palm Beach county and southeastern Martin county, is at such a decision point regarding its disposal options (Dent, 1982). However, due to the requirement of having a structural disposal method in addition to whatever wastewater reuse is developed, the cost savings are reduced from all of the capital and operating costs to only the operating costs. These costs were evaluated for the ENCON region, and for both deep well injection and percolation/evaporation ponds the capital costs in each case were $.48/1000 gallons; whereas the operating costs were only .05$/1000 gallons--indicating a significant economic impact due to this regulation (Robinson, 1981). The Florida DER has established this requirement because they don't want <u>any</u> substandard effluent to be applied to the irrigation sites, where public contact may become a possibility (Mozella, 1983).

A substantial impact on this subject may already have decided the issue. Treweek and TeKippe (1982) constructed water quality topographs (plots of water quality with respect to time and distance that, coupled with stringent water quality standards, and the effluent dilution requirements, the decision was made to construct "coastal wastewater treatment plants, and outfalls with diffusers. Each of these outfalls, (which are used by many of the major treatment plants in south Florida) may become licensed to discharge primary treated wastewater in the near future. This would ultimately have a large negative impact on wastewater reuse as a water supply alternative.

Apparently, at this time, it was found that the policy of SFWMD of encouraging wastewater reuse in order to improve the regional water supply, and DER's policies on reuse conflicted, but Rogers (1982) found that the conflicting policies between DER and SFWMD concerning reuse could be resolved. He points out that the requirement of the District for 3 day storage of effluent until it reaches the receiving water body matches that of the DER. In order to demonstrate ways that the Florida DER could encourage reuse, Maloy (1982) suggests rewarding municipalities for participating in wastewater reuse projects by sliding scales of increasing state matching funds.

The historic drought precipitated discussion within and outside the SFWMD on requiring wastewater reuse to some extent. Niego (1982b) outlines the question of whether the SFWMD has the authority to deny water use permits based on the availability of wastewater for Reuse. In Niego (1982a, b). Contingent to any proposed rule is a required analysis of the impact of the costs of the regulation, part of which this project will attempt to address.

In a broad outline of the major costs and projects to be accomplished in the study, Sample (1982) determined that the major capital, operating, and maintenance costs to be evaluated were:

1. transmission lines,
2. pumping,
3. additional treatment costs (tertiary filtration),
4. costs of storage and/or an alternative disposal during wet periods,
5. costs of alternative disposal methods (as required), and alternative supply methods, and
6. benefits due to increased water supply.

District-Wide Survey of Supply and Demand of Wastewater

The first task of this study was to identify potential users and possible suppliers of wastewater District-wide, and to determine the relative balance between the two. This is useful in obtaining an estimate of the potential regional significance of wastewater reuse within the SFWMD. It will also point out which areas in the system are most likely to be supply constrained and which areas are most likely to be demand limited.

To identify the potential suppliers, the names, design capacity, treatment type, and disposal method of all treatment plants within the District of 1 mgd or more capacity were obtained from a centralized computer listing provided by the Department of Environmental Regulation (DER). As there were some missing data within this list for a small fraction of the treatment plants, it was supplemented by information from the various 201 planning documents and information from regional planning councils such as: Barker, Osha, and Anderson, Inc. (1975); Broward, County of, Planning Dept. (1980); Camp, Dresser, and McKee (1981); CH_2M Hill and Hensley Schmidt, Inc. (1979); CH_2M Hill (1982), Dade County, Office of Planning (1982); Frederick Bell, Inc. (1977); Greeley and Hansen, and Connell Assoc. (1973); Howard Needles Tammen and Bergendoff (1980); Johnson-Prewitt and Associates, Inc. (1978); Palm Beach County, Area Planning Board, Environmental Quality Division (1978); Palm Beach County, Area Planning Board of (1981) Phillips, K.J., et al.(1982); Robert and Company Associates, and William M. Bishop, Inc. (1978); Ross, Saarinen, Bolton, and Wilder (Camp, Dresser and McKee) (1979); Russell and Axon, Inc, and Barker, Osha, and Anderson, Inc. (1980); Russell and Axon, Inc. (1980); Russell and Axon, Inc. and PRC Harris, Inc. (1982); Smith and Gillespie Engineers, Inc. (1978); Southwest Florida Regional Planning Council (1980), Stiller, D.B., and Assoc. (1982); and Williams, Hatfield, and Stoner, Inc. (1982).

Counties that are only partially within the district were surveyed, and only those treatment plants located within the SFWMD boundaries were included. Total capacities by county are presented in Table 2-1. The individual treatment plants, their design capacities, type of treatment, and disposal methods are presented as Appendix Table A-1.

The values in Table A-1 were used in the following analysis in order to determine an accurate estimate of the expected wastewater supply within each county. A comparison of these capacities with historical flows in several counties revealed large discrepancies indicating that the capacities are inadequate as an indicator of present supply capability or of the capability at any specific time in the future. These discrepancies probably arise because capacities are meant to cover peak rather than average flows and generally include capacity installed to handle future growth although the amount of this excess present capacity seems to vary significantly from county to county. For this reason projections of average wastewater flows were formulated for the District by county using projected 1990 populations, an estimated percentage of the population served by sewer systems and a planning estimate of wastewater generated of 100 gallons per capita per day. The projected populations were taken from the most recent medium growth rate projections produced by the Bureau of Business and Economic Research of the University of Florida, 1982. For counties not entirely within the District future District shares of population were estimated to be the same as 1980 shares developed from the 1980 Census of Population and Housing . The percentages of the population served by sewers were also estimated using the shares of dwelling units so served from the 1980 Census of Population and Housing. The year 1990 was selected as a reasonable time in the future when comprehensive wastewater reuse systems could be implemented. The projected 1990 average wastewater flows by county are presented in column 2 of Table 2-1.

The potential supply figure represents an upper bound to the wastewater reuse potential in a given county, since it is assumed that any potential system is feasible as long as there is a supplier and a user. In fact, other problems including proximity within the county and direct cost considerations may well serve to further limit the possible system. These considerations are more thoroughly investigated in Chapter 5. The figures roughly correspond to population using average per capita usage, with the exception of the West coast counties of Lee and Collier, which, due to their rapid growth, lack of regional facilities, and a high seasonal population, have a large amount of unutilized capacity. The data show that the less populated counties in the District (i.e., Glades, Hendry, Okeechobee, and Polk), have very little capacity or wastewater flows available for reuse. Dade, Broward, Palm Beach, and Lee counties, on the other hand, have the largest supply capabilities, and projected flows. Palm Beach county clearly has the most potential demand, followed by Broward, Dade, Lee, Collier, and Martin. Within this group, only Dade and Broward counties have more supply than demand. Those counties that have more supply than demand in Table 2-1 are italicized. Taking the minimum of the potential demand and the potential supply for each county as an indication of the maximum size limitation of any wastewater reuse system within any county provides the data in column 5 of Table 2-1.

Selection of the Test Area

A bar chart was constructed based on the information given in Table 2-1 (see Figure 2-3). This was done in order that the respective counties could be compared among the 3 factors previously defined, 1990 wastewater flow , potential for wastewater reuse, and maximum wastewater reuse system. By far the greatest potential is within the three Lower East Coast counties,i.e., Dade, Broward, and Palm Beach. The total of 248.2 MGD represents about one quarter of the estimated potable water consumption within the District. Three quarters of the potential system capacity would be located in the populous Lower East Coast counties of Dade, Broward and Palm Beach; with Broward county showing the largest single share (32.2%).

However, having a wastewater reuse system would have significant impact on water supply capabilities only during periods when the source (aquifer) is not full and discharging. Thus, in the Lower East Coast, a wastewater reuse system would contribute to water supply capabilities only when discharges are not being made to tidewater. Once this occurs (discharges stop), the wastewater reuse system will tend to have a cumulative impact on total water in the aquifer approximately equal to the sum of the daily wastewater reuse for the period of no discharge. For the Lower East

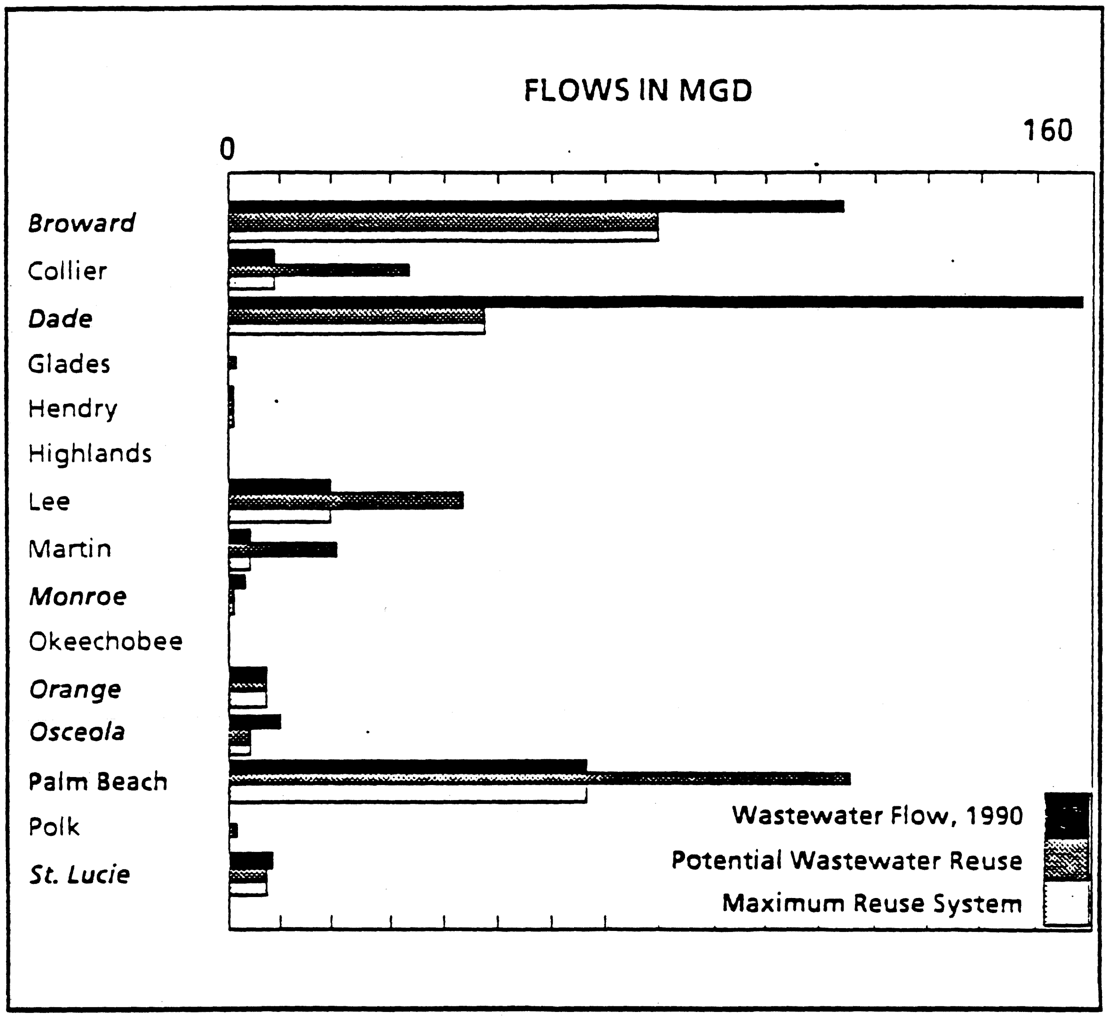


FIGURE 2-3: SUMMARY OF WASTEWATER REUSE POTENTIAL WITHIN THE SFWMD

Coast counties this could amount to a maximum of 71,500 AF at the end of a drought which brought a four month period of no discharge. The significant potential size of the wastewater reuse system compared with other water supply augmentation options, indicates that a closer look should be taken at the costs and impacts of such a system on users and suppliers, and on the benefits of the regional system as a whole. These costs and impacts are developed and discussed in Chapters 3 and 4 and are used to test the economic feasiblity in eastern Palm Beach County in Chapter 5. Palm Beach County was chosen for the analysis mainly because it has the largest potential for wastewater reuse due to the large concentration of golf courses within the area. The other 2 counties, Broward and Dade, may also be candidates for consideration in later analysis (not a subject of this research).

CHAPTER 3: ANALYTICAL APPROACHES TO SOLVING COMPLEX WATER RESOURCES PLANNING PROBLEMS WITH APPLICABILITY TOWARDS WASTEWATER REUSE PLANNING

In planning or designing any wastewater irrigation system, several economic conditions prevail that complicate the analysis. The economies of scale involved are non-linear functions of many unknown variables, and several simplifications and/or optimization procedures may need to be performed in order for the problem to be solved. This is especially true in preliminary planning studies, in which case the cost of obtaining more data may actually exceed the cost of the design (Clark and Dorsey, 1982). This chapter elucidates how others have attacked this problem from widely varying points of view. The next chapter develops techniques adapted from these sources so that they may be applied to the study in eastern Palm Beach County, Florida.

The methods of analyzing these types of problems were grouped somewhat arbitrarily into the following four major categories:

- Economic studies: Studies that use generalized microeconomic criteria to judge the feasibility of wastewater reuse projects.
- Cost estimation techniques: Use of various methods, mainly regression analysis, in order to evaluate costs of wastewater reuse projects and thereby determine their feasibility.
- Planning models: Use of operations research techniques to optimize proposed networks of wastewater sources and sinks (suppliers and users).
- Cost Allocation techniques: How to divide up the non-separable costs of a wastewater reuse project among the various users.

Of course, studies within these categories may overlap to varying degrees, but consideration of all of these approaches is necessary to develop a consensus in evaluating the costs and benefits of wastewater reuse.

Economic Studies

As a water supply alternative, a wastewater reuse system must compete in the marketplace for available funds with other available water supply options. Young (1982) presents a economic model in which he applies basic microeconomic principles to aid in evaluating the factors that influence decisions on reuse. He evaluates the positive and negative aspects of wastewater reuse with regard to the economic impact of its quantity and quality, organic and nutrient content, and heavy metals and viruses. As there is no reason to assume the equilibrium price (for wastewater) is a positive value, the charge should be based in part on amount to be provided, the desired wastewater characteristics, and alternative disposal options, availability of alternative sources of water supply, and public concern. This means that if it costs more to dispose of the wastewater than it would to implement a reuse system, then it may instead prefer to pay subsidy to encourage the reuse of wastewater.

Horne, et al. (1981) , and the Orange and Los Angeles Counties (1982), present a screening/market analysis. They found that southern California is an unusual case in that no other area in the U.S. lies as far from its source of water supply as Los Angeles and Orange counties. As such, the large extent to which wastewater reuse is utilized in southern California is primarily based on two considerations, namely the dry climate, and the relatively high alternative costs of water supply. Neither of these conditions are present in southern Florida, so care must be taken in applying the results from the OLAC (Orange and Los Angeles Counties Water Reuse Study) analysis. Their three steps to a preliminary analysis were:

1. Customer screening
2. Evaluating the market priorities-Ranked A-D in order of level of required treatment
3. Identifying the service areas

The study found that most of the cost of a reuse project is capital (60-75%), and most of the project cost is in the distribution system elements. Part of the purpose of the study was to develop a set of criteria in order to evaluate the potential users quickly, using statistical cost functions of relevance to the area.

Bruce and Lee (1981) also did a market survey and analysis for the EBDA (East Bay Discharger's Authority) located on the Southeastern shore of San Francisco Bay. This study evaluated possible wastewater re-users as to their cost-effectiveness, based on available technology. This was accomplished by estimating the costs, comparing, and screening the possible users in an iterative process thereby reducing the list of possible projects considerably. They compared wastewater reuse with existing water supply costs and the local share of capital projects, and the incremental cost of freshwater supplies, and ranked the users in terms of cost-effectiveness. In their analysis, they evaluated the costs of serving several users, and developed the curves shown in Figure 3-1 to help in screening potential users, in order to serve the most economically efficient ones. These curves illustrate the economies of scale of area (related to flow), and a similar relationship of costs with distance.

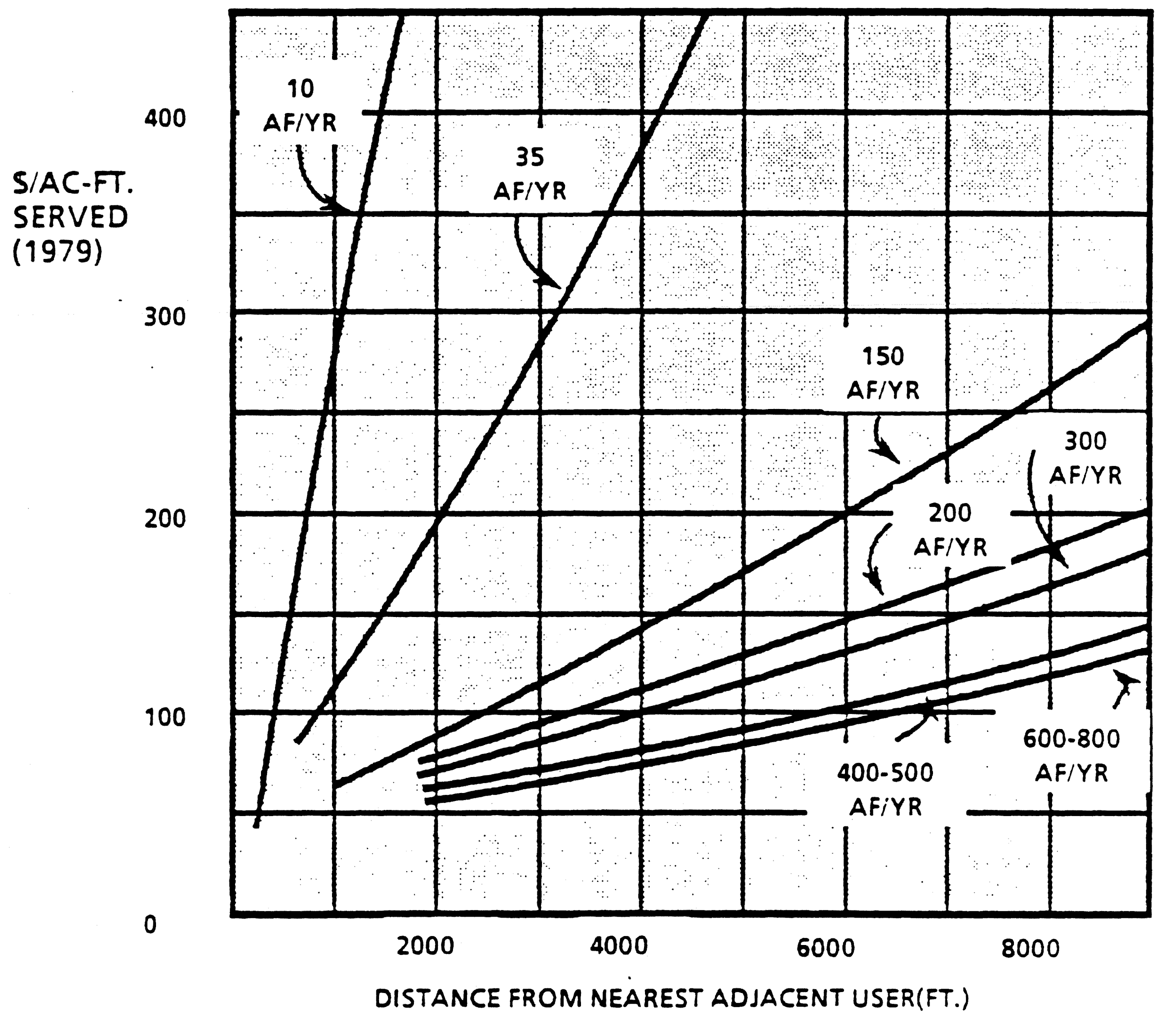


FIGURE 3-1: EBDA COST CURVES FOR IRRIGATION RATES FROM 10 TO 800 AF/YR., VS. DISTANCE FROM THE NEAREST USER

Clark, et al. (1982) indicates that the water supply problem in the Washington, D.C. metropolitan area is due to the highly variable flows in Potomac River, and the lack of storage facilities. They did a simple cost allocation, dividing the costs between wastewater treatment and water supply (60/40). They found that wastewater reuse was the worst alternative of the different options available to the area, and would only become feasible if wastewater standards were required to meet Drinking Water standards. Water conservation was found the best alternative for the Washington area.

A summary of the benefits of reuse is provided by Donovan and Bates (1980):

- Conservation of water
- Recycling of nutrients
- Cost and energy savings
- Reduction in the discharge of pollutants
- Realization of other public priorities (such as recreation)
- Encouragement of industrial recycling

The study by Schmidt et al. (1975) presents a checklist for determining the potential practicality of wastewater reuse. This list is essentially the main variables that will have an impact on the cost analysis.

1. Existing or future freshwater supply is limited relative to demand.

2. Existing or future fresh water supply is expensive.

3. The area presently includes or will include individual reusers of large volumes of water.

5. Requirements for improved wastewater effluent are impending or anticipated.

6. Wastewater dipsosal is expensive; e.g., a long outfall line is required.

Cost Estimation Techniques

These studies present numerical models which attempt to approximate the production function relationships between the modelled inputs and outputs, in most cases quantity and cost, in terms of easy to use and updated equations, of a power function relations of one or two variables.

Gutherman et al. (1979) present tables of sample data and cost curves for components of various water treatment facilities. Although cost equations were not provided, simple and multiple regression can be performed on the data taken from the tables. None of the statistical data necessary in judging the accuracy of these curves were provided. However, the authors state that the relationships passed the necessary criteria for statistical significance.

Perhaps the most comprehensive evaluation of these relationships is the one by Clark and Dorsey (1982, pg. 618). They found that "economic appraisals are necessary to eliminate non-cost-effective alternatives and, to concentrate research and engineering studies on the most promising designs". They developed five categories of steadily improving levels of cost estimating procedures, shown in Table 3-1. Also, a conceptual analysis of the expected accuracy from the various types of cost estimates can be found in Figure 3-2, which illustrates how far off the estimate can be "the first time," when little or no data are available, and shows the learning curve of decreasing costs for similar projects as they are attempted later..

TABLE 3-1: DEFINITION OF FIVE BASIC TYPES OF ESTIMATES OF TOTAL PLANT COSTS (Clark and Dorsey, 1982)

TYPE OF EQUATION	CHARACTERISTICS	PURPOSE	USUAL RELIABILITY %
1. Order-of-magnitude ratio	Rapid. Very rough	Preliminary indication. Check on result by more detailed method.	About + 30 to − 60
2. Study (commonly called a factor estimate)	Flow diagram, material and energy balance, type and size equipment	For generalized evaluations. Guidance for further investigation. Basis for process selection. Research and development guidance.	± 30
3. Preliminary budget authorization	Add surveys and some foundation engineering, transportation facilities, buildings, structures, lighting.	Basis for decision to undertake detailed engineering. Sometimes basis for budget authorization. Can be for generalized evaluation but usually for site-specific installation.	± 20
4. Definitive project control	More detailed engineering. Not based on complete specifications and working drawings. Requires experienced estimating organization and substantial outlay	Sometimes the basis for budget authorization. Provides improved estimate of project to be built. For site-specific installations.	± 10
5. Detailed firm bid	Complete site surveys, specifications, and working drawings.	Made to control cost of project being built. For site-specific installations.	± 5

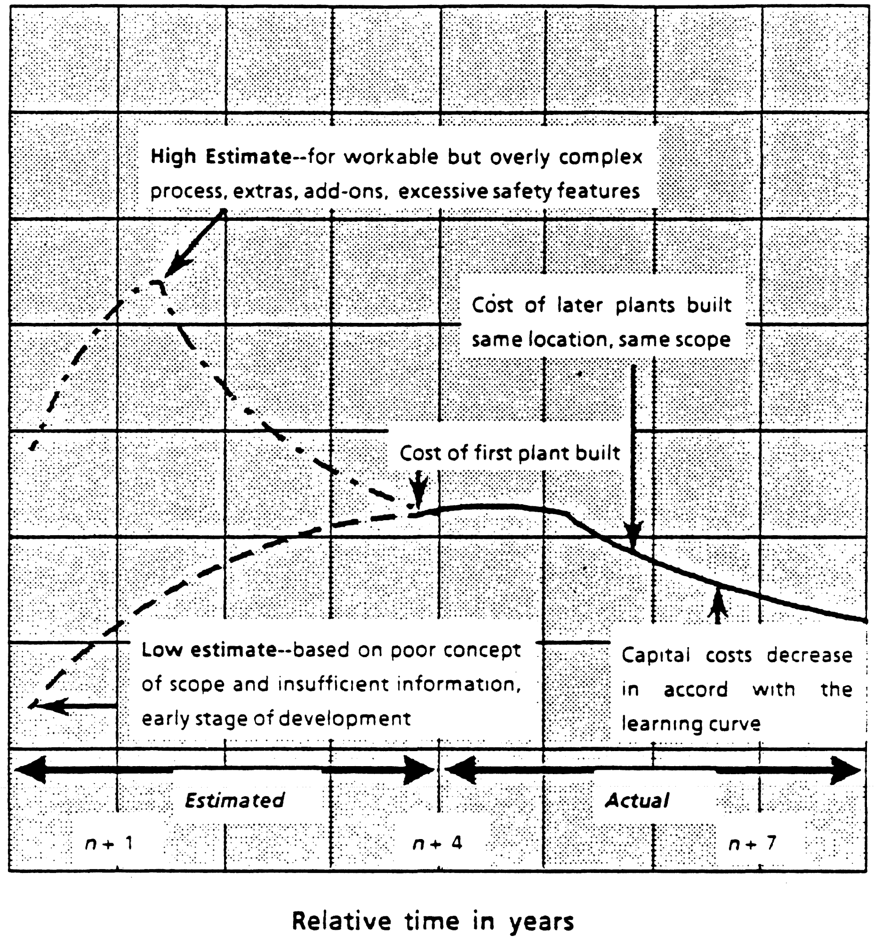


FIGURE 3-2: EFFECT OF VARIOUS FACTORS ON PROJECTED AND ACTUAL CAPITAL COSTS (Clark and Dorsey, 1983)

The classic paper by Linaweaver and Clark (1964) presents water transmission costs clustered with the main variables of capacity, distance and materials. They present tables of actual pipelines costs brought to one time base, from which multiple and simple regressions were performed to find equations for the optimal diameter for the pipelines. They estimated operating and maintenance costs for pumping as 8% of the annualized capital costs.

Marsden, et al. (1973, pg. 2106) present the general functional forms of cost equations and develop a classical rigorous approach to cost estimating based on multiple variables. They caution against using regression results for future planning or operating rules, as the cost equations, by their nature, only match historical data, and cannot take into consideration future events, such as:

1. Relative prices of inputs have changed, requiring a different mix of inputs for producing a particular level of clean effluent at least-cost.
2. Technological changes that can substantially reduce cost are introduced.
3. Existing plants are likely to be an inefficient combination of technologies embodied in a series of additions or alterations that were made in response to earlier price and technology changes or to quality or quantity adjustments in the input or output.
4. Existing plants are not likely to be cost minimizers, because they are not operated for profit.

They stressed the need for an overall system model and analysis, and using the regression equations in conjunction with specific engineering and physical principles.

Reed, et al. (1979) emphasized wastewater reuse as a disposal option called land treatment, defining several types of this process: slow rate, rapid infiltration, overland flow (this analysis is only using slow rate application of wastewater). They give generalized cost equations for various structural requirements of a land treatment system, an example of which is shown below in Figure 3-3 for chlorination facilties.

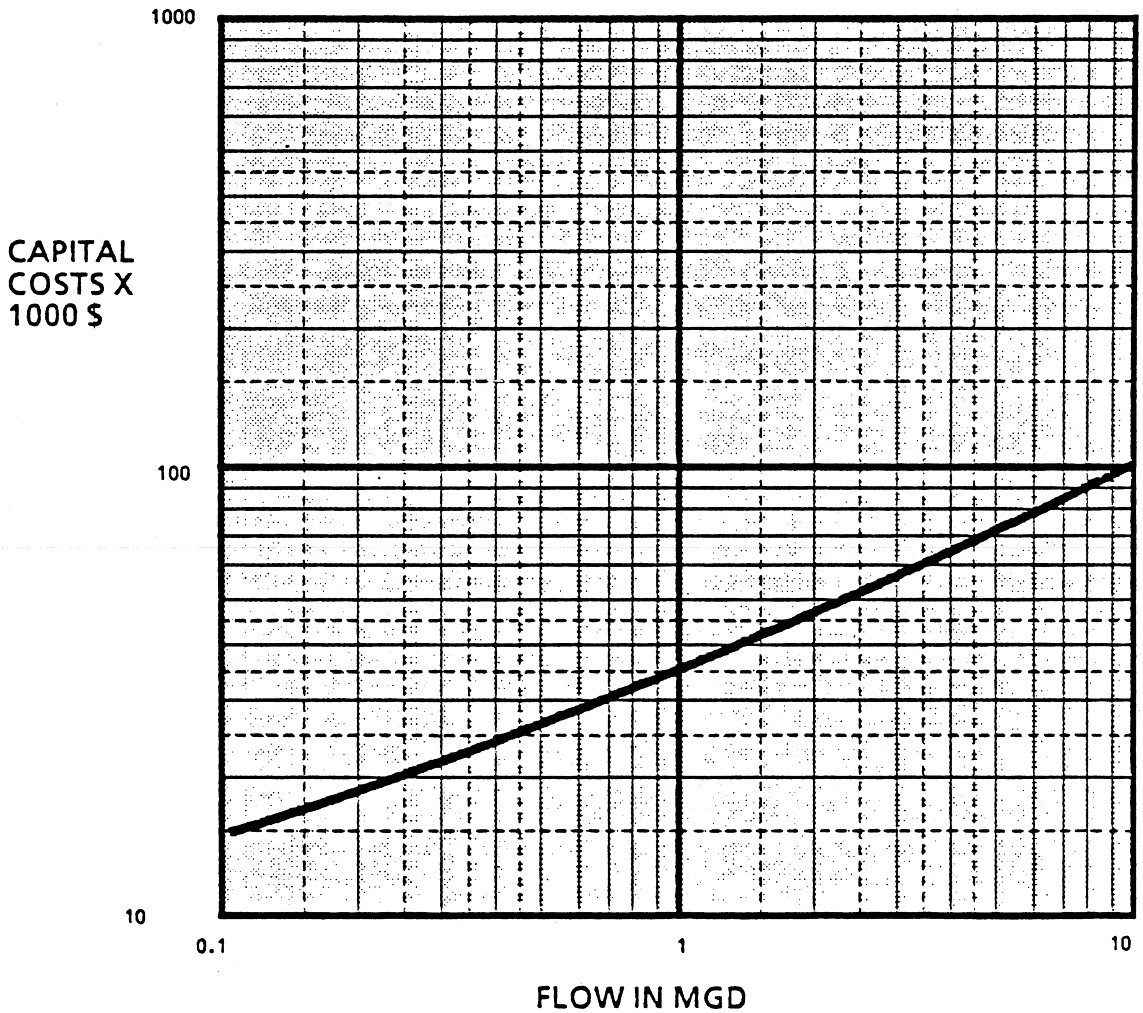


FIGURE 3-3: ADDITIONAL CHLORINATION FACILITIES
NEEDED FOR WASTEWATER REUSE
(Reed et al. 1979, costs are 1973)

Harris, et al. (1982) developed a computer model (CAPDET) that evaluated costs about at the level of stage three of Clark and Dorsey (1982). This model analyzes and estimates costs based on statistical cost data for various wastewater treatment facilities, providing much itemized detail. The model is available to users in tape form or as an on-call library.

For a comparison of costs, Schmidt et al. (1979) give one of the few tabulations of costs for reuse projects, concentrating mainly in the western states. They included deep-well injection as wastewater reuse, which is not considered the case in Florida.

A theoretical analysis by Deb et al. (1978), gives statistical equations of pipelines in both capital and operating costs, along with pumping costs, and performs an optimization scheme in order to find the least cost diameter for a given pipe. This method will be adapted later in the theory section to be used in the wastewater reuse study.

Operations Research Techniques

These methods use operations research techniques to develop models representing a wastewater reuse system in conjunction with cost equations developed from the previous authors in order to evaluate the option of wastewater reuse in the planning situation. A problem in using this method is that assumptions made to solve the problem eliminate the realistic considerations necessary in solving it, namely the concave, non-linear nature of the objective function. This non-linearity is necessary in order to account for the significant economies of scale that are so prevalent in water resources systems. The following pages present the major contributors of models of this nature.

Perhaps the most comprehensive approach, was attempted by Bishop and Hendricks (1971), and Bishop et al. (1974, 1975). They applied the classical transshipment or transportation problem to the problem of determining the optimal strategies for water reuse, as compared against other water resources options. Costs were assumed to be linear, the objective function was to minimize the cost of meeting water supply and wastewater treatment to satisfy water quality standards. They found that the locational advantages of water and wastewater plants were important. This model was applied to the Salt Lake City region in Bishop and Hendricks (1971). An obvious shortcoming of this model was the linear objective function. A following analysis by Rios and Maldonado (1981) applied the linear program to Puerto Rico, but was limited to one source.

Klooz and Hendricks (1982) applied a matrix of input-output tables to model the quantity of wastewater reuse in the Cache La Poudre River Basin in northern Colorado.

Joeres et al. (1974) suggest a trade-off between economies of scale inherent in wastewater treament plants and added pipe network collection costs. They used mixed integer programming to approximate piecewise linear concave cost curves, incorporating capacity limits, and quality limits, in a planning model of the wastewater system in Dane County, Wisconsin.

Mulvihill and Dracup (1974) used non-linear concave cost functions, allowing for only one large user. The objectives were to: minimize the cost of supplying water from several sources (including wastewater), and to determine the capacity expansion schedule of the water and wastewater treatment processes.

Pingry and Shaftel (1979) formulated a transshipment-style non-linear model which took into account flow requirements and water quality. The problem was solved by an iterative method in which the problem was formulated as a transshipment problem with a non-linear objective function, solved for a set of water quality parameters, which were then found by use of a search technique.

Fordham (1981) developed a piecewise linearization process for the demand and cost functions, using an out-of-kilter iterative method to solve the transshipment formulated water reuse problem. This model was applied to Carson City, Nevada. This method is similar to the one later presented by Ocanas and Mays (1981a).

Mandl (1981) surveys the state of the art of network models and algorithms that are used in irrigation and wastewater systems. He suggests that the problem with the models is the objective function, i.e., it is concave, and non-linear, in order to account for the economies of scale. As there is no "best" model, the user must make a tradeoff between computational efficiency, quality of the solution, and validity of the model.

In Phillips et al. (1982) a mixed integer programming model was applied to areawide wastewater management in Nassau County, New York. Its main advantage is that it does not require large amounts of computer time, and may be useful in preliminary screening for 201 studies.

Ocanas and Mays, (1981a), (1981b), and (1981c) developed a non-linear programming model for determining the optimum reuse of wastewater on a regional basis, minimizing total costs of water supply, considering water quantity and quality, many sources, users, and treatment facilities, resulting in both linear and nonlinear constraints. The techniques developed were the large-scale generalized reduced gradient and the successive linear programming with rejection (both are iterative search techniques). Solution of the problem was achieved through an out-of-kilter algorithm. Application to San Antonio, Texas to the year 2060 was applied, local optima were found, but were not guaranteed to be global. An example of a system that Ocanas and Mays modelled is shown in Figure 3-4.

Cost Allocation Methods

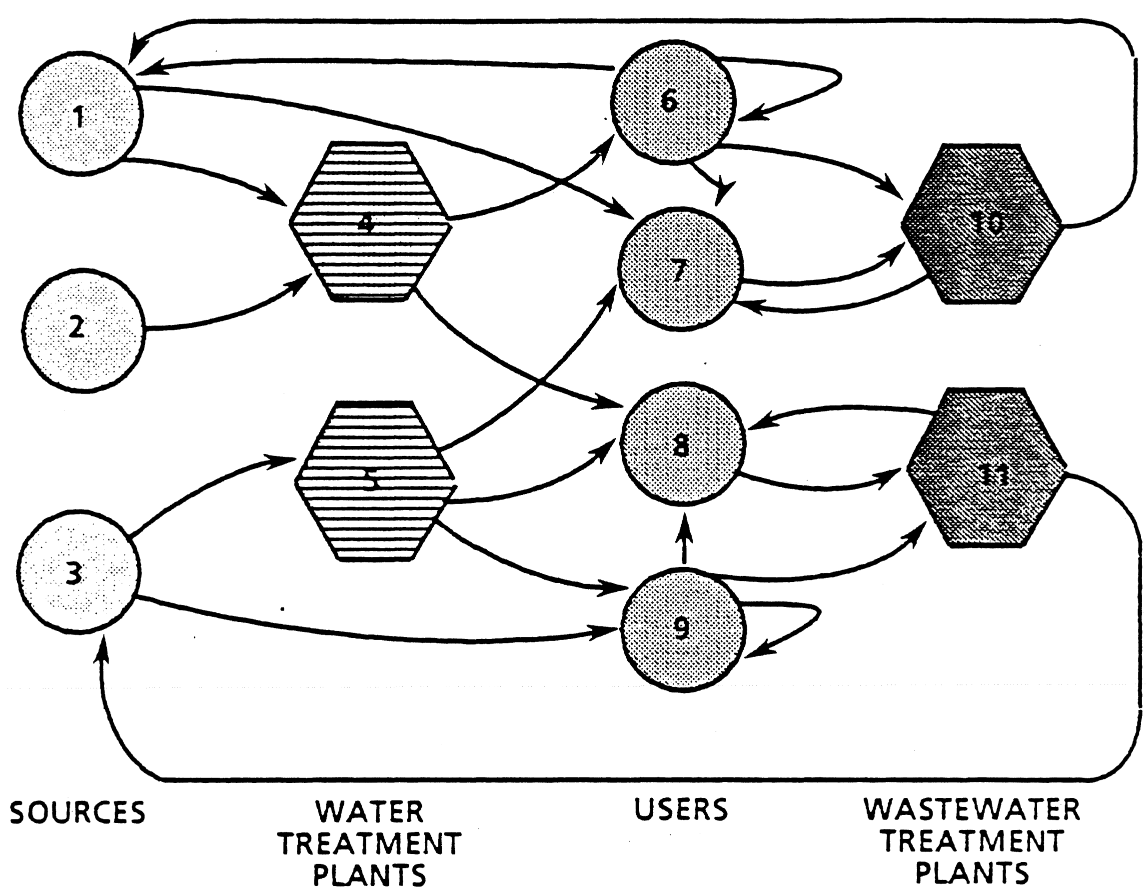


FIGURE 3-4: WASTEWATER REUSE FLOW NETWORK EXAMPLE (Ocanas and Mays, 1981a)

These analytical methods were developed in response to the problem of equitably dividing the costs of any multiple user water resources project. Presented here are the authors whose cost allocation method was chosen to be applied to the wastewater reuse project. The method of choice is from Heaney and Dickinson (1982) who term it the Minimum Cost, Remaining Savings (MCRS) method. It was proposed as an improvement over existing cost allocation techniques, such as the Separable Costs, Remaining Benefits method (SCRB). The main differences between these methods are how they satisfy the equity conditions that no individual or group will be forced to pay more for its share of a project than it would on its own.

The following criteria are presented as a guide to the selection of a cost allocation method (presented in Heaney and Dickinson (1982, pg. 476) from Ransmeier (1942):

1. The method should have a reasonable logical basis. It should not result in changing any objective with a greater investment than the fair capitalized value of the annual benefit of this objective to the consumer. It should not result in charging any objective with a greater investment that would suffice for its development at an alternate single purpose site. Finally, it should not charge any two or more objectives with a greater investment than would suffice for alternate dual purpose or multiple purpose improvement.

2. The method should not be unduly complex.

3. The method should be workable.

4. The method should be flexible.

5. The method should apportion to all purposes present at a multiple purpose enterprise a share in the overall economy of the operation.

Heaney and Dickinson (1982, pg. 478) list six obvious ways of allocating costs:

1. equally,
2. proportionally to a physical measure of use,
3. entirely to highest priority group up to limits of their benefit,
4. proportionally to benefit in excess of assigned separable cost,
5. proportionally to excess cost to provide the service by some alternate means, or
6. using the remaining benefits method described in (5).

Their method involves the use of graphical representations which will be presented in chapter 4. The method that they develop, in equations (also presented in chapter 4) satisfies the equity criteria, allowing for stable coalitions.

Young et al. (1982) illustrate the relationship between the number of users in a coalition, and the cost savings (over the last coalition) in Figure 3-5. As the size increases, the cost savings increase (to follow economies of scale), but the cost savings decrease after an optimal point. They also present the following equity principles (pg. 465):

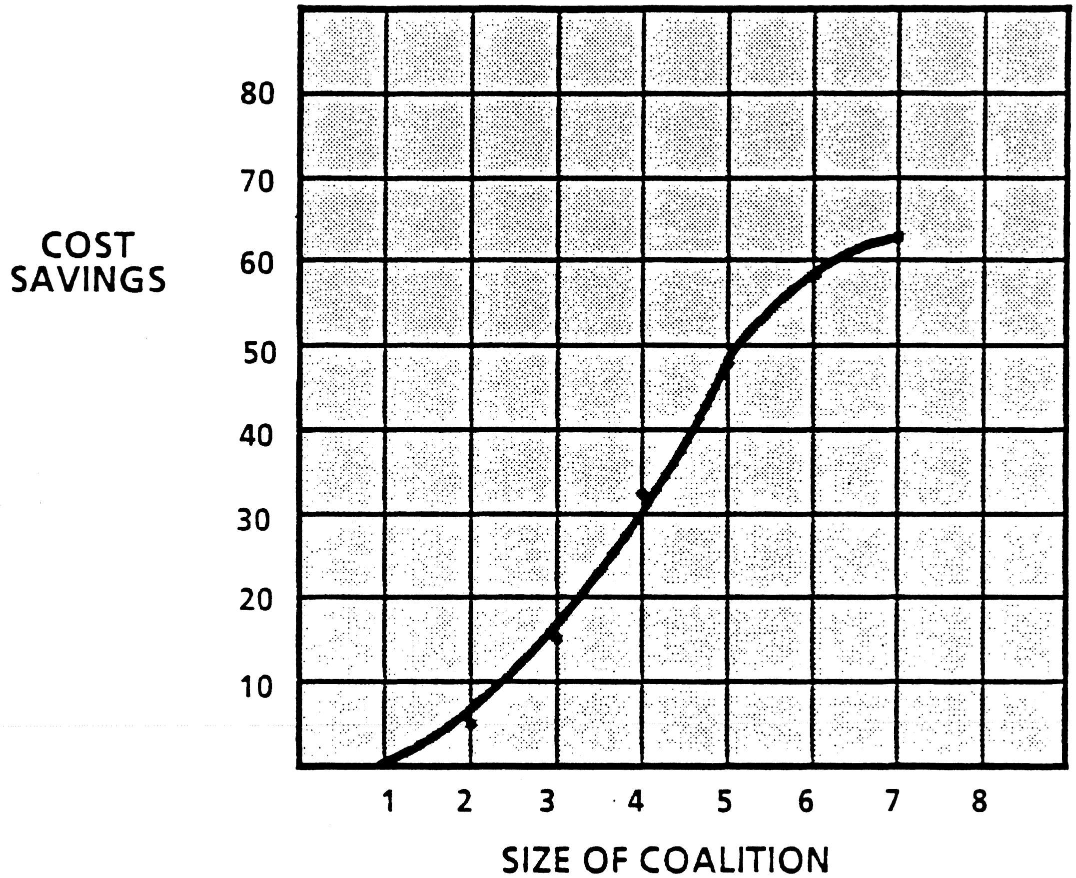


FIGURE 3-5: COST SAVINGS AS A FUNCTION OF THE SIZE OF COALITIONS, (Young et al. 1982)

1. Individual rationality-marginality-no individual should forced to pay more than what it can obtain in another coalition.

2. Group rationality-marginality-no group should be forced to pay more for its share in a project than an alternative coalition including itself would give it.

3. Direct costs-costs incurred by a group no matter what choice is made.

4. Monotonicity an increase in total costs shall not result in some participants having to pay less than before.

5. Simplicity

They evaluate several different allocation methods with respect to their meeting these criteria, (after estimating the costs of water project costs in Sweden), and found that the SCRB method fails almost all tests-inidicating it is one of the worst ways of allocating costs. The proportional nucleolus method passes all tests with the exception of simplicity (due to the fact that a large number of linear programs need to be run to obtain a result). Because of this, and for the reason that the data available was sketchy at best, the simple method of basing the charge on population was used in later analyses of the same area.

McConagha and Converse (1973) examine the trade-off between pipeline (transportation), and treatment costs (capacity). They developed a heuristic algorithm to solve the general problem by iterative techniques, the allocation of costs to the communities was by several different methods based on population, or the "added pipe rule"--that community (or group) which causes a new trunk pipeline to be built should pay for it.

Loehman et al. (1979) examine the implementation of a cost allocation method that, by assessing a "fair" charge to each member of a regional wastewater treatment system, would encourage a regional system. They suggest that only the subsidized cost (minus federal contribution) be considered for costs to the municipalities (there are diseconomies in applying this method). They also suggest that piping costs be allocated separately from treatment costs, so that pipeline costs are allocated for any section of pipe in proportion to flow, but only for the users of that section (doesn't satisfy marginal costs criterion).

James and Lee (1971, pg. 539) outline the different cost allocation methods in a matrix, suggesting that the method should be adjusted by the user in order to meet social goals as they state:

> Cost allocation affects the price of project output. Price affects use. Efficient use occurs when price equals marginal cost. Charges affect income distribution. Thus, because cost allocation directly affects economic and social efficiency, the allocation method should be used which does the most to promote the desired social goals.

Loughlin, (1977, 1978) suggests that the feasibility of a project and its cost allocation are independent of each other, and presents an adjusted SCRB method that he claimed met some additional equity criteria. Rossman (1978) adjusted this adjusted SCRB method further to satisfy his interpretation of the equity criteria.

Summary

By reading the literature, and examining the methods by which others have attempted to solve similar problems, it is easy to see that the problem of determining the feasibility of a water resources alternative such as wastewater reuse is a complex task, and a complete solution may be out of reach. But, with a judicious combination of the techniques developed by others, a reasonable approximation can be achieved so that wastewater reuse can be evaluated as a water supply alternative. The methods adapted from the literature will be presented in the following chapter.

CHAPTER 4 METHODOLOGY FOR THE FEASIBILITY STUDY

Selected ideas and approaches (introduced in Chapter 3) of analyzing the costs involved in water resources projects are adapted in this section, which mainly concerns itself with developing the theory and method to assess the relative economic impacts of wastewater reuse. The problem consists of five major parts, three of which will be subsections in this chapter, one of which has already been addressed, and one of which will be addressed in the following chapter. These are:

1. Identifying the major users and suppliers of wastewater within the SFWMD, and selecting the "test" area.
2. Determining the minimum physical facility requirements that will need to be constructed and/or modified (if existing facility).
3. Evaluating the costs of constructing the required facilities.
4. Evaluating the alternative costs (i.e., for disposal or alternative water supply).
5. Allocating the costs among the respective users.

Assessing the costs and/or benefits of a wastewater reuse system i.e., determining where the impact will lie, is the first step towards quantification of the costs of major facilities. Economic principles from the studies shown in Chapter 3 will be incorporated into the methodology, and costs avoided and/or alleviated will be estimated, and subtracted (or added) in order to determine the actual true cost of the system.

The physical requirements of the possible wastewater reuse systems, determined by examining other water reuse systems (Sullivan, et al. 1973), coupled with the regulatory constraints, predetermine the following impacts:

1. The supplier would have to apply tertiary filtration to secondarily treated water to meet DER requirements as to the finished water quality applied to the reuse site.

2. The supplier would have to provide capacity for storing effluent for three days.

3. The supplier or user would have to construct and operate pipelines to deliver the water to the place of use.

4. The supplier would reduce the use of the alternative effluent disposal method and save operating and maintenance costs and possibly some capital costs.

5. The user would reduce the use of the present facility which now supplies it water (wells, pumps, or public water supply systems), at some operating cost savings.

6. The user would have to integrate the wastewater into the system without violating restrictions on the mixing of wastewater and stormwater.

7. The user could count on reduced impacts during any declared water shortage, since the use of the wastewater would be exempt from any restrictions.

8. The regional water supplier could count on more water being available thereby reducing demand during droughts, which would reduce the need for regional system improvements.

These requirements are summarized in Table 4-1 which shows the impacts and whether each impact would result in additional costs or reduce costs. Most of these costs involve both capital and operating and maintenance costs, with the possible exception of some of the costs avoided.

For example, no capital costs savings can be credited towards wastewater reuse for the non-utilization of an ocean outfall, but the operating costs of the outfall can be credited towards wastewater reuse. Table 4-1 also specifies the impacted group, which was determined mainly by the location and purpose of the group involved. This framework limits the scope of the potential impacts, which of course is a simplifying assumption made so that the major costs can be evaluated. Essentially no impacts are expected on the treatment plants in so far as their collection, primary and secondary treatment systems are concerned, i.e., all costs will be borne by the marketplace. In the same way it is assumed that the users will continue to operate with the same irrigation (sprinkler) system, with a minimum of conversion costs.

TABLE 4-1: IMPACT CATEGORIES FOR WASTEWATER REUSE SYSTEMS

CATEGORIES	IMPACT	IMPACTED GROUP
Tertiary filtration	higher cost	supplier
Additional chlorination	higher cost	supplier
Storage facilities	higher cost	supplier
Transporting water to the user	higher cost	supplier
Alternative effluent disposal	cost avoided	supplier
Present water supply source	cost avoided	user
Separating waste and stormwater	higher cost	user
Fertilizer requirements	cost avoided	user
Water shortage impacts	cost avoided	user
Regional supply capacity	cost avoided	Regional water manager

The next step is to detail the cost relationships which were used to generate the treatment, storage, water transport, effluent disposal and present water supply costs.

Cost Relationships

Cost relationships in treatment systems show very good economies of scale, as they vary mainly with the capacity (flow) of the plant (Gutherman et al. 1979). Presentations of these relationships vary widely in their accuracy, and in the magnitude of their scope. First order estimates (such as "primary treatment") contrast to the second or third order estimates which detail the costs (such as "filtration-- backwash filter--construction materials") with a resultant increase in accuracy from +/- 60% to +/- 30% (Clark and Dorsey, 1982).

The purpose of these relationships is to evaluate different alternatives with a minimum of engineering design information, in order to make enlightened economic decisions. Some authors have criticized the use of statistical cost equations (Marsden et al. 1973). However, lacking other information, they serve a purpose. As long as the results are not extrapolated and used with caution, they can help illustrate the relative cost impacts of water resources projects. The EPA has produced numerous texts documenting costs curves and regression relationships for components of treatment system (see Table 4-2).

Marsden et al. (1973) present the generalized power function form of the statistical cost equation, which is:

$$C=f_1(x_1.....x_n)=\alpha_0 \prod_{i=1}^{n} x_i^{\alpha_i} \qquad x_i>0 \tag{4-1}$$

C is the symbol for costs. If equation 4-1 is log transformed, and represents only one x_i(the independent variable) the natural logarithm of α_0 is the y intercept, and α_1 is the slope of the equation.

Equation 4-1 can be expanded to include as many terms as necessary, including all of the major variables that have a statistical impact on the result. In many cases, flow, Q, is the only significant variable, leading to the following general cost equation:

$$C=\alpha Q^{\beta} \tag{4-2}$$

where α and β are parameters of equation 4-2. α is the y-intercept, and β is the slope of the log-transform of Equation 4-2.

A frequent representation for pumping systems is to include head, H, as a variable, which becomes:

$$C=\alpha Q^{\beta_1} H^{\beta_2} \tag{4-3}$$

where α, β_1, β_2 are parameters of equation 4-3. Representing cost as a function of the diameter of pipe results in a similar equation:

$$C=\alpha D^{\beta} \tag{4-4}$$

The use of these equations not only standardizes the cost estimating procedure, but, by separating out the component costs of each treatment system, achieves greater accuracy, and allows for separate updating, and conversion to local figures. This was the approach used in collecting and updating the cost equations found in the literature, and tabulated in Table 4-2. These costs were selected from the various references indicated. In some cases, sample cost data were available; in others, only the graphical representation. In a few cases the equations were given, but few of the studies gave the statistical information needed to ascertain the accuracy of the relationship(s). They are all in one time base, January 1983, and all localized for the West Palm Beach, Fla. area. Using these equations, it is possible to evaluate the most of the expected capital, operating, and maintenance costs of a designed wastewater reuse system numerically.

Table 4-3 illustrates the costs updating factors that were used in order to bring all of the collected cost data to one time base, January, 1983. The data in Table 4-3, under the respective source, represents the denominator of the cost updating factor, the final column (Jan., 1983) represents the numerator. The costs were updated and transformed from the national norm to the area of West Palm Beach, Fla., by the indices listed in Tables 4-4. The cost equations were then multiplied by the indices found in Table 4-4 to localize the national average estimates.

TABLE 4-2 : EQUATIONS USED TO ESTIMATE CAPITAL, OPERATING, AND MAINTENANCE COSTS OF WASTEWATER REUSE FACILITIES

FACILITY	EQUATION(S)
Gravity filter (Gutherman *et al.*) construction:	
excavation	$1800Q^{.59901}$
equipment	$28900Q^{.69806}$
concrete	$13500Q^{.56330}$
steel	$8000Q^{.55305}$
labor	$37900Q^{.59019}$
pipe	$9500Q^{.73684}$
electrical	$17800Q^{.54705}$
housing	$15400Q^{.77921}$
contingencies	$25600Q^{.66069}$
Gravity filter O&M:	
energy	$2400Q^{.86331}$
materials	$860Q^{.72147}$
labor	$1000Q^{.53384}$
Media, Dual fil.: (Gutherman *et al.*)	
materials	$6400Q^{.80912}$
Backwash fil. const, peak flow rates, typical factor = 5:(Gutherman *et al.*)	
equipment	$2400Q^{.78004}$
labor	$1000Q^{.46432}$
pipe	$4500Q^{.48321}$
electrical	$8300Q^{.31159}$
contingencies	$2000Q^{.55613}$
Backwash fil. O&M:	
labor	$250Q^{.13405}$
energy	$200Q^{1.00043}$
maint	$380Q^{.40610}$
Surface washing const:	
equip	$8600Q^{.72415}$
labor	$1000Q^{.73539}$
pipe	$2800Q^{.57514}$
electrical	$14000Q^{.37436}$
contingencies	$3700Q^{.59754}$
Surface washing O&M:	
labor	$80Q^{.46826}$
energy	$130Q^{.97356}$
maintenance	$200Q^{.20830}$
Storage < 10MGD, 3 day detention time required (DER)::Reed *et al.*)	
construction	$17000Q^{.3654}$
lining	$26000Q^{.7750}$
embankment	$21700Q^{.4072}$
O&M:	
labor	$550Q^{.3328}$
materials	$200Q^{.5068}$
10-5000 MGD:	
construction	$12700Q^{.7220}$
lining	$22300Q^{.3944}$
embankment	$35100Q^{.4240}$
O&M:(Reed *et al.*)	
labor	$640Q^{.36974}$
materials	$100Q^{.8853}$
Chlorination:(Reed *et al.*)	
Capital	$61100Q^{.6316}$
...O&M:	
Chlorine	$2250Q$
materials	$1800Q^{.5322}$
labor	$4500Q^{.077}$
Submersible pumps,(Gutherman *et al.*) TDH = 50 ft:	
Capital:	
excavation	$1700Q^{.20175}$
gpm	$450Q^{.20175}$
equipment	$18700Q^{.29266}$
gpm	$2250Q^{.29266}$
concrete	$1500Q^{.51187}$
gpm	$50Q^{.51187}$
labor	$3500Q^{.12519}$
gpm	$1500Q^{.12519}$
pipe	$2300Q^{.15965}$
gpm	$800Q^{.1536}$
electical	$970Q^{.12390}$
gpm	$430Q^{.12390}$
contingencies	$4700Q^{.23968}$
gpm	$980Q^{.23968}$
O&M:	
energy	$4800Q^{1.0024}$
gpm	$7Q^{1.0024}$
labor	$1400Q^{.23405}$
gpm	$320Q^{.23405}$
maintenance	$150Q^{.27991}$
gpm	$20Q^{.27991}$
Centrifugal pumps:(Gutherman *et al.*)	
Capital:	
equipment	$310Q^{.78152}H^{.69174}$
gpm	$2Q^{.78152}H^{.69174}$
labor	$700Q^{.68914}H^{.22625}$
gpm	$8Q^{.68914}H^{.22625}$
pipes & valves	$4100Q^{.75655}$
gpm	$29Q^{.75655}$
electrical	$280Q^{.30860}H^{.53109}$
gpm	$Q^{.30860}H^{.53109}$
contingencies	$270Q^{.77240}H^{.48164}$
gpm	$2Q^{.77240}H^{.48164}$
O&M:	
energy	$29QH$
gpm	$0.04QH$
labor	$3300Q^{.50443}$
gpm	$120Q^{.50443}$
maintenance	$300Q^{.85775}$
gpm	$Q^{.85775}$
total	$160Q^{.85194}H^{.73788}$
gpm	$0.6Q^{.85194}H^{.73788}$
Turbine Pumps:(Gutherman *et al.*)	
Capital:	
equipment	$2900Q^{.68394}H^{.29858}$
gpm	$33Q^{.68394}H^{.29858}$
labor	$2200Q^{.63240}H^{.04590}$
gpm	$34Q^{.63240}H^{.04590}$
pipes & valves	$5800Q^{.68134}$
gpm	$67Q^{.68134}$
electrical	$200Q^{.65082}H^{.70649}$
gpm	$3Q^{.65082}H^{.70649}$
contingencies	$1300Q^{.67403}H^{.23608}$
gpm	$16Q^{.67403}H^{.23608}$
O&M:	
energy	$400Q^{1.02044}H^{.35905}$
gpm	$0.5Q^{1.02044}H^{.35905}$
maintenance	$340Q^{.82443}$
gpm	$2Q^{.82443}$
labor	$5800Q^{.42875}$
gpm	$350Q^{.42875}$
Pipeline Costs	
PVC pipe (diameter <12 inches): Capital costs only (O&M estimated at .5% of capital costs, yearly):(Dodge, 1983)	
labor	$.26D^{.4587}L$
materials	$.12D^{1.7832}L$
Ductile iron pipe (diameter > 12 inches):(Dodge, 1983)	
labor	$.32D^{.88832}L$
materials	$.27D^{1.5549}L$
equipment	$29D^{.88982}L$
On-site replumbing costs:(OLAC, 1982)	
total	$75100Q$
Service connection costs::(OLAC, 1982)	
total	$125Q^{.39204}$
Ocean outfalls (for comparison): Capital costs only (O&M estimated at 2% of capital)::(Dames&Moore, 1978)	
pumps	$660Q^{1.26}$
pipe	$1500Q^{1.37}$
diffuser	$700Q^{0.91}$
Evaporation/Percolation ponds::(Reed *et al.*)	
O&M only:	
labor	$22000Q^{.6092}$
materials	$2800Q^{.5333}$

SYMBOLS USED

VARIABLE	PARAMETER	UNITS
Q	flow	mgd, or gpm
H	head	feet of water
L	length	linear feet
D	diameter	inches

TABLE 4-3: COST UPDATING FACTORS

CATEGORY	SOURCE	INDEX VALUES					
		Reed 1973	D&M 1977	Guth. 1980	OLAC 1982	Dodge 1983	Jan., 1983
Construction-capital:							
excavation	Bureau of Land Reclamation (BLR)	0.36	0.49	1.03	NA	1.44	1.44
equipment	Bureau of Labor Statistics (BLS) General purpose machinery, code 114	124.3	198.3	221.3	303.3	308.1	308.1
labor	Engineering News Record wage index (ENR), skilled labor	84.8	110.5	247	NA	350.03	350.03
pipes & valves	BLS valves & fittings, code 1013	132.7	224.4	236.4	NA	325.1	325.1
electrical	BLS electrical & instrumentation, code 117	111.0	152.0	167.5	NA	234.5	234.5
concrete	BLS concrete	128.9	189.9	221.1	NA	1.53	1.53
contingencies	ENR construction cost index	92.6	125.8	265.38	NA	369.8	369.8
total	ENR builders cost index	55.8	72.4	254.76	NA	342.35	342.35
Operation and Maintenance:							
energy	electric rates	0.03	0.03	0.03	NA	06	06
labor	ENR skilled labor or wage rate	84.8	110.5	247	NA	350.03 (14.1)	350.03 (14.1)
maintenance	Producers Price Index	121.2	178.3	199.7	NA	283.9	283.9
materials	ENR materials index or price quote	38.2	53.9	NA	NA	340.3	340.3
total	Producers Price Index	121.2	[illegible]	199.7	NA	283.9	283.9

Estimates of Cost Impacts

In this subsection estimates of the cost impacts for each of the ten categories in Table 4-1 are presented and discussed. These cost impacts result from the application of the cost relationships presented in the previous subsection and from other data which are presented below. The relationships between the costs and the size, length covered, type of alternative discharge, and other relevant variables are presented so the reader can become familiar with the size and sensitivity of each of the cost impact categories.

TABLE 4-4: COST LOCALITY FACTORS (West Palm Beach, Fla.)*

CATEGORY	INDEX VALUE
Capital:	
equipment	1.001
labor	0.711
pipes & valves	0.963
electrical	0.963
contingencies	0.942
Operation and Maintenance:	
energy	none
labor	0.711
maintenance & materials	0.781

*Computed from Engineering News Record construction cost indexes for differing metropolitan areas.

Tertiary Filtration: In order to meet the requirement of the Florida DER that the total suspended solids (TSS) concentration be less than 5 mg/l before application to land, some type of "tertiary" treatment (beyond secondary treatment) is required. Many different treatment methods are possible, but the most common are tertiary filtration or alum coagulation. Tertiary filtration consists mainly of the physical treatment of adsorption on some type of filter media; usually coal, gravel, or sand. Some biological breakdown within the media also occurs. Alum coagulation uses a chemical/physical process in which alum slowly coalesces with the suspended particles, causing their weight to increase, and settling to occur (Diversified Utilities, 1979). The capital costs for tertiary filtration are larger, whereas the operating and maintenance costs for alum coagulation are larger (due to higher chemical costs). However, due to the reliability and regulatory acceptability of tertiary filtration, it was chosen as the design treatment process.

The major construction components, (and modifications of the cost) involved with tertiary filtration are:

1. gravity filter,
2. filtration media,
3. backwash pumping, and
4. surface washing.

The gravity filter cost represents the actual construction of the filter. The filtration media is the cost of the sand, gravel or coal medium, to be installed within the filter. Backwash pumping facilities are needed in order to help clean the filter by reversing the flow during the backwash cycle. Surface washing keeps the surface of the filter clean and free of debris.

The major operating and maintenance cost components of these processes are: energy, labor, and maintenance (on materials), under each of the components listed above except for the filtration media.

All of the equations for these costs are listed in Table 4-2 (as taken from Gutherman et al. (1979). Each component was broken into subcomponents to allow for separate updating of all types of costs involved to January 1983, and multiplied by the local factors.

The cost of tertiary filtration represents a good example of economies of scale, as most of the exponents of the cost equations are less than 1.0. Construction costs dominated operating costs. In the study, with the given applicable design in Palm Beach county, the ratio of tertiary filtration costs to total secondary treatment costs ranged from 60-90%, indicating that the tertiary filtration process constitutes a major fraction of the treatment costs (not including transportation costs). Figure 4-1 shows the total treatment costs for the designed wastewater reuse facilities as they vary with acreage. This figure includes tertiary filtration, chlorination, and storage, but the dominant portion of the costs is that of tertiary filtration.

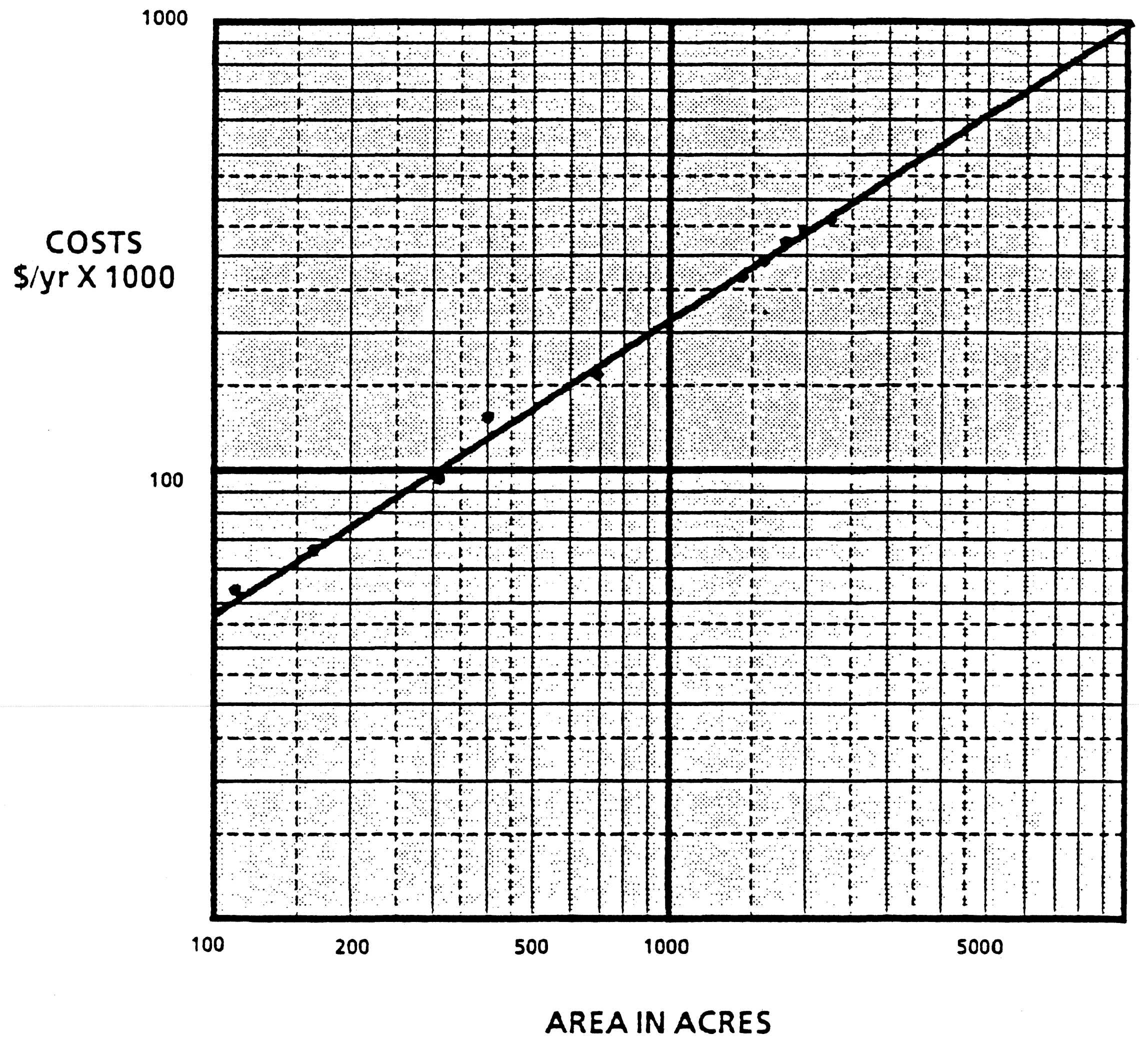


FIGURE 4-1: ANNUALIZED TREATMENT COSTS AS A FUNCTION OF THE AMOUNT OF IRRIGATED AREA (Jan., 1983, P. B.Co., Fla.)

A further, more detailed itemization of the capital, operating, and maintenance costs is shown following (equations from Table 4-2), with a total flow of 2.99 MGD:

Gravity filter (Gutherman et al.)
construction:

excavation	$1800Q^{.59901}$
equipment	$28900Q^{.69806}$
concrete	$13500Q^{.56330}$
steel	$8000Q^{.55305}$
labor	$37800Q^{.59019}$
pipe	$9500Q^{.73684}$
electrical	$17800Q^{.54705}$
housing	$15400Q^{.77921}$
contingencies	$25600Q^{.66069}$

Total 320669.31$

Media, Dual fil.: (Gutherman et al.)

materials	$6500Q^{.80912}$

Total 68464.51$

Backwash fil. const, peak flow rates, typical factor = 5:(Gutherman et al.)

equipment	$2400Q^{.78004}$
labor	$1000Q^{.46432}$
pipe	$4500Q^{.48321}$
electrical	$8300Q^{.31159}$
contingencies	$2000Q^{.55613}$

Total 15714.49$

Surface washing const:

equip	$8600Q^{.72415}$
labor	$1000Q^{.73539}$
pipe	$2800Q^{.57514}$
electrical	$14100Q^{.37436}$
contingencies	$3700Q^{.59754}$

Total 55178.14$

Total Capital Costs 430208.45$

Gravity filter O&M:		
energy	$2400Q^{.86331}$	
materials	$860Q^{.72147}$	
labor	$1000Q^{.53384}$	
Total		37665.82$/yr.
Backwash fil. O&M:		
labor	$260Q^{.13405}$	
energy	$200.42Q^{1.00043}$	
maint	$380Q^{.40610}$	
Total		8063.22$/yr.
Surface washing O&M:		
labor	$80Q^{.46826}$	
energy	$130Q^{.97356}$	
maintenance	$210Q^{.20830}$	
Total		6481.22$/yr.
Total Operating and Maintenance Costs		13753.21$/yr.
Total Costs, Amortized (i ≐ 10%)		67501.29$/yr.
Total Costs, unit charge		.061¢/1000 gallons

Additional Chlorination: To meet the DER requirement of no detectable fecal coliforms in the effluent, further chlorination (beyond that already done after secondary treatment) is required. This is to insure that no contamination will result from spraying public areas with the effluent.

The cost equations used are from Reed et al. (1980) and can be seen in Table 4-2. The main capital cost is construction and purchase of equipment; the main operating and maintenance costs are chlorine, materials, and labor. All of these relationships show economies of scale as can be seen from the cost equation. Following is an example of costs estimated from equations in Table 4-2 for a 2.99 MGD reuse chlorination unit:

Chlorination:(Reed et al.)		
Capital	$61100Q^{.6316}$	
Total Capital costs		122153.20$
...O&M:		
Chlorine	$2250Q$	
materials	$1800Q^{.5322}$	
labor	$4500Q^{.077}$	
Total Operating and Maintenance costs		14819.14$/yr.
Total costs, Amortized (i = 10%)		30879.11$/yr.
Total costs, unit charge		0.029¢/1000 gallons

Storage Facilities: Storage facilities were designed to meet the three day minimum requirement for wastewater of the DER. It is assumed that at most sites more storage is available,(because of hydraulic requirements), and since a backup disposal method is required, further storage capabilities beyond the minimum would be redundant.

The equations used were taken from Reed et al. (1979) and can be seen in Table 4-2. Using the three day detention time requirement they were converted to flow from a volume variable. Total design flows less than 10 mgd are costed by a different set of equations than those greater than 10 mgd. The major cost components of the capital costs were: construction, lining (PVC), and embankment. Land costs were included as part of the construction costs when the survey was taken. The major operating costs were labor and materials. The storage facility is a simple excavated reservoir, with the exception of the addition of PVC lining to conserve the treated water (once money is spent treating the water to advanced secondary standards, it would not be cost- effective to let it seep into the ground). The storage facilities must be located at the treatment site, not only to save money, but because DER will not allow storage of possibly substandard quality effluent in golf course lakes (it would be impossible to route it back to the treatment facility). However, the lake can be used as backup storage of good quality effluent.

The costs for storage facilities of a wastewater reuse system have good economies of scale of volume, and can be represented as a function of flow only if a 3 day required detention time is assumed. As shown in Table 4-2, the exponents of the cost equations are all much less than 1.0. The equations from Table 4-2 were used to evaluate costs for storage facilities (both construction and operation and maintenance costs) for the needed storage facilities in the following chapter. By evaluating a few of the cases, it can be seen that the cost of storage facilities is a minor fraction of the total treatment costs. Because of this, it can be concluded that the storage costs are a minor component of the overall costs of a wastewater reuse system. However, they will be included in the analysis. Itemized estimates of costs of storage facilities can be seen following for a 2.99 MGD facility:

Storage $<$ 10MGD, 3 day detention time required (DER):(Reed et al)		
construction	$16900Q^{.5884}$	
lining	$25900Q^{.7750}$	
embankment	$21700Q^{.4072}$	
Total Capital costs		126974.44$
O&M:		
labor	$550Q^{.3328}$	
materials	$200Q^{.5068}$	
Total Operating and Maintenance costs		1143.02$/yr.
Total costs, Amortized (i = 10%)		14998.07$/yr.
Total costs,	unit charge	0.014¢/1000 gallons

<u>Transporting Water to the User</u>: Piping costs are the most difficult to evaluate, as the pipe cost varies linearly with distance, non-linearly with diameter, which, in turn is non-linearly related to the flow of the user. The equations used in the study are tabulated in Table 4-2, as functions of labor, materials, and equipment (to be added together). Other factors impacting these costs are the efficiency and head of the pumps selected, the static head of the system, the age of the pipe, etc. There is also an inherent tradeoff between pumping costs and pipeline costs (i.e., the larger the pipe, the lower the pumping costs, and vice versa). An optimization analysis was performed to select diameters of the respective planned pipelines with a minimum of given information (mainly the user's flow). This is presented in the following section. The costs to the user of pipelines varies quite substantially due to groupings of users flow, and length of the pipeline. Figure 4-2 gives examples of annualized costs for selected pipeline cases, taken from the design data. It shows the non-linear nature of this variable in both flow and distance. The pipeline construction cost was found to be the largest

component of the total pipeline costs within the range selected in the design. Following is an itemization of typical costs calculated from equations in Table 4-2, for a 1.36 MGD demand, 2 pipes, each of diameter 8 inches, one 6200 feet in length, and the other 1220 feet in length:

Centrifugal pumps:(Gutherman et al.)

Capital:		
equipment	$310.11Q^{.78152}H^{.69174}$	
gpm	$1.87Q^{.78152}H^{.69174}$	
labor	$704.47Q^{.68914}H^{.22625}$	
gpm	$7.75Q^{.68914}H^{.22625}$	
pipes & valves	$4109.39Q^{.75655}$	
gpm	$29.10Q^{.75655}$	
electrical	$276.59Q^{.80860}H^{.53109}$	
gpm	$1.39Q^{.80860}H^{.53109}$	
contingencies	$274.54Q^{.77240}H^{.48164}$	
gpm	$1.75Q^{.77240}H^{.48164}$	
Total Capital costs		46790.11$
O&M:		
energy	$29.97QH$	
gpm	$0.04QH$	
labor	$3379.27Q^{.50443}$	
gpm	$124.57Q^{.50443}$	
maintenance	$297.68Q^{.85775}$	
gpm	$1.09Q^{.85775}$	
Total Operating and Maintenance costs		16256.40$/yr.
Pipeline Costs		
PVC pipe (diameter < 12 inches):		
Capital costs only:(Dodge, 1983)		
labor	$.2580D^{.2587}L$	
materials	$.1205D^{1.7832}L$	
Total Capital costs		49669.18$
Total Operating and Maintenance costs estimated at .5% of capital costs, yearly)		198.68$/yr.
Total costs, Amortized (i = 10%)		29034.94$/yr.
Total costs,	unit charge	0.059¢/1000 gallons

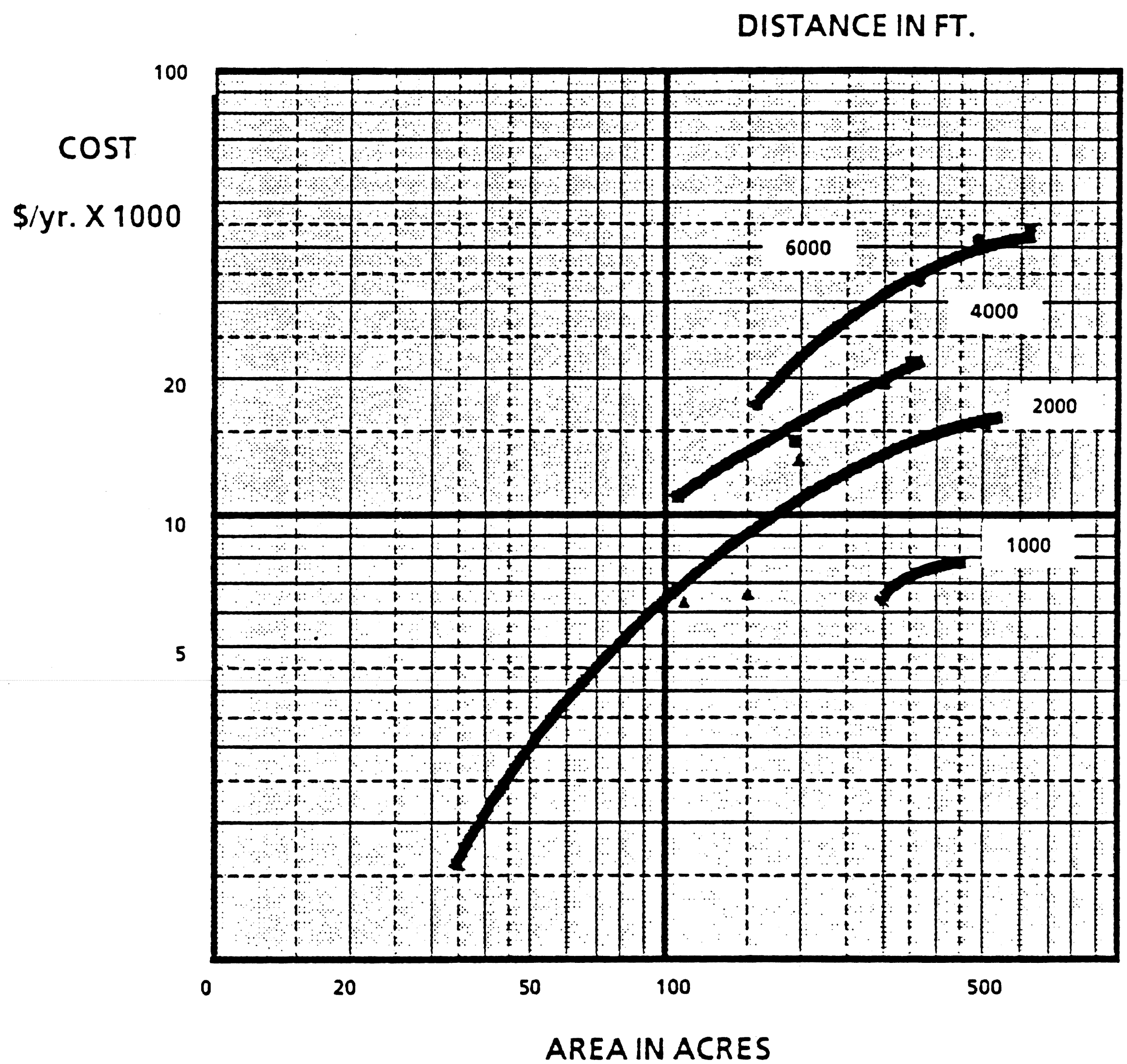


FIGURE 4-2: COST ESTIMATES OF VARIOUS WASTEWATER REUSE PIPELINES VS. AREA AND DISTANCE(Jan., 1983, P. B. Co., Fla.)

Alternative Effluent Disposal: The DER requires an alternative disposal method for a reuse system, so no savings can be expected from capital costs. It is assumed, however, that operating costs can be saved by not utilizing the alternative disposal method. These, however, are only a fraction of the capital costs (as mentioned before).

TABLE 4-5: OPERATING COSTS OF DISPOSAL METHODS

REGION/SUBREGION	TREATMENT PLANT	DISPOSAL SYSTEM	CAPACITY MGD	COST ¢/1000g
ENCON	ENCON regional	perc. pond	4.0	5
Central/North Central	Anchorage Drive	intracoastal outfall	4.85	0
	Seacoast (main)	perc. pond	3.6	4
	Cabana Colony	perc. pond	0.35	10
Central/East Central	East Central Reg.	Deep well inj.	40.0	3
Central/Royal Palm	Royal Palm Beach	perc. pond	1.1	7
Central/Acme	Acme	perc. pond	1.5	6
South Central	S.C. #1	perc. pond	1.5	9
	S.C. #2	perc. pond	2.5	4
	Village of Golf	perc. pond	0.5	9
	S.C. Regional	ocean outfall	12.0	0
Southern	Glades Road	ocean outfall	10.0	0
	S.R. #1	perc. pond	0.5	9
	S.R. #2	perc. pond	3.72	4

These cost savings to the supplier vary with the type of disposal, but the type, and operating and maintenance costs for each are listed in Table 4-5 for each treatment plant in the eastern Palm Beach County area. Three types of disposal are currently practiced in the SFWMD, i.e., deep well injection, percolation/evaporation ponds, and ocean outfalls. Those facilities utilizing ocean outfalls have very low operating costs, so their savings are assumed to be negligible. Within Palm Beach county, only one facility currently uses deep- well injection to dispose of its wastewater (East Central Regional); and one is contemplating it (ENCON). The costs for this option depend on the number and size of the wells, as well as the flow. Robinson (1981) estimated costs for various deep-wells in assessing the cost effectiveness of the different treatment options within the ENCON region. These costs were used in assessing the East Central Region's alternative disposal savings. The operating costs for the evaporation/percolation pond can be found in Table 4-2 (from Reed, et al. ,1979). All of these costs show economies of scale of flow, and represent significant savings in some cases,except for the case of outfall dischargers, as the costs are too low in comparison with the other alternatives. Examples of these costs can be found in Table 4-5, which estimates the operating costs for different treatment plants and disposal systems in eastern Palm Beach county.

Present Water Supply Source: These cost savings to the user were estimated by permit information (what type of facilities exists at the permit site, and type of pumps or wells therein), cost equations from Table 4-2 and commercial water rates for the service area of the potential user (ACT Systems, 1980, or local water rate structures). For those potential users, now possessing a SFWMD permit, it was estimated that the operating cost (since capital cost is already spent, no savings from it results) of these various systems is about .05 $/1000 gallons, based on average flow rates and operation and maintenance cost equations for the type of pump in operation at the respective sites. Those sites that currently use potable water are paying very high commercial rates -- as much as 1.83 $/1000 gallons. With this variability, it is felt that these costs will dominate in certain situations -- i.e. when the user is on a potable water system.

Separating Wastewater and Stormwater: With regard to wastewater reuse, the District's regulatory staff has required that the following criteria be met by surface water management systems when wastewater is involved:

1. Effluent shall be discharged into isolated lakes which have storage capacity for the effluent (3 day volume minimum) plus the contributing area runoff volume for a 3 day/25 year rainfall event, prior to overflow into the stormwater system.

2. Effluent may only be discharged into any portion of the stormwater system if a water quality monitoring program gives positive assurances that water quality degradation will not result and that State water quality standards can be met. A continuous monitoring program would be a requirement if such discharge were permitted, and continuation of the discharge would be contingent on satisfactory monitoring results (Rogers, 1982).

In view of the complementary requirements of the DER, and the decision to store the water on the supplier's site, the impact of this requirement is viewed to be negligible.

Fertilizer Requirements: The wastewater applied to the irrigation sites will probably contain more nutrients than the present water supply source for that site. The user may then be able to apply less fertilizer at the site, and save money . These savings could amount to as much as 20% of the present fertilizer cost of the site (Augustine, 1983), a substantial amount at those sites which utilize large quantities of fertilizer. However, the city of St. Petersburg found that there were additional fertilizer costs because wastewater utilization resulted in higher application rates which results in nutrient leaching (Suddath, 1983). Due to the large variation in fertilizer use within the SFWMD, the question of leaching, and the lack of information as to the nutrient value of the wastewater, quantification of this benefit or cost is not possible, so a net value of 0¢/1000 gallons was used.

Water Shortage Impacts: As mentioned, one of the beneficial aspects of wastewater reuse is the exemption by the District of such use during a water shortage period. The District, in exempting reused wastewater from the various levels of irrigation restriction, placed a value upon the technique since reusers are not, in any way, taxing the freshwater resource, especially during periods of drought. In return for that action and in response to the reusers' assistance in helping to recharge the aquifer system, the exemption was promulgated.

Aside from the security of being able to always use water (and this, in fact, may be in doubt), the impact of this category due to wastewater reuse cannot be estimated. Since no large user has ever been completely cut off in South Florida, even during the recent extreme drought, and data regarding this impact is non-existent, the value of this impact was not quantified.

Regional Water Supply Costs: From a regional water supply perspective, the interest in wastewater reuse arises from a perception that this supply alternative could help mitigate problems with the present or prospective inadequacy of local surface and groundwater supplies. In this view, wastewater reuse can be substituted for other changes to the regional water supply system which would bring equivalent improvements. The impact on the regional water supply system can thus be measured in terms of the costs of these alternative improvements that can be avoided because of the wastewater reuse. The appropriate alternative cost to use would be that which is the least cost alternative for each basin under investigation.

Analyses completed by the SFWMD can shed some light on these costs. They are presented in Table 4-6 showing the estimated capital plus operating costs in dollars per thousand gallons of additional supplies made available during a drought period. These measures do not exhaust the potential cost effective alternatives especially as might be applicable in specific locations. They do, however, present a relevant group for comparative purposes. In considering the water supply value of wastewater reuse, it should first be noted that some conservation measures can actually save money. For instance, District calculations indicate that programs for installing indoor water conservation devices such as recently undertaken by the City of Orlando can be expected to save more in water heating and water and sewer treatment costs than they would cost to implement. Second, in areas where additional water can be stored in or distributed through existing regional supply facilities the alternative supply costs are likely to be very low as is indicated by the water supply backpumping and Holeyland Storage Area costs. In other areas the remaining choices are more limited but would include deep well storage and retrieval, desalination and transporting water from areas of adequate supply such as the inland portions of coastal counties. The costs of deep well storage have been presented because of their potential applicability in both the Lower West Coast and Upper East Coast planning areas.

The costs per thousand gallons presented in Table 4-6 are not directly comparable to the wastewater reuse costs. This is because the former refer to additional water supplied during a dry period. Wastewater reuse would only add to regional supply capabilities when the basin is not discharging water that leaves the system. For example, during wet periods when coastal canals are discharging, wastewater reuse would only contribute to runoff and would not increase water supply capabilities. However, once the coastal discharge stop, wastewater reuse would mean additional water in the coastal basin. For purposes of this study it has been assumed that discharges leaving the system cease for a period of four months during dry periods. Thus the costs in Table 4-6 will be multiplied by .33 (1 year ÷ 4 months) to account for the regional water supply benefits of wastewater reuse on the basis of the wastewater used through the full year.

TABLE 4-6: COSTS FOR SELECTED ALTERNATIVE WATER SUPPLY MEASURES IN SOUTH FLORIDA

Measure	Cost of Additional Dry Season Supply $/1000 Gallons	Areas Where Applicability Has Been Studied	SFWMD Source Reference
Retrofit of Indoor Water Fixtures	Negative	Urban Areas	*An Analysis of Water Supply Backpumping for the Lower East Coast Planning Area*
Water Supply Backpumping	\$.008 to \$.018	Coastal Dade, Broward & Palm Beach Counties	Same as above
Holeyland Storage Area	\$.021	Lake Okeechobee and Lower East Coast Basins	*Water Quality Management Plan for the S-2 and S-3Drainage Basins in the Everglades Agricultural Area*
Cyclic Storage in Confined Aquifers	\$.13 to \$.35	Upper East Coast, Lower West Coast	*Advanced Water Supply Alternatives for the Upper East Coast Planning Area* and *Water Use and Supply Development Plan*, Volume III C.

Pipeline Optimization

In the construction of any pipeline system, there is an inherent tradeoff between pipeline construction cost, which increases with the diameter of the pipe, and pumping plant operating costs (notably energy costs), which, in a given flow range, decreases with an increase in the diameter of the pipeline. Deb (1978) performed an optimization analysis which, given the cost equations for the various component costs of a pipeline, selected the optimum diameter which minimized total costs. In order to include more recent statistical data, which break down each of the component costs into subareas (e.g., pipeline construction can be broken into excavation, labor, materials, and other related costs); and to enable the costs to be updated separately with their own respective indices (which increases the accuracy of the indexing procedure); Deb's procedure has been modified as detailed below.

The capital costs for laying any type of pipe can be represented by the following equation:

$$Y_1 = \sum_{i=1}^{n_1} k_{1i} D^{m_{1i}} L \qquad \text{4-5}$$

where D is the diameter of the pipe in inches, L is the length of the pipe in feet, the m's and k's are derived factors from cost data, n_1 represents the number of terms in the equations selected, and Y_1 is in total \$.

Annual operation and maintenance costs of a pipeline can be estimated as .5% of the capital costs (Orange and Los Angeles Counties, 1982). Also, engineering, legal and contingency fees can be estimated at 25% of the construction cost, and the capital costs can be annualized by multiplying the above formula by the Capital Recovery Factor, *R*, computed from the following equation (*i* is the interest rate, and *N* is the life of the equipment):

$$R = \frac{i(1+i)^{N}}{(1+i)^{N} - 1} \tag{4-6}$$

The total costs of laying a pipeline can then be brought together, under one time base, resulting in the following equation:

$$Y_1 = \sum_{i=1}^{n_1} k_{1,i} D^{m_{1,i}} (1.25 R_{1,i} + .005) L \tag{4-7}$$

Where $R_{1,i}$ is the capital recovery factor for pipeline component, i (Y_1 is in units of \$ per year).

The capital costs of centrifugal pumps can be broken into components, also, and summed to obtain a function of the total costs for pumping facilities. The capital cost of pumping facilities, in total \$, can be represented as:

$$Y_2 = \sum_{i=1}^{n_2} k_{2,i} H^{m_{2,i}} Q^{m_{3,i}} \tag{4-8}$$

where H is the total dynamic head in feet, and Q is the flow in mgd, and Y_2 is in units of total \$.

Operation and maintenance costs for pumping facilities can be represented similarly, but the summation will be broken out to allow of unit charges for labor and/or electricity to be entered:

$$y_3 = Ek_{3,1}QH + lk_{3,2}Q^{m_{4,2}} + k_{3,3}Q^{m_{4,3}} \tag{4-9}$$

where E is in \$/kilowatt-hours, and l is in \$/hour, skilled labor, and y_3 is in units of \$ per year.

Combining equations 4-7, 4-8, and 4-9 yields the total cost, z,:

$$Z = \sum_{i=1}^{n_1} k_{1,i} D^{m_{1,i}} L(1.25R_{1,i} + .005) + 1.25 \sum_{i=1}^{n_2} k_{2,i} R_{2,i} H^{m_{2,i}} Q^{m_{3,i}} +$$

$$Ek_{3,1}QH + lk_{3,2}Q^{m_{4,2}} + k_{3,3}Q^{m_{4,3}} \tag{4-10}$$

substituting for H, (since $H = H_S + H_f$; and $H_f = LQ^p/(.0955C^pD^q)$ from Deb (1978), with the total z in units of \$ per year:

$$Z = \sum_{i=1}^{n_1} k_{1,i} D^{m_{1,i}} L(1.25R_{1,i} + .005) + \sum_{i=1}^{n_2} k_{2,i} R_{2,i} Q^{m_{3,i}} \left[H_s + \frac{LQ^p}{.0955C^pD^q} \right]^{m_{2,i}} +$$

$$E k_{3,1} Q \left[H_s + \frac{LQ^p}{.0955C^pD^q} \right] + l k_{3,2} Q^{m_{4,2}} + k_{3,3} Q^{m_{4,3}} \qquad \textbf{4-11}$$

To find the optimal diameter, the derivative of the above function, with respect to D, must be take and the result set equal to zero, below:

$$\frac{dz}{dD} = \sum_{i=1}^{n_1} 1.25LR_{1,i} k_{1,i} m_{1,i} D^{m_{1,i}-1} + \sum_{i=1}^{n_2} .005Lk_{1,i} m_{1,i} D^{m_{1,i}-1} -$$

$$\frac{qLQ^p}{.0955C^pD^{q+1}} \left\{ \sum_{i=1}^{n} R_{2,i} k_{2,i} Q^{m_{3,i}} m_{3,i} \left[\frac{LQ^p}{.0955C^pD^q} \right]^{m_{3,i}-1} \right\} - \frac{qEk_{3,1}Q^{p+1}L}{.0955C^pD^{q+1}} = 0 \qquad \textbf{4-12}$$

Assuming the third term is small, as in Deb (1978) we obtain the following equation;

$$\frac{dz}{dD} = \sum_{i=1}^{n_1} 1.25R_{1,i} m_{1,i} k_{1,i} D^{m_{1,i}-1} + \sum_{i=1}^{n_2} 005k_{1,i} m_{1,i} D^{m_{1,i}-1} - \frac{qEk_{3,1}Q^{p+1}L}{.0955C^pD^{q+1}} = 0 \qquad \textbf{4-13}$$

Substituting January, 1983 cost data, from equation in Table 4-2, for PVC pipe and ductile iron pipe (greater than 12 inches in diameter) we obtain:

for <u>ductile iron pipe:</u>

$$\frac{dz}{dD} = .04382D^{-.11168} + .06254D^{.5549} + .03924D^{-.11018} - .00029Q^{2.85}D^{-5.86} = 0 \qquad \textbf{4-14}$$

for <u>PVC pipe:</u>

$$\frac{dz}{dD} = .0101D^{-.7413} + .03265D^{.7832} - .000207Q^{2.85}D^{-5.86} = 0 \qquad \textbf{4-15}$$

To solve this equation for the minimum diameter, the Newton-Raphson method of finding roots to an equation was used. This requires the second derivative for the above equations, which are as follows:

for <u>ductile iron pipe</u>:

$$\frac{d^2z}{dD^2} = -.00489D^{-1.11168} + .03470D^{-.4451} - .00432D^{-1.11018} +$$

$$+ .001699Q^{2.85}D^{-6.86} = 0 \qquad \textbf{4-16}$$

for <u>PVC pipe</u>:

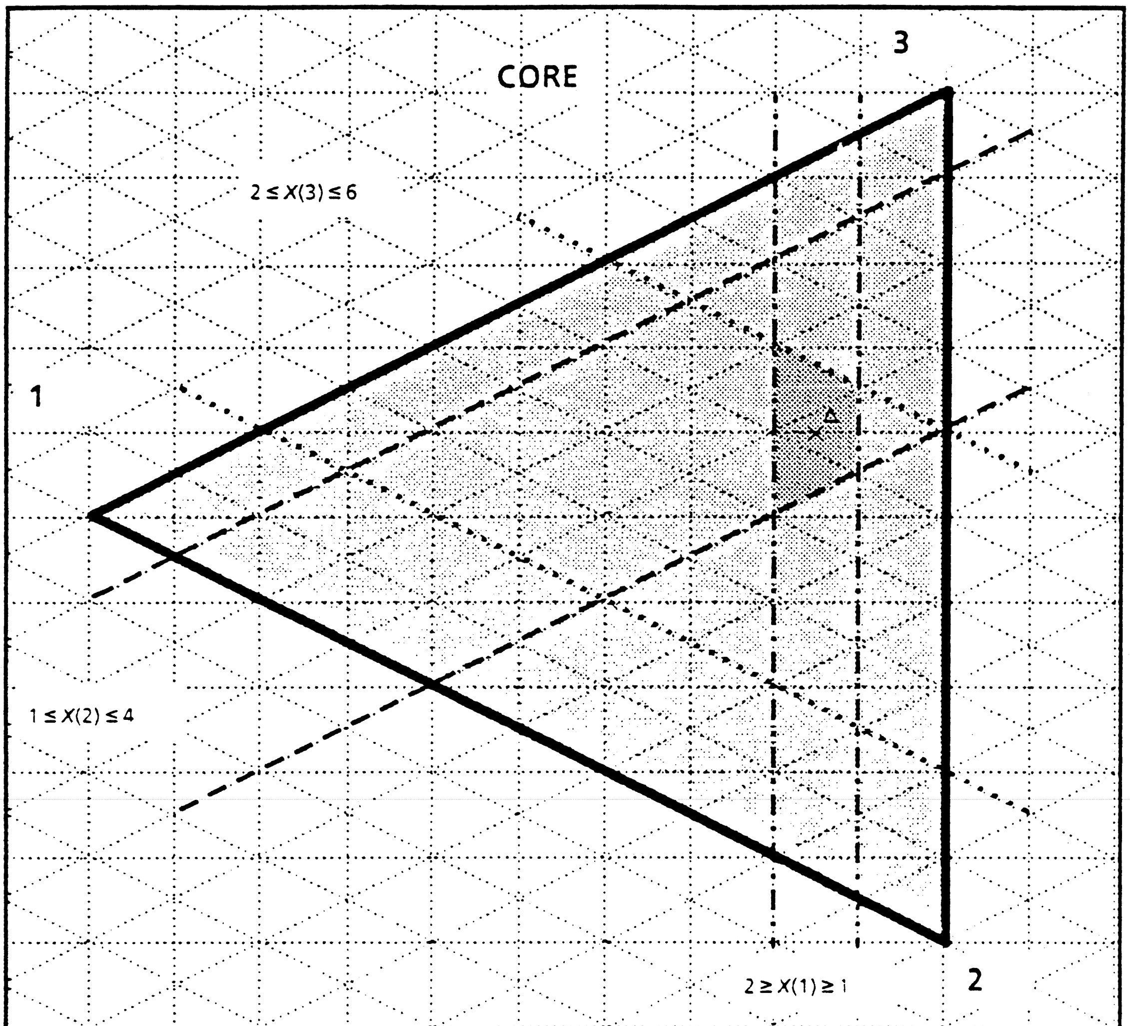
$$\frac{d^2z}{dD^2} = -.00749D^{-1.7413} + .02557D^{-.2168} + .001213Q^{2.85}D^{-6.86} = 0 \qquad \textbf{4-17}$$

Newton's method is then employed using the following iterative scheme:

$$D_n = D_{n-1} - \frac{\frac{dY}{dD}(D_{n-1})}{\frac{d^2Y}{dD^2}(D_{n-1})} \tag{4-18}$$

iterating untill $|D_n - D_{n-1}| < .01$.

A FORTRAN subroutine was written that computes the size of the optimal diameter of a pipeline, based on the flow (area and application rate) through the pipe. This program is included in the appendix (B), and was revised to become a FORTRAN subroutine of a main costing program. As a check, to see that there is only one true optimum in the range of diameter used, both the cost equations and the derivatives were plotted for diameters from 1 to 50 inches in diameter; and separate for each area. These curves can be found in figures B-1 and B-2. They are separated into first and second cases for resolution purposes only. In figures B-3 and B-4, the cost equations, although somewhat jagged, appear to have only one minimum in the stated range. In figures B-1 and B-2, the first derivative approaches zero, or crosses zero at only one point in the stated range.



TRIANGULAR GRAPH KEY

Each unit represents one representational unit in total costs (both capital and operating costs). The core is the shaded area--this is the region in which all constraints imposed by the members are satisfied. The geographic center of this area is the MCRS Solutions on the right

MCRS Solution:

(X) (10/7, 16/7, 23/7)

SCRB Solution:

(Δ)(11/8, 17/8, 7/2)

FIGURE 4-4: GRAPHICAL REPRESENTATION OF A 3 MEMBER COST GAME USING ISOMETRIC GRAPH PAPER (Heaney and Dickinson, 1982)

For a three member group, these conditions can be represented graphically on isometric graph paper, and appear in Figure 4-4 (from Heaney and Dickinson, 1982). The shaded region in the center of the triangle represents the region in which all constraints imposed by the equity conditions are satisfied. The center of the core represents the Minimum Cost, Remaining Savings (MCRS) solution. Contrasted with the MCRS is the Separable Costs, Remaining Benefits (SCRB) solution, which is not in the perfect center, and is faulty in that it does not always lie in the core (as it does in this case).

The set of equations 4-19 through 4-21 can be grouped together into the following linear program which finds the upper and lower bounds on each x(i) in order that the core, or the region that satisfies all three axioms of fairness can be determined.

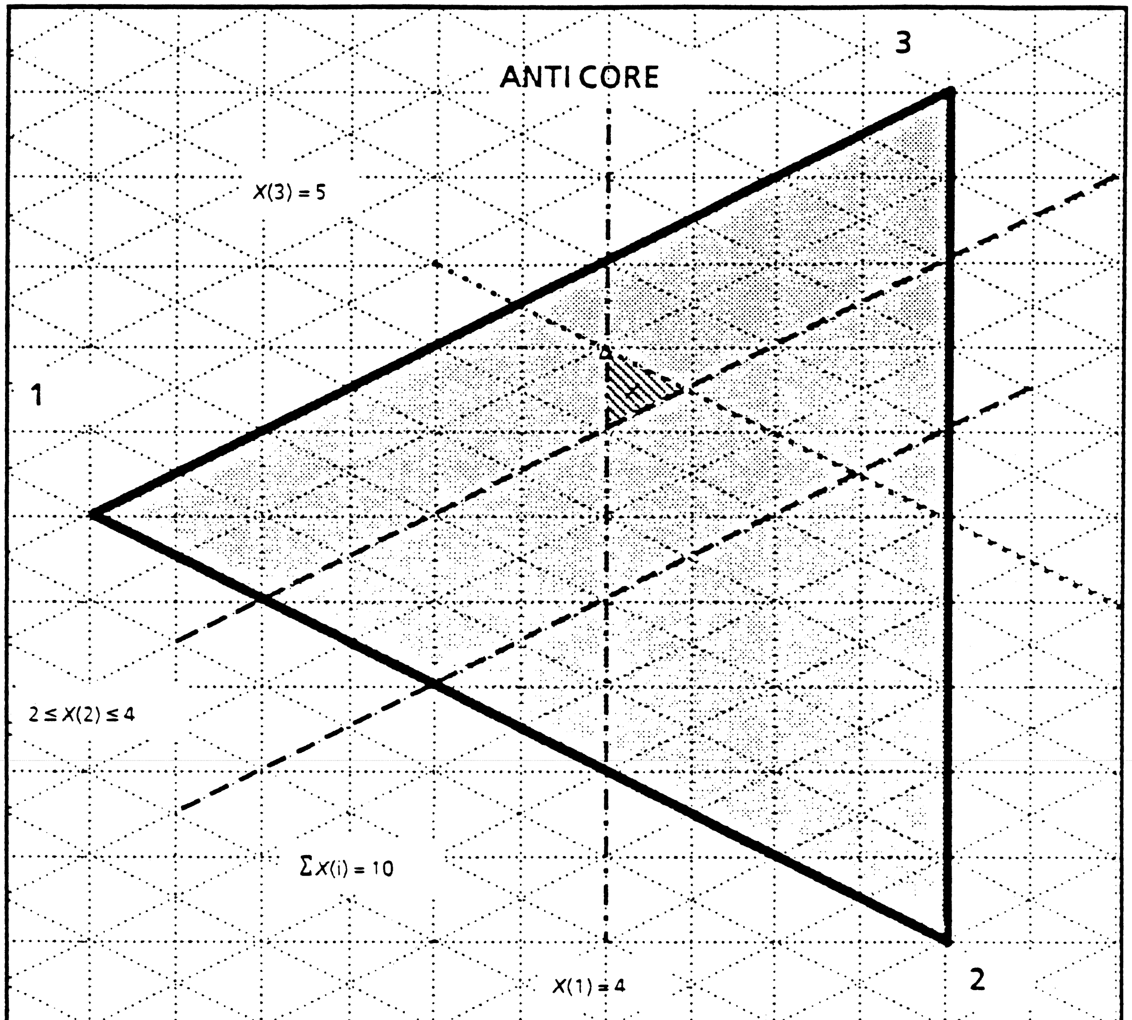
$$\max \text{ or } \min \; x(i)$$

subject to:

$$x(i) \leq c(i) \quad \forall i \in N \qquad \text{4-19}$$

$$\sum_{i \in S} x(i) \leq c(S) \quad \forall S \subset N \qquad \text{4-20}$$

$$\sum_{i \in N} x(i) = c(N) \qquad \text{4-21}$$



TRIANGULAR GRAPH KEY

Each unit represents one representative unit in total costs (both capital and operating costs). The anti core is the shaded area--this is the region in which most of the constraints imposed by the members are satisfied. The geographic center of this area is the MCRS Solutions on the right.

MCRS Solution:
(X) (3.68, 1.58, 4.74)
SCRB Solution:
(Δ)(4, 1, 5)

FIGURE 4-5: ANTI CORE OF A 3 MEMBER COST GAME USING ISOMETRIC GRAPH PAPER (Heaney and Dickinson, 1982)

$$x(i) \geq 0 \tag{4-22}$$

In some cases, a core will not exist, and an equitable solution may not be possible. Figure 4-5 represents such a case. A compromise solution was picked by the MCRS solution, as it lies in the region called the anti-core-the area where most of the constraints imposed by the equity conditions are satisfied. The SCRB solution does not pick a very reasonable compromise solution, as it lies to the edge of the anti-core, and satisfies less of the constraints than the MCRS solution does. The following linear program, represented by Equations 4-23 through 4-26, essentially does the same task, finding the optimum θ in which the core first appears.

$$\min \theta$$

subject to:

$$x(i) \leq c(i) \qquad \forall i \in N \tag{4-23}$$

$$\sum_{i \in S} x(i) - \theta c(S) \leq c(S) \qquad \forall S \subset N \tag{4-24}$$

$$\sum_{i \in N} x(i) \qquad = c(N) \tag{4-25}$$

$$x(i) \geq 0 \tag{4-26}$$

However, in such cases as these, the coalitions will not be stable, i.e., some members will be unhappy. If left out, they can disrupt the remaining coalitions. This disruption continues indefinitely.

Equations 4-27 through 4-29 are used in determining the MCRS solution. First, the β factor, that is the factor each user should pay out of the non-separable costs, is obtained by summing the difference between the maximum bound (determined by linear programming) of x_i and its minimum bound, dividing this difference by the sum of all the differences for the x_i's within the group. This factor should add up to one, as all costs must be covered. The non-separable cost is determined by subtracting the sum of all the minimum costs for the x_i's from the cost for the grand coalition. Finally, the MCRS solution cost for each x_i is determined by Equation 4-29.

$$\beta(i) = \frac{x(i)_{max} - x(i)_{min}}{\left\{ \sum_{i \in N} \left[x(i)_{max} - x(i)_{min} \right] \right\}} \tag{4-27}$$

$$nsc = c(N) - \sum_{i \in N} x(i)_{min}, \text{ and} \tag{4-28}$$

$$x(i) = x(i)_{min} + \beta(i)(nsc) \tag{4-29}$$

As the number of participants in the proposed project increases, so does the complexity of the problem of allocating the costs among the different users fairly. The potential cost savings for the members within the coalitions also gets larger. To evaluate all of the possible coalitions would take an enormous amount of time, as the number of coalitions is 2^n-1, which, for an 18 member coalition, for example, would result in 262,143 possible groupings. However, it is unnecessary to evaluate extraneous coalitions whose bounds will, in all likelihood, be superseded by other, less expensive coalition partners. This procedure can only be done arbitrarily, with a considerable amount of subjective judgement, although in most cases the decision is quite obvious. Since the costs being evaluated are usually for future projects--and the accuracy of the equations used is between $\pm 30\%$ (Clark and Dorsey, 1983), eliminating the marginal groups in this manner can be rationalized (Young et al. 1982).

Allocating the costs in this manner will be compared with dividing the costs proportionally based on flow requirements. The "added pipe rule" suggested by McConagha and Converse (1973) will be used, i.e., users will only pay proportionally based on the pipelines added to accommodate them (and others). This simple method has been proven to violate all the equity criteria (Young et al. 1982), with the exception of simplicity.

Summary

The previous sections of this chapter have laid the groundwork and theory necessary to proceed with the evaluation of the economics of a water reuse system in South Florida. The flow chart depicted in Figure 4-6 summarizes the steps involved in each of these tasks. In the case of the pipeline optimization, the cost analysis, and the cost allocation, computer programs were written (see REUSE in Appendix B) to aid in the computation of the large amounts of data that were compiled manually in the design stage (which will be reviewed in the following chapter). The final step of the analysis (the selecting of the cost-effective users) involves the logical rules set forth earlier in this chapter, in determining the actual additional costs and/or benefits due to the proposed system.

The reader is cautioned against using these estimates of costs across-the-board, as they represent static costs, i.e., they are only valid if the proposed system was built, and would probably increase as users are weeded out. Looking at the flow chart analysis, however, it indicates that in the future, it may be possible to "close the circle" or re-route the previously found cost-effective users back through the whole process, in an iterative process, until some sort of stability is reached. The non-linear nature of the problem remains intact, and the problem becomes solvable.

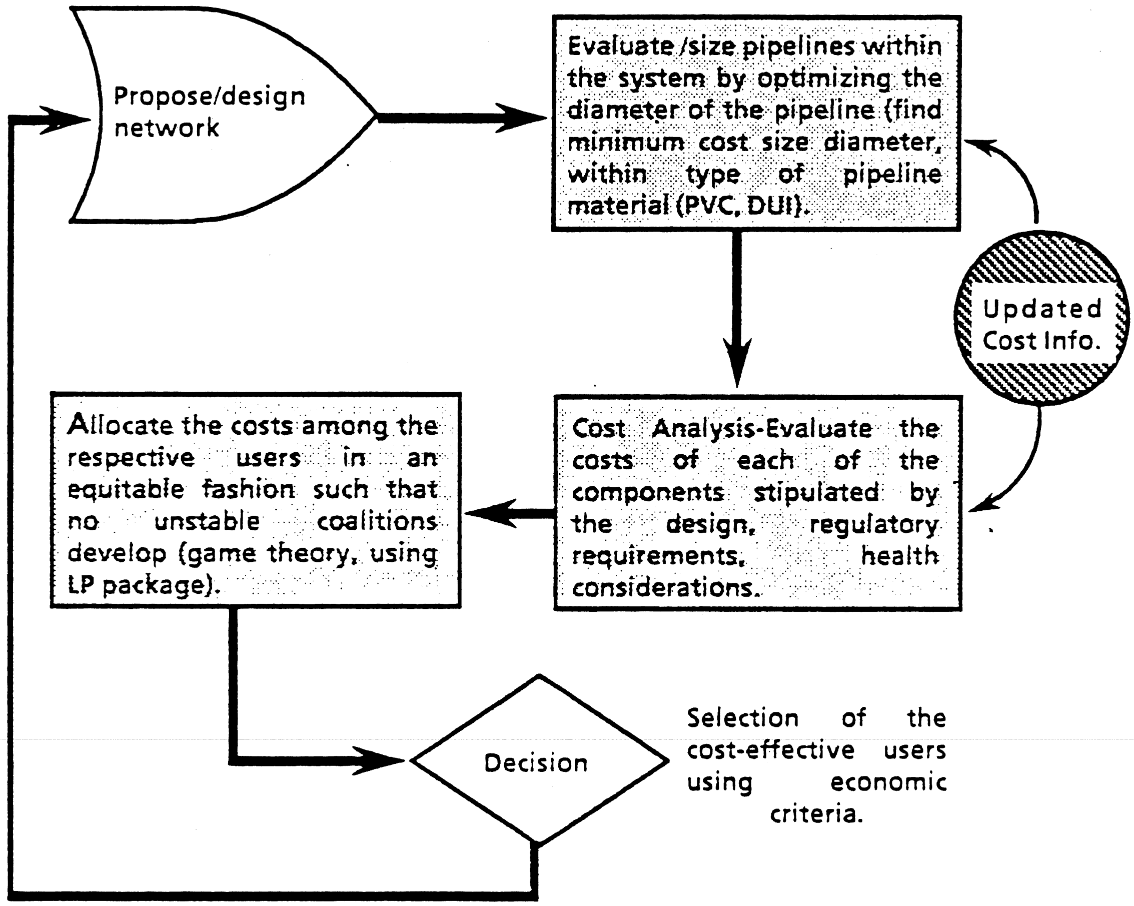


FIGURE 4-6: FLOW CHART FOR WASTEWATER REUSE FEASIBILITY ANALYSIS

CHAPTER 5: APPLICATION AND RESULTS FOR EASTERN PALM BEACH COUNTY, FLORIDA

The cost relationships developed and presented in the previous chapter allow the reader to understand how costs vary as size, distance, method of alternative disposal, and other characteristics change. The method of pipeline optimization enables the computation of the costs of pipelines for the region concerned without detailed design data. The vast array of data can be transformed into costs by a single computer program. The costs can be allocated by the two methods given in the last part of the chapter. This chapter emphasizes the design of the prospective water reuse system within the respective 201 boundaries of eastern Palm Beach County, Fla., and then presents the data from the cost analysis.

Design of the System Networks

The system that was designed considered for inclusion all wastewater treatment plants and potential users listed in Tables A-1 and A-2. In addition, a few plants smaller than the 1 MGD capacity criterion of these tables were included because these plants increased the economies of the planned wastewater reuse system (irrigation sites were close, and no other treatment plant with excess capacity was located within the region of concern).

Pipeline design was facilitated by use of computervision reconstructions of land use maps (with the assistance of the Land Resources Division of SFWMD). This system generated maps depicting golf courses, cemeteries, recreational areas, and wastewater treatment plants separately and identified as such. The U. S. Geological Survey (USGS) quadrangle maps, covering the eastern Palm Beach county region were used in addition to Mark Hurd aerial quadrangle maps to identify the sites of potential users. The design was made on the computervision maps, because the background data on other land use types wasn't printed, allowing for a clean work space.

The overall design was completed for each of the seven different 201 planning regions and subregions within the county. The western half of the county, consisting of mostly agricultural and wetland areas, was immediately eliminated from contention, as there was little or no treatment capacity within an economical distance to serve them (although, at a later date, as population expands to the west, it may become feasible). As a first step, routes for the pipelines were selected between the treatment plants and the respective irrigation sites. These were drawn along what was estimated to be the shortest distance along major rights of way, which should be reasonably close to an optimal path. Judgement was used to determine when lines should be shared and when they should be separated. In most cases, there was little question as to where the lines should go, taking into consideration costs of right-of way acquisition and other constraints. It had been suggested that the SFWMD could provide right-of-way along its canals, but this idea was abandoned because the legal/regulatory questions made it impossible.

The computervision system also provided gross estimates of area for the different sites, and this information was used when District permit information was unavailable (due to the unreliability of this data). Recreational sites were generally not included, as it was felt that the average size was too low to justify inclusion within the system, and that the more stringent DER, HRS, or county health regulations which apply to these areas would further reduce their feasibility. A few sites were dropped out also, due to their large distance to any treatment plant in their respective areas.

The finished design can be seen in Figures D-1 to D-9. Tables D-1 through D-14 explain the pipelines which serve the system (in greater detail than available on the maps), and provide information on the respective users identified on the map only by their Palm Beach County Area Planning Board (1981) number. This number, when superseded by the letters "GC" identifies the user as a golf course, "PK" for a Park, and "CM" for a cemetery. Figure 5-1 delineates the different 201 regions, or sub-regions, while the other figures show the system in detail. The pipelines within each region were labelled with letters, and their total lengths were computed with the help of the HP-81 digitizer system.

Procedure for Evaluating/Allocating Costs of the Networks

The information from Tables D-1 through D-14 was input into a FORTRAN program "REUSE" that evaluates the costs of the treatment systems (itemizing each component, and the total) for the respective networks, and calls a subroutine, "OPTIM" that determines the optimal diameters of the pipes of the systems, as outlined earlier. These programs can

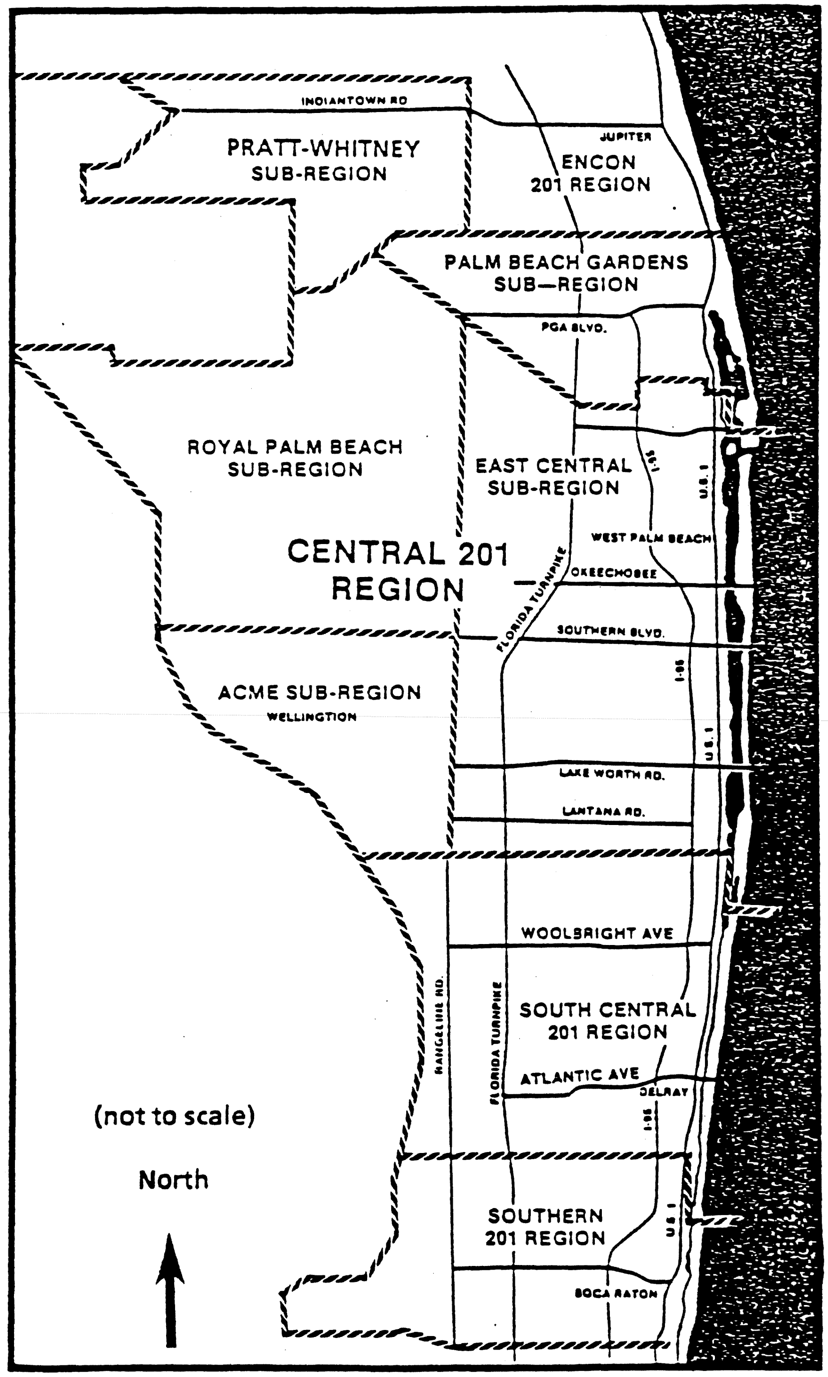


FIGURE 5-1: "201" WASTEWATER PLANNING REGIONS FOR EASTERN PALM BEACH COUNTY, FLA.

be found in appendix B. These two steps were all that was necessary in order to allocate the costs using the simple "added pipe rule" method described earlier. But in order to allocate the costs using the game theory method, many different combinations of the respective users within each network have to be evaluated and costed. The total costs from these methods then become the constraints of a linear program. The Multi-Purpose Optimization System of Northwestern University (MPOS) was used, and tables of the input and samples of output can be found in appendix C.

In using the simple method of cost allocation, the costs were allocated to each system user with each paying a user charge (¢/1000 gallons) on each pipeline in proportion to its share of the flow. A total was then formed as the sum of the treatment costs, pipeline costs, replumbing costs (to convert the site to wastewater, keeping the lines separate) of about 2¢/1000 gallons (calculated form Table 4-2), and alternative disposal costs (a cost avoided, computed from Table 4-5 and information from various 201 studies). The total represents the additional cost to the supplier of providing usable wastewater to the system customers. It would, therefore, represent the minumum price at which water would be sold. A negative total indicates that the supplier would be willing to give the water away (or pay a subsidy to take it away), as the cost of wastewater reuse disposal is cheaper than the alternative least cost disposal method. These system supply costs as allocated to users are presented in Appendix D, Tables D 1-7.

The willingness of the user to purchase wastewater has been estimated by the costs of alternative supplies that would be avoided. This was either the cost of operating the wells and pumps, or the costs of water purchased from a utility. This cost avoided was assumed to be the maximum the user would be willing to pay. When the maximum that the user would be willing to pay exceeds the minimum that the suppliers would be willing to charge, there is a potential match. Both the supplier and the user would have an incentive to participate with the final price/charge subject to negotiation between the participants. The difference between these two is termed the net cost savings, and indicates the strength of the match, (see the last column of Tables D-1-7). The users are grouped by their 201 regions and/or groups within, and are listed in order of cost-effectiveness.

Using the MCRS method, after the costs for the combinations of users were determined, and the MPOS programs were run (a run was made for each variable, maximizing and minimizing it as the objective function in order to determine the upper and lower bounds of it). The β value was then calculated using Equation 4-27 for each user, and the MCRS solution was found using Equations 4-28 and 4-29. The following analysis was made identical to the method used for the simple cost allocation, and these results are listed in Tables D-8-13. The last entry in the table represents the summation of the total costs, i.e., pooling all the benefits and costs within the groups.

To illustrate the MCRS method, a three member subregion was picked, the Royal Palm Subregion, shown in Figure 5-2. Thre are three potential users, identified as #29GC: Indian Trail Country Club, 175 acres; #30GC: Royal Palm Country Club, 170 acres; and a Cemetery, #1CM, 41 acres. This information was used in the computer program REUSE, and the output was analyzed using Equations 4-27 thru 4-29. The lower and upper bounds calculated from this method are shown in Figure 5-3 on triangular graph paper. Table 5-1 illustrates the calculation of costs from this analysis. (Note: in this case, the 2¢/1000 gallons was already added in). After calculating a fair charge for each user, X_i from Equation 4-29, the values are transformed to ¢/1000 gallons by dividing them by: (area) X(2.6937)X(2.0)X(.001440)X(365000). The alternate disposal cost is then listed, and the maximum supplier charge is the difference between X(i) and the alternative disposal cost. The maximum user charge is listed, and the maximum supplier charge is subtracted from it to obtain the net savings, in ¢/1000 gallons. Finally, cumalative savings are found by summing these savings after they are converted to $/year format.

These values will differ slightly from the values in Table D-11, the program that was used in the District analysis was altered to reflect several corrections. The overall result remains the same however, as Royal Palm Beach does not appear to be a good subregion for wastewater reuse.

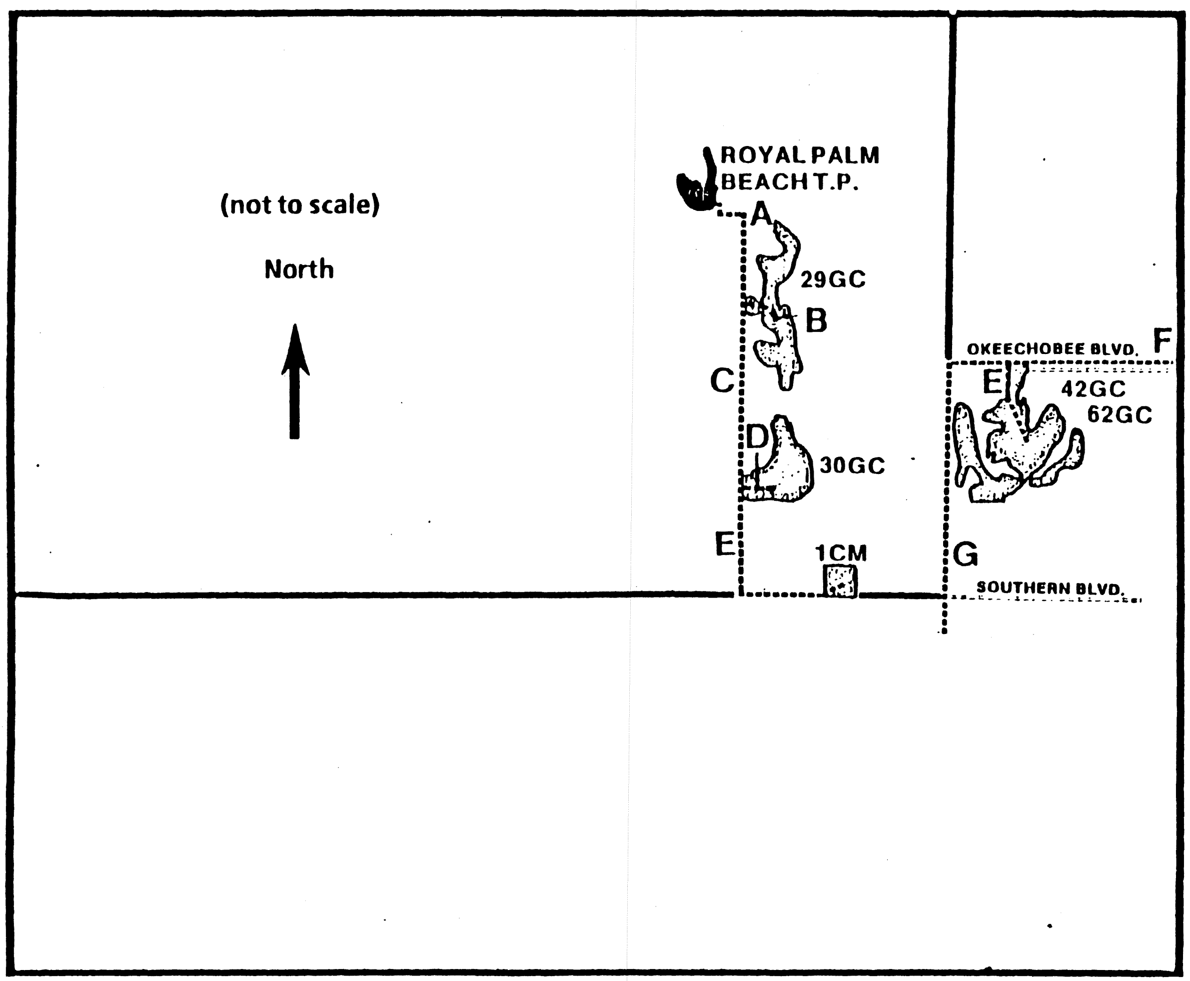
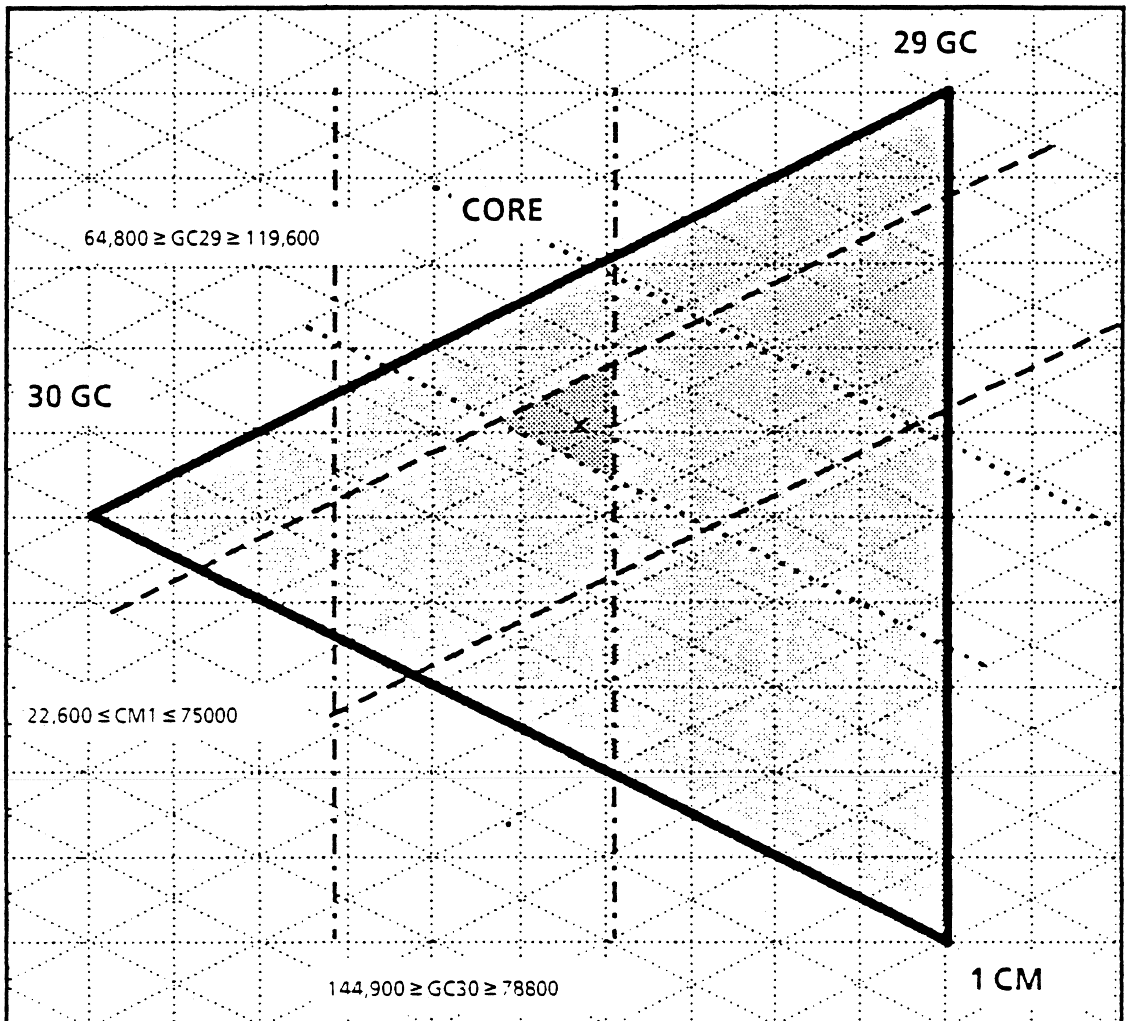


FIGURE 5-2: CENTRAL 201 REGION, ROYAL PALM SUBREGION

TABLE 5-1
USER'S UNIT COST INFORMATION USING LP
CENTRAL 201 REGION-PALM BEACH COUNTY-ROYAL PALM BEACH SUBREGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		β(*i*)	X(*i*)		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000					
Indian Trail C C	Royal	29GC	64842	119625	3161	81833	17	7	10	5	-5	-24068
Royal Palm C C	Royal	30GC	78874	104391	.3813	109017	22	7	15	5	-10	-73622
Cemetery	Royal	1CM	22624	75061	3026	42956	37	7	30	5	-25	-102646

Note: Non-separable costs totalled $66917.35/year.
Conversion costs were added in.



TRIANGULAR GRAPH KEY

Each unit represents 10,000 $/year in total costs (both capital and operating costs). The core is the shaded area--this is the region in which all constraints imposed by the members are satisfied. The geographic center of this area is the MCRS Solutions on the right

MCRS Solution:

GC30	**=**	**109000$/yr.**
GC29	**=**	**81800$/yr.**
CM1	**=**	**42900$/yr.**

FIGURE 5-3: GRAPHICAL REPRESENTATION OF A 3 MEMBER COST GAME APPLIED TO THE ROYAL PALM 201 SUBREGION

Cost Effectiveness Evaluation

It is now possible to estimate the overall cost effectiveness of a wastewater reuse system within Palm Beach County. In Tables 5-2 and 5-3, the results from Appendix D are presented for the two methods of cost allocation. In Table 5-2, many of the prospective users are eliminated by cost considerations, as indicated by the column in the table. Both regional water supply benefits and environmental damages were estimated as costing less than 1¢/1000 gallons, and were neglected due to the lack of impact on the analysis.

By summing the costs for the system by the flows required, the final network found from this method consisted of 1163 acres, or about 7.49 MGD, or 8,39 AF/yr., costing a total of $2,179,000/year (but for each user, this is equivalent to what they are spending for disposal and/or supply). This represents an additional water supply capability of 2750 AF during a four month period of no discharge to the salt water system. This figure represents about 9% of the total possible within the Palm Beach County area. The users are cost effective under the assumptions previously given, and could be prime candidates for detailed design studies. This analysis is very sensitive to the alternative disposal costs, and the estimated water supply costs.

Using the MCRS method of cost allocation, summarized in Table 5-3, the net cost effective system was 15.19 MGD, and if the users were summed (that is they continued to be charged what they were charged for disposal and/or supply as they were before the system, in order to spread the benefits, and increase the users in the system), the net zero cost system would increase to 38.34 MGD. This represents a significant increase in the size of the system, and the impact it could make.

The reader is cautioned against making broad conclusions from this analysis as the model presented in this paper is static, that is, as the users were evaluated as to their cost-effectiveness, they were presented, whereas a dynamic model (and a more accurate one) may be possible in which the process is put into a loop. In other words, the output from this method would be put back into the start of the cost evaluation process. It is expected that more users will drop out this way, with the result probably being somewhere between the two methods, or between 7.49 MGD and 15.19 MGD. The process gives good lower and upper bounds to aid in the decision analysis.

TABLE 5-2
PALM BEACH COUNTY WASTEWATER REUSE POTENTIAL & FINAL COSTS

201 Region	Treatment Plant	Type Disposal	Capacity Mgd	Demand Mgd	Eliminated By Capacity Mgd	Eliminated By Cost Mgd	Net Cost ¢/1000 g	Rework Mgd	Avg. Cost ¢/1000 g.	Net Savings ¢/1000 g.
ENCON	ENCON	Deep well or perc.	4	9.26	5.27	3.2	36	0.79	39	128
Central - North	Anchorage Dr	Intracoastal dis.	4.85	3.06	0.00	3.06	19	0.00		
	Seacoast Main	Perc. pond	0.4	3.89	3.49	0.40	16	0.00		
	Cabana	Perc. pond	0.35	1.30	0.95	0.35	20	0.00		
East	East Central	Deep well	40.00	18.97	0.00	14.67	14	4.80	42	15
R P B	Royal Palm	Perc. pond	1.1	2.99	1.89	1.10	20	0.00		
Acme	Acme	Perc. pond	1.5	6.07	4.57	1.50	14	0.00		
South Central	S.C. #1	Perc. pond	1.5	1.20	0.00	1.20	27	0.00		
	S.C. #2	Perc. pond	2.5	4.08	1.58	2.50	17	0.00		
	Village of Golf	Perc. pond	0.5	1.28	0.78	0.00	16	0.49*	26	-14
	SC Main	Ocean outfall	12.0	19.63	7.63	11.83	15	0.17*	49	-21
Southern	Glades Road	Ocean outfall	12.0	21.87	11.87	6.07	16	3.93	16	28
	S.R. #1	Perc. pond	0.5	1.23	0.73	0.50	17	0.00		
	S.R. #2	Perc. pond	3.72*	2.33	0.00	2.33	18	0.00		

*Deleted from total due to bad economics after rework.

TABLE 5-3
PALM BEACH COUNTY WASTEWATER REUSE POTENTIAL & FINAL COSTS USING LINEAR PROGRAMMING

201 Region	Treatment Plant	Type Disposal	Capacity Mgd	Demand Mgd	Eliminated By Capacity Mgd	Eliminated By Cost Mgd	Net Mgd	Cost eff. ¢/1000 g	All users ¢/1000 g	Net 0 Mgd
ENCON	ENCON	Deep well or perc.	4	9 26	5.26	1.21	2.79	26	-42	8 63
Central North	Anchorage Dr	Intracoastal dis.	4 85	3 06	0 00	3.06	0.00	--	-14	--
	Seacoast Main	Perc. pond	0 4	3 89	0 00	3.89	0.00	--	-7	0 0
	Cabana	Perc. pond	0 35	1 30	0 95	0.35	0 00	--	-5	0 0
East	East Central	Deep well	40 00	18 97	0 00	12.55	6.42	19	-12	16.32
R P B	Royal Palm	Perc pond	1 1	2.99	1 89	1 10	0.0	--	-8	0 0
Acme	Acme	Perc pond	1 5	6 07	4 57	1.50	0.0	--	-13	0 0
South Central	S C #1	Perc. pond	1 5	1 20	0.00	1.20	0.0	--	-5	0 00
	S C #2	Perc. pond	2 5	4 08	1 58	1 64	0.85	1	-2	4.08
	Village of Golf	Perc pond	0 5	1 28	0.78	0.11	0.89	0	-.3	1.28
	SC Main	Ocean outfall	12 0	19 63	7 63	11.83	0.17	4	-7	3 96
	S C Oc	Ocean outfall		1.52	--	1.50	0.00	--	-17	0.00
Southern	Glades Road	Ocean outfall	12.0	17 8	5 8	12.0	0.00	--	-11	0.00
	Glades, 1 oc	Ocean outfall	--	0.17	--	0 00	0.17	5	--	0.17
	Glades 2 oc.	Ocean outfall	--	1 26	--	--	1.26	35	-59	1.26
	Glades 3 oc.	Ocean outfall	--	2.64	--	--	2.64	15	--	2.64
	S R #1	Perc pond	0 5	1 23	0 73	0.50	0.00	--	-5	0.00
	S R. #2	Perc pond	3 72*	2.33	0 00	2.33	0 00	--	-9	0 00
Total							15.19			38.34

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

As indicated previously, of a total demand for reused water of 83 MGD, 7.5 MGD was found to be cost effective using the simple "added-pipe" rule allocation method, 15.2 MGD using the MCRS method, and pooling all the benfits and costs resulted in 38.3 MGD. It is expected that the true cost effective system size will lie somewhere in between these values. The reader is cautioned against using these estimates too broadly, as the model presented in this report is static, i.e., it does not take into consideration the effect users will have on the costs (they will increase) when some users are eliminated due to cost considerations. It is felt that a computer model that incorporates the whole analysis in the fashion of Figure 4-6 could be developed. This model would eliminate most linear limitations, basically, by using the iterations and the allocation analysis, it would come up with a stable solution (hopefully), that approximates the true economic reality closely.

It should be mentioned here that the model is very sensitive to changes in the water use demand of 2 inches per week. A more realistic approach would be to have a variable rate for each prospective user according to their water use in the past. The model does indicate that wastewater reuse as a water supply option, even under the best of considerations cannot compete against other water supply options such as conservation, which are of an order of magnitude lower in cost.

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APPENDIX A:

DISTRICT-WIDE INVENTORY OF WASTEWATER SOURCES AND POTENTIAL WASTEWATER IRRIGATION SITES

TABLE A-1 WASTEWATER TREATMENT PLANTS WITHIN THE

JURISDICTION OF THE SOUTH FLORIDA

WATER MANAGEMENT DISTRICT*

BROWARD COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
BOUD #2 North Regional	63.2 MGD	Extended aeration to the Atlantic Ocean
Boud Palmdale Plant 1B	1.0 MGD	Contact stabilization discharge to evapoperc. lake. Thence to surface water
Coral Springs Improve. District	2.0 MGD	Contact stabilization aerated oxidation pond to seepage ditch
Davie, Town of Utility System 2	1.0 MGD	Contact stabilization with tertiary filters to oxidation pond
Deerfield Beach, City of	4.0 MGD	Contact stabilization to Hillsboro Canal Div. to Broward N. Reg.
Fort Lauderdale - Coral Ridge	8.0 MGD	Activated sludge & contact stabilization & aux. trickling filter plant

*Includes all treatment plants with a capacity greater than or equal to 1 mgd.

BROWARD COUNTY TREATMENT PLANTS - CONTINUED

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Fort Lauderdale Plant A	8.2 MGD	Activated sludge, with ZIMPRO sludge treatment
Gulfstream Utility Company	2.5 MGD	Contact stabilization
Hollywood Wastewater Treatment Plant	38.0 MGD	
Lauderhill East	2.3 MGD	Complete mix activated sludge discharges to C-12 Canal to Boud North Reg.
Lauderhill West	6.0 MGD	Contact stabilization with tertiary filters to perc. ponds
Lohmeyer, G. T. Regional WWTP	25.0 MGD	Oxygen activated sludge to Intracoastal
Margate, City of, WWTP	6.0 MGD	Activated sludge WWTP discharging to 24 in. disposal well
Modern Pollution Control	1.0 MGD	Percolation pond
North Lauderdale, City of	3.2 MGD	Act sludge with cont. stab. discharge to perc. ponds and to canal
Oakland Park, City of	4.1 MGD	Activated sludge

BROWARD COUNTY TREATMENT PLANTS - CONTINUED

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Plantation, City of	1.2 MGD	Contact stabilization
Plantation, City of # 1 North	3.3 MGD	Contact stabilization with oxidation pond ditch to Holloway Canal, C-11 Canal
Sunrise #5 East	1.2 MGD	Contact stabilization
Sunrise North Plant 1A	3.3 MGD	Contact stab. perc. ponds spray irri-gation and evaporation
Sunrise Plant #2	2.3 MGD	Contact stab. & pure oxygen with tertiary pressure filters, discharge to ponds
Sunrise System #5 West	1.25 MGD	Contact stabilization & aerobic sludge digestor
Sunrise, City of Plant 1B	4.5 MGD	Contact stab. discharging to lagoons for spray irrigation
Sunrise, City of Plant 3	3.0 MGD	Contact stabilization
Tamarac, City of West WWTP	4.9 MGD	Contact stab. discharging to canal system with spray irrigation
Total	200.45 MGD	

COLLIER COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
City of Naples	5.4 MGD	Activated sludge (comp mix) effluent to pond to Gordon River
Collier County District A STP	1.5 MGD	Extended aeration to perc. ponds
Coon Key Pass Fishing Villas	12.0 MGD	
Immokalee Water & Sewer District	1.5 MGD	Oxidation ditch (extended aeration)
Marco Island Utilities	1.0 MGD	Contact stabilization to polishing pond thence to spray irrigation
Parkway Trailer Park	5.0 MGD	Extended aeration
Witches Brew	7.5 MGD	Extended aeration to drainfield
Total	33.9 MGD	

DADE COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Andover Subdivision	1.7 MGD	Activated sludge discharges to Snake Creek Canal
Aventura MDWSA	1.5 MGD	Contact stab. discharges to 5 acre lake overflow to ICW. Div. No-dist. reg. 8/81
Cutler Ridge	4.0 MGD	Complete mix utilizing aeration clarification chlorination
Homestead Air Force Base	3.0 MGD	
Homestead, City of	2.2 MGD	Contact stabilization to perc. pond
Kendale Lakes WWTP	3.2 MGD	Activated sludge with discharge to deep injection well
Leisure City STP Units 1,2&3	2.38 MGD	2.38 MGD Total: .63 MGD act. sludge. 1.25 MGD cont. stab. .0.50 MGD ext aer.
MDW&SA South District Regional WWTP	50.0 MGD	Activated sludge discharge to deep injection wells
MDWASA Central District WWTP	121.0 MGD	Activated sludge discharge to ocean outfall

DADE COUNTY TREATMENT PLANTS - CONTINUED

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
MDWASA Goulds-Perrine	6.0 MGD	Contact stabilization STP discharging to seepage trenches
MDWASA N. District WWTP	60.0 MGD	Oxygen activated sludge discharging to Atlantic Ocean
MDWASA Opa-Locka	12.0 MGD	Thru N. Miami outfall no data available
MDWASA Westwood Lakes	2.7 MGD	Discharging to Snapper Creek Canal
MDWASA Sunny Isles	5.7 MGD	Primary STP thru North Miami outfall data inconsistent
North Miami Beach Utility Co.	1.7 MGD	Contact stabilization discharging to Intracoastal Waterway
North Miami Plant 1	10.0 MGD	Primary wastewater TP discharge North Miami Ocean outfall
North Miami Plant 2	6.0 MGD	Primary WWTP discharge thru North Miami Ocean outfall

DADE COUNTY TREATMENT PLANTS - CONTINUED

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Opa Locka Airport STP	1.0 MGD	Secondary hi-rate trickling filter to Biscayne Canal. Flow div. to N. Dist.
S. Dade Utilities-Bel Aire	1.0 MGD	Contact stabilization to soakage pit
Sky Lake Development	1.0 MGD	Contact stabilization to soakage trench
Sunset Park General Waterworks	5.7 MGD	Complete mix sewage treatment with deep well injection
Total	302.78 MGD	

LEE COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Cape Coral, City of (Plant B)	4.0 MGD	Contact stabilization to Caloosahatchee River
Fiesta Village	5.0 MGD	Contact stabilization perc. ponds spray irrigation
Ft. Myers Beach Sewer District	2.7 MGD	Contact stabilization with effluent to polish and perc. ponds
Ft. Myers, City of (Raleigh St. Plant)	9.0 MGD	Pure oxygen/aeration & trickling filter with effluent to Caloosahatchee River
Ft. Myers, City of	6.0 MGD	Contact stabilization with effluent to Caloosahatchee River
Lehigh Utilities, Inc.	1.4 MGD	Contact stabilization to retention pond
Sanibel Sewer Systems #4	1.0 MGD	Contact stabilization to retention pond
Waterway Estates 1667 Inlet	1.08 MGD	Contact stabilization to Caloosa. River
Total	70.13 MGD	

HENDRY COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
U. S. Sugar	2.5 MGD	Secondary treatment, retention
Total	2.5 MGD	

MARTIN COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Hutchinson Island	7.5 MGD	STP with surge TNK tert. filters dual drainfields
Stuart, City of	2.0 MGD	Trickling filter and act. sludge fac./St. Lucie River to deep well prim. outfall sec.
Total	9.5 MGD	

MONROE COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Captain's Cove	15.0 MGD	Extended air with effluent to two boreholes
Key West, City of	4.3 MGD	None: Raw collection w/outfall to Atlantic
Sombrero Landing	5.0 MGD	Extended aeration
Total	24.3 MGD	

OKEECHOBEE COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Okeechobee, City of	4.0 MGD	Contact stabilization w/disposal via spray irrigation
Total	4.0 MGD	

ORANGE COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
OCS&W Dept/Sand Lake Road WWTP	15.0 MGD	Contact stabilization sewage treatment plant
Orlando/McLeod Road WWTP#2, City of	12.0 MGD	High rate trickling filter sewage treatment plant
Total	17.0 MGD	

OSCEOLA COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Kissimmee, City of (Interim)	1.0 MGD	Contact stabilization with underdrained sprayfield
Kissimmee/Martin Street, WWTP	1.7 MGD	Contact stabilization sewage treatment plant w/effluent to Lake Tohopekaliga
Reedy Creek Improvement District	6.0 MGD	Activated STP
St. Cloud, STP, City of	1.0 MGD	Trickling filter to St. Cloud Canal Tert. filters
Total	9.7 MGD	

PALM BEACH COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Acme Improvement District	1.5 MGD	Activated sludge
Belle Glade, City of	2.0 MGD	Contact stabilization
Boca Raton, City of	10.0 MGD	Contact stabilization
Century Village	1.9 MGD	Contact stabilization with discharge to perc. pond & golf courses
East Central Regional WWTP	40.0 MGD	Extended aeration to five deep injection wells
Loxahatchee Env. Control District	4.0 MGD	Extended aeration chem precip. settling, chlorination to pond
Pahokee, City of STP	1.2 MGD	

PALM BEACH COUNTY TREATMENT PLANTS-CONTINUED

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Palm Beach Co. #3	2.5 MGD	Contact stabilization to perc. pond
Palm Beach Co. System #5 - Le Chalet	1.5 MGD	Contact stabilization
Royal Palm Beach Utility Co.	1.1 MGD	Contact stabilization
Seacoast Util. - Palm Beach Gardens	3.6 MGD	Complete mix activated sludge
Seacoast Utilities	4.8 MGD	Activated sludge STP with offsite disposal
South Central Reg. Plant #2 (PBC)	2.5 MGD	Contact stabilization discharging to nine perc. ponds
South Central Regional WWTRP	15.0 MGD	Activated sludge to ocean outfall
South Palm Beach Util. Corp. (Amer. Homes)	3.0 MGD	Contact stab. tertiary alum. coagulation dual media filtration to ponds
Total	94.6 MGD	

ST. LUCIE COUNTY TREATMENT PLANTS

NAME	DESIGN CAPACITY	TYPE TREATMENT & DISPOSAL
Fort Pierce Utility Authority	5.0 MGD	3.5 MGD activated sludge & 1.5 contact stabilization
GDU - Port St. Lucie - North	2.0 MGD	Complete mix facility discharging to St. Lucie River
Total	7.0 MGD	

TABLE A-2 POTENTIAL WASTEWATER IRRIGATION SITES WITHIN THE JURISDICTION OF THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

BROWARD COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
American Golfers Club(Incl. in Coral Ridge Prop.)		
Arrowhead Golf and Country Club		153 Acres
Bonaventure Assoc.	06-00108-W	243 Acres
Broken Woods Golf	06-00376-W	67 Acres
Broward Comm. College	06-00354-W	16.67 Acres
Broward Co. Aviation(Ft. Laud/Hollywood Air.)	06-00431-W	54.5 Acres
Broward Co. Parks Dept.(Sports Complex)	06-00310-W	432 Acres
Broward Co. Park & Rec.(Lakeview Park)	06-00382-W	85 Acres
Broward Co. Rec. Dept.(Lyon's Tradewinds Pk)	06-00347-W	425 Acres
Broward Memorial Gardens		
Century Village East	06-00076-W	780 Acres
Colony West Country Club		150 Acres
Cooper Colony Country Club	06-00407-W	60 Acres
Coral Ridge Country Club	06-00105-W	212 Acres
Coral Ridge Properties(Village II GC)	06-00412-W	136 Acres
Country Club of Coral Springs	06-00377-W	103 Acres
Crystal Lake Country Club	06-00394-W	117 Acres
Dania Country Club	06-00250-S	35 Acres
Deerfield Country Club	06-00034-W	62.7 Acres
Deerfield High School	06-00385-W	17.5 Acres
D C Properties(Deer Creek CC)	06-00244-W	175 Acres
Diplomat Country Club		105 Acres
Ece Grande Golf Course		61 Acres
Emerald Hills Country	06-00061-W	108.5 Acres
Emerald Hills Country Club	06-00062-W	64.7 Acres

BROWARD COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
Evergreen Cemetery		
Forest Lawn Memorial	06-00068-W	40 Acres
Foxcraft Golf and Tennis		83 Acres
FPA Corporation	06-00024-W	662 Acres
Ft. Lauderdale Country Club	06-00056-W	280 Acres
Ft. Lauderdale, City of	06-00122-W	248 Acres
Goodyear Tire & Rubber(Blimp Base)	06-00336-W	30 Acres
Highland Meadows MHP	06-00048-W	50 Acres
Highland Village MHP	06-00059-W	20 Acres
High School CCC, Bro.	06-00245-W	25 Acres
Hillcrest Golf & Country Club	06-00099-W	140 Acres
Hollybrook Golf & Tennis	06-00406-W	170 Acres
Hollywood Beach Golf & Country Club		77 Acres
Hollywood Lakes Country Club		285 Acres
Hollywood Memorial Gardens	06-00075-W	45.65 Acres
Hollywood Memorial Gardens	06-00063-W	28.82 Acres
Hollywood, City of	06-00052-W	205 Acres
Inverrary Country Club	06-00344-W	320 Acres
Jacaranda Country Club	06-00149-W	260 Acres
Lago Mar Country Club		169 Acres
Lauderdale Lakes, City of	06-00181-W	8 Acres
Lauderdale Memorial Gardens		
Lauderdale Memorial Park		
Leisureville Fairway		N/A
Leonard W.(Adios Country Club)	06-00416-W	102.4 Acres
Mainlands Golf Course		16 Acres
Martinique Village		139 Acres
Montwood, Inc.(Woodmont Country Club)	06-00089-W	281 Acres
Nationwide Builders(Holiday Springs G&CC)	06-00021-W	120 Acres
Oakridge Country Club	06-00307-W	170 Acres
Orange Brook Golf Course		205 Acres

BROWARD COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
Oriole Golf & Tennis Club		160 Acres
Palm-Aire Country Club	06-00357-W	19 Acres
Pembroke Lakes Golf	06-00026-W	80 Acres
Pine Island Ridges Golf Course		333 Acres
Pines Par Three		N/A
Plantation Golf Club	06-00408-W	32 Acres
Pompano Beach, City of	06-00081-W	45 Acres
Pompano Beach, City of(Pompano Beach GC)	06-00025-W	150 Acres
Pompano Beach Country Club		45 Acres
Pompano Park Golf Club		
Pompano Park Raceway	06-00193-W	90.3 Acres
Queen of Heaven Cemetery	06-00106-W	24 Acres
Rolling Hills Golf	06-00393-W	160 Acres
Sabal Palm Country Club	06-00083-W	120 Acres
Sharon Gardens Memorial Park(2 cemeteries)		
So. Broward Park Dis. Com.	06-00130-W	140 Acres
Spring Tree Country Club		213 Acres
Star of David Memorial Gardens		
Sunrise Country Club		189 Acres
Sunset Golf Course		N/A
Sunset Memorial Gardens		
Tamarac Country Club	06-00383-W	145 Acres
Tam O'Shanter Country Club	06-00384-W	90 Acres
Temple Beth El Memorial Gardens		
Westlawn Memorial Gardens		
Whispering Lakes Golf	06-00023-W	35 Acres
Woodlands Golf Assoc.	06-00094-W	245 Acres
Wynmoor Limited	06-00039-W	130 Acres
Total		10,288.74 Acres

COLLIER COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Big Cypress Country Club		N/A
City Natl. Bank of Miami(Eagle Creek G & T)	11-00179-W	125 Acres
Club at Pelican Bay		N/A
Collier Dev. Corp.	11-00021-W	144 Acres
Country Club of Naples	11-00064-W	115 Acres
Forest Lake Country Club		98 Acres*
The Glades, Inc.	11-00020-W	245 Acres
Golden Gate Golf	11-00138-W	77 Acres
High Point Country Club	11-00019-W	15 Acres
Hole-In-The-Wall Golf Club	11-00030-W	180 Acres
Imperial Golf Club	11-00058-W	260 Acres
Kings Lake, Ltd.	11-00145-W	50 Acres
Lakeland Country Club		98 Acres*
Lely Estates, Inc.(Lely CC)	11-00131-W	300 Acres
Manchester Inv, Inc.(Sherwood Park)	11-00196-W	50 Acres
Marco Island Utilities	11-00104-W	741 Acres
Marco Shore Golf & Country Club		N/A
Moorings Golf Club	11-00054-W	38 Acres
Naples Bath & Tennis	11-00008-W	80 Acres
Naples Golf & Beach Club	11-00063-W	107 Acres
Naples Memorial Gardens	11-00220-W	12 Acres
Natl Audubon Society	11-00048-W	N/A
Palm River Country Club	11-00139-W	75 Acres
Pine Lakes Country Club		98 Acres*
Placid Lakes Country Club		N/A
Quail Run Country Club	11-00224-W	55 Acres
Riviera Golf Club	11-00053-W	85 Acres
Royal Poinciana Golf Club	11-00045-W	312 Acres
Shelter Corp. of Canada (Bear's Pan CC)	11-00130-W	150 Acres
Smith, G C	11-00045-W	45 Acres
Spanish Wells Country Club		N/A
The Moorings, Inc.	11-00200-W	44 Acres

COLLIER COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
US Home Corporation	11-00050-W	45 Acres
US Home Corporation(Foxfire)	11-00221-W	125 Acres
US Home Corporation(Lakeland CC of Naples)	11-00150-W	53 Acres
West Fla. Investments(Bay Forest)	11-00206-W	50 Acres
Whispering Pines, Inc.	11-00210-W	54.16 Acres
Wilderness Country Club	11-00057-W	170 Acres
Wyndemere Holdings	11-00167-W	232 Acres
Total		4,425.16 Acres

DADE COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Bayshore Golf Course		153 Acres
Biltmore Golf Course		82 Acres
Bleaufontaine, Inc.	13-00024-W	120 Acres
Briar Bay Golf Course		38 Acres
California Club North		130 Acres
California Country Club		360 Acres
Calusa, Inc.	13-00072-W	105 Acres
Club West, Inc.(CC of Miami)	13-00109-W	225 Acres
Colonial Palms Golf Course		83 Acres
Continental Golf Course		23 Acres
Coral Gables, City of	13-00055-W	139 Acres
Coral Gables, City of	13-00049-W	1.48 Acres
Coral Gables, City of	13-00056-W	57.8 Acres
Costa Del Sol Golf Course		326 Acres
Country Club Aventur	13-00052-W	225 Acres
Crooked Creek Golf Course		87 Acres
Diplomat Presidential		265 Acres
Doral Country Club	13-00061-W	600 Acres
Doral Pk Joint Venture	13-00107-W	110 Acres
Fla. Inter. University	13-00021-W	70 Acres
Fontainbleau East and West		464 Acres
Granada Golf Course		43 Acres
Greynolds Park		67 Acres
Haulover Beach Golf Course		46 Acres
Homestead AFB Golf Course		93 Acres
Indian Creek		93 Acres
Kendale Lakes Golf & CC	13-00031-W	170 Acres
Kendale W. Golf & CC	13-00032-W	77.34 Acres
Key Biscayne Golf Course		98 Acres
Kings Bay Country Club		184 Acres
La Gorce Country Club		66 Acres

DADE COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
Metro Dade County	13-00071-W	293 Acres
Miami Lakes Inn & CC	13-00019-W	53.5 Acres
Miami Shores Country Club	13-00041-W	120 Acres
Miami, City of(Melreese CC)	13-00095-W	50 Acres
Miami, City of(Miami CC)	13-00090-W	95 Acres
Normandy Shores Golf Course		149 Acres
Palmetto Country Club		177 Acres
Par Three Golf Course		45 Acres
Redland Golf & Country Club	13-00074-W	110 Acres
Riviera Country Club	13-00088-W	105 Acres
Sago Bay Golf Course		N/A
The California Club	13-00034-W	120 Acres
Trafalgar Dev. of Fla.	13-00020-W	110 Acres
Turnberry Isles Country Club		61 Acres
Westview Country Club	13-00022-W	55 Acres
Total		6,145.12 Acres

GLADES COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Airboats of Buckhead, Inc.	22-00005-W	5 Acres
General Development Corp.	22-00006-W	190 Acres
Hendry Isles Golf Course		
Total		195 Acres

HENDRY COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Clewiston Golf Course		98 Acres*
Layton, J	26-00147-W	31 Acres
Total		129 Acres

HIGHLANDS COUNTY WASTEWATER IRRIGATION SITES

No Golf Courses in SFWMD

LEE COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Alden Pines, Ltd.	36-00204-W	55 Acres
Ayers & G. Drake, Tru H(Corkscrew G.)	36-00252-W	113 Acres
Boca Grande		98 Acres*
Bonita Bay	36-00282-W	2375 Acres
Bonita Springs Golf & CC	36-00186-W	160 Acres
Cape Coral CC & Golf Course	36-00056-W	187 Acres
Cape Coral Exec. Golf Course	36-00051-W	29 Acres
City of Ft. Myers	36-00019-W	135 Acres
Cypress Lake Country Club		N/A
Cypress Pines Country Club	36-00303-W	89.2 Acres
Eagle Ridge Golf Course		N/A
Eastwood Golf Course	36-00368-5	N/A
El Rio Golf Club	36-00026-W	35 Acres
Equity Service Group(Paddle Creek)	36-00278-W	22.1 Acres
Fiddlesticks Country Club	36-00287-S	98 Acres*
Fort Myers Country Club		98 Acres*
Lake Lawn Country Club	36-00070-W	33 Acres
Landing Yacht & Golf Club	36-00138-W	150 Acres
Lan Ron Builders, Inc.(Lake Fairways MHP)	36-00212-W	35 Acres
Lee County School Board	36-00133-W	23 Acres
Lehigh Acres Dev.(Mirror Lakes)	36-00143-W	160 Acres
Lehigh Acres Dev.(Lehigh Acres CC)	36-00144-W	115 Acres
Lehigh Corporation(Deer Run GC)	36-00351-W	67 Acres
Lochmoor Country Club	36-00025-W	81 Acres
Mariner Prop., Inc.(Casa Ybel Beach & Sport)	36-00107-W	10 Acres
McGregor Villas, Inc.	36-00138-W	150 Acres
Myerlee Country Club	36-00268-S	98 Acres*
Palmetto Pine Country Club	36-00032-W	95 Acres
Punta Gorda Isles Co.	36-00066-W	365 Acres

LEE COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
San Carlos Golf, Inc.	36-00308-W	90 Acres
Seven Lakes Assoc.	36-00088-W	125 Acres
Stardial Investments(Bay Beach GC)	36-00322-W	45.5 Acres
Suncoast Investments(Del-Tura CC)	36-00264-W	79 Acres
S Seas Plantation Co.	36-00109-W	75 Acres
The Dunes Golf & Country Club	36-00044-W	109 Acres
Timberlake, Ltd.(The Forest)	36-00161-W	120 Acres
Useppa Island		35 Acres
Whiskey Creek Country Club, Inc.	36-00055-W	52 Acres
Total		5,606.8 Acres

MARTIN COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Crane Creek Country Club	43-00027-W	64.3 Acres
Eaglewood Joint Venture(PUD)	43-00220-W	50.1 Acres
Heritage Ridge Golf Club	43-00126-S	33 Acres
Holiday Country Club		N/A
Indian River Plantation	43-00042-W	127 Acres
Joe's Point Venture	43-00130-W	34 Acres
Jonathan's Landing	43-00221-W	180 Acres
Jupiter Golf Club, I C.	43-00054-W	298 Acres
King Mountain Condo Assn.	43-00013-W	45.6 Acres
Mariner Sands Dev. Co.	43-00064-W	215 Acres
Martin Co. Bd. of	43-00156-W	30 Acres
Martin Co. Golf & CC	43-00031-W	160 Acres
Mid-Rivers, Inc.	43-00069-W	105 Acres
Miles Grant Country Club	43-00067-W	88 Acres
Mobile Oil Estates	43-00030-W	458 Acres
North Trail Golf Club	43-00026-W	35.4 Acres
Pipers Landing, Inc.	43-00198-W	66.4 Acres
Ranch Colony, Inc.	43-00138-W	230 Acres
River Bend Golf Course	43-00091-W	67.59 Acres
Southern Realty Group(Martin Down's CC)	43-00204-W	101.3 Acres
The Little Club Condo	43-00202-W	20 Acres
The Yacht & Country Club	43-00032-W	140.1 Acres
Turtle Creek Club	43-00140-W	105 Acres
Total		2,653.79 Acres

MONROE COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Key West Golf Course	44-00003-S	60.5 Acres
Ocean Reef Club, Inc.	44-00001-W	57 Acres
Total		117.5 Acres

OKEECHOBEE COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	RRIGATED AREA
Okeechobee Golf and Country Club		N/A

ORANGE COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Blue Mountains Joint Venture	48-00121-W	253 Acres
Greater Orlando	48-00063-W	178 Acres
Orange Lake Country	48-00135-W	237.5 Acres
Orlando Naval Training	48-00091-W	59 Acres
Sea World of Florida	48-00058-W	248 Acres
Total		975.5 Acres

OSCEOLA COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Little England, Inc.	49-00118-W	498 Acres
Total		498 Acres

PALM BEACH COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Arvida Corporation	50-00489-W	90 Acres
Atlantis Country Club	50-00452-W	100 Acres
Atlantis Golf Club	50-00406-W	150 Acres
Banyan Golf Club	50-00443-W	140 Acres
Belle Glade Golf Course		N/A
Belvedere Golf Club	50-00849-W	25 Acres
Biernbaum, R.	50-00697-W	135 Acres
Boca Del Mar Associates	50-00054-W	142 Acres
Boca Del Mar Assoc.	50-00055-W	116 Acres
Boca Greens Country Club	50-00632-W	140 Acres
Boca Grove Plantation	50-00841-W	179 Acres
Boca Lago Country Club, Inc.	50-00888-W	202.6 Acres
Boca Raton Hotel & Club	50-00328-W	120 Acres
Boca Raton, City of	50-00832-W	165 Acres
Boca Rio Golf Club	50-00292-W	163 Acres
Boca Teeca Corp.	50-00088-W	100 Acres
Boca Woods Country Club	50-00737-W	200 Acres
Boynton Beach, City of	50-00951-W	110 Acres
Cadillac Fairview In.	50-00981-W	155 Acres
Cadillac Fairview	50-01001-W	88.26 Acres
Century Village West	50-00688-W	101 Acres
Century Village, Inc.	50-00890-W	60.7 Acres
City of Boynton Beach	50-00039-W	20 Acres
City of West Palm Beach	50-00257-W	17.5 Acres
City of West Palm Beach	50-00247-W	35 Acres
City of West Palm Beach	50-00256-W	45 Acres
City of West Palm Beach	50-00487-W	110 Acres
Country Manors Condo.	50-00150-W	37.6 Acres
Covered Bridge Condo.	50-00050-W	45 Acres
Crouch/Palermo Fla.	50-00945-W	120 Acres
Crystal Lakes RV Resort & Golf C.	50-00828-S	N/A
Delray Beach Country Club	50-00944-W	120 Acres

PALM BEACH COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
Delray Dunes Golf & CC	50-00851-W	120 Acres
Dept. of Natural Resources	50-00741-W	812 Acres
DGC Assoc. by Pair, Inc.	50-00534-W	190 Acres
Dimentional Builders, Inc.	50-00526-W	80 Acres
Eastpointe Country Club	50-00941-W	123.9 Acres
EPIC Corporation	50-00059-W	168 Acres
Flagler System, Inc.	50-00203-W	200 Acres
Fla. Atlantic University	50-00655-W	240 Acres
Fla. Planned Communities	50-00110-W	216 Acres
Fla. Power & Light Co.	50-00742-W	8.3 Acres
Forest Hill Golf, Inc.	50-00099-W	25 Acres
Fountains Golf & Racquet	50-00440-W	225 Acres
Fountains of Palm Beach	50-00165-W	100 Acres
Frenchmans, Inc.	50-00091-W	168 Acres
Gould Florida, Inc.	50-00883-W	632 Acres
Greentree Villas Condo.	50-00472-W	80 Acres
Greenway Village S	50-00642-W	22 Acres
Gulf Stream Golf Club	50-00377-W	160 Acres
Hidden Valley Golf	50-00970-W	10 Acres
High Point of Delray	50-01030-W	31.55 Acres
High Point of Delray	50-00666-W	68.2 Acres
Holigolf, Inc.	50-00255-W	35.2 Acres
IBM C/O Jerry Delane	50-00502-W	39.7 Acres
John I. Leonard High School	50-00140-W	20 Acres
John T. Oxley Farms	50-00007-W	116 Acres
Jonathan's Landing	50-00237-W	120 Acres
J.D.M. Country Club	50-00852-W	590.8 Acres
Kings Point Community Assoc.	50-00975-W	95 Acres
Kings Point Housing	50-00971-W	220 Acres
Lake Worth, City of	50-00866-W	97 Acres
Levitt Homes, Inc.	50-00760-W	11.1 Acres
Lion Country Safari, Inc.	50-00374-W	400 Acres

PALM BEACH COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
Lone Pine Golf Club	50-00954-W	40 Acres
Lost Tree Club, Inc.	50-00421-W	130 Acres
Lucerne Lakes Golf Course	50-00388-W	55 Acres
Lucerne Park, Ltd.	50-00967-W	32.6 Acres
Markborough Properties	50-00845-W	197 Acres
Mark M. Nicolaysen	50-00032-W	40 Acres
Mayacoo Lakes Country Club	50-00537-W	160 Acres
Meadowbrook Mobile Home Park	50-00120-W	41 Acres
Mirror Lakes Home.	50-00583-W	23.6 Acres
No I Condo Assoc.	50-00848-W	40 Acres
N. Palm Beach Co WCD	50-00617-W	507 Acres
Oriole Homes Corporation	50-00078-W	101 Acres
Palm Greens #2 Condo.	50-00859-W	70 Acres
Palm Hill Villas	50-00865-W	19 Acres
P.B Co. Parks & Rec. Dept.	50-00814-W	21.4 Acres
P.B. Lakes Golf Club	50-00233-W	95 Acres
Pelican Harbor, Inc.	50-00725-W	11 Acres
Perini Land & Dev. Co.	50-01022-W	190.7 Acres
Pierce	50-00394-W	115 Acres
Pine Tree Golf Club, Inc.	50-00535-W	160 Acres
Presidential Country Club	50-00224-W	247 Acres
P.B. National Golf & CC	50-00268-W	70 Acres
Quail Ridge, Inc.	50-00419-W	197 Acres
Radice Corporation	50-00908-W	89.8 Acres
Retirement Builders	50-00855-W	71 Acres
Royal Palm Beach Colony	50-00269-W	175 Acres
Royal Palm Memorial Gardens	50-00218-W	81 Acres
Royal Palm Yacht & CC	50-00159-W	131.3 Acres
Royal Palm Bch. Golf & CC	50-00561-W	170 Acres
Sandalfoot Cove Country Club	50-00411-W	155 Acres
Seminole Golf Club	50-00349-W	105.4 Acres
St. Andrews Dev. Corp.	50-00799-W	658 Acres

PALM BEACH COUNTY WASTEWATER IRRIGATION SITES - CONTINUED

NAME	PERMIT NUMBER	IRRIGATED AREA
Summit Assoc, Ltd.	50-00331-W	327 Acres
Tequesta Country Club	50-00223-W	100 Acres
The Hamlet of Delray	50-00284-W	114.2 Acres
The Little Club, Inc.	50-00434-W	33 Acres
The Trails Golf & Country Club	50-00896-W	47 Acres
Trafalgar Dev. of Fla.	50-00111-W	357 Acres
Univ. Park Country Club	50-00119-W	60 Acres
Villa Delray Golf	50-00049-W	130 Acres
Village of N. Palm Beach	50-00084-W	127.2 Acres
Willow Bend Assoc.	50-00631-W	25 Acres
Total		14,377.61 Acres

POLK COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Grenelefe Corporation	53-00029-W	40 Acres
Poinciana Golf & Racquet	53-00020-W	120 Acres
River Ranch, Inc.	53-00017-W	45 Acres
Total		205 Acres

ST. LUCIE COUNTY WASTEWATER IRRIGATION SITES

NAME	PERMIT NUMBER	IRRIGATED AREA
Ft. Pierce-St. Lucie C RB	56-00001-W	640 Acres
General Development Corp.	56-00100-W	225 Acres
Hollingsworth EL	56-00390-W	50 Acres
Indian Pines Golf Club	56-00101-W	50.4 Acres
Total		965.4 Acres

APPENDIX B:

PIPELINE OPTIM IZATION AND COSTING PROGRAMS WITH SAMPLE OUTPUT

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PDP-11 FORTRAN-77 V4.1-13        10:16:37     14-Nov-83           Page 1
REUSE.FTN;37               /CK/F77/TR:ALL/WR

               PROGRAM REUSE
               COMMON AREA,DIAM,N
C              PROGRAM REUSE(MODIFIED)
               DIMENSION PIPE(5),PUMP(5),PUMPOM(5),TOTAL(5),
          $HEAD(5),FLOWM(5),FLOWG(5),PIPOM(5)
               REAL MEDIA,MEDIAA,MEDTG
               DIMENSION DIAM(5),DIST(5),AREA(5)
               CHARACTER*60,REGION,TIM*8
               CHARACTER*2,PIPID(5)
               OPEN (UNIT=2,TYPE='OLD',FILE='GOLF.DAT',ORGANIZATION=
          $'SEQUENTIAL')
               OPEN (UNIT=3,TYPE='OLD',FILE='COSTS.DAT',ORGANIZATION=
          $'SEQUENTIAL',ACCESS='APPEND')
               N=5
C  THE FOLLOWING DATA VALUES REPRESENT THE CAPITAL RECOVERY FACTORS:
C  CRF1         PIPES      10% SALVAGE     10%INTEREST      30YEARS
C  CRF2         PUMPS      10% SALVAGE     10%INTEREST      10 YEARS
C  CRF3         FILTER      0% SALVAGE     10%INTEREST      20 YEARS
C  CRF4         STORAGE     0% SALVAGE     10%INTEREST      30 YEARS
C  CRF5         CHLOR       0% SALVAGE     10%INTEREST      15 YEARS
C  LENGTHS OF TIME WERE ESTIMATED FROM OLAC STUDY.......
               DATA CRF1/.10547/CRF2/.15647/CRF3/.11746/
               DATA CRF4/.10608/CRF5/.131474/
               READ (2,140) REGION
               READ (2,155) (PIPID(I),AREA(I),DIST(I),I=1,N)
               CALL IDATE (I1,J1,K1)
               CALL TIME (TIM)
               CALL OPTIM
               WRITE (3,165) REGION
               WRITE (3,147)
               WRITE (3,145)
               AREATO=AREA(1)
               DO 5 I=1,N
C    5         WRITE (3,150) PIPID(I),AREA(I),DIAM(I),DIST(I)
               WRITE (3,147)
C
C
C
C FLOW IN MGD (FLOWM) AND GPM (FLOWG) AT AN APPLICATION RATE
C OF 2 INCHES PER WEEK..........
               DO 10 I=1,N
               FLOWG(I)=2*AREA(I)*2.6937
               FLOWM(I)=FLOWG(I)*(1440./1000000.)
     10        CONTINUE
C
               FLOWGT=2.0*AREATO*2.6937
               FLOWMT=FLOWGT*(1440./1000000.)
C  COST OF PIPE, CAPITAL, IN DOLLARS PER 1000 GALL....
C
               DO 25 I=1,N
               IF (DIAM(I).GE.12) GO TO 20
               PIPE(I)=1.25*(.258*(DIAM(I)**.2587)*DIST(I)+.1205*
          $(DIAM(I)**1.7032)*DIST(I))
               PIPOM(I)=(.005/1.25)*PIPE(I)
               GO TO 22
```

```
0036     20        PIPE(I)=1.25*(.3249*(DIAM(I)**.88832)*DIST(I)+.2649*
               *(DIAM(I)**1.5549)*DIST(I)+.2905*(DIAM(I)**.88982)*
               *DIST(I))
0037               PIPOM(I)=(.005/1.25)*PIPE(I)
0038     22        CONTINUE
         C
         C
         C
         C  HEAD OF SYSTEM IN FEET
0039               C=100.
0040               HSTAT=0.0
0041               IF (DIAM(I).GE.12) C=120.
0042               HEAD(I)=HSTAT+(DIST(I)*(FLOWG(I)**1.85)/((.0955*
               *(C**1.85)*(DIAM(I)**4.86))))
         C
         C
         C
         C
         C
         C
         C  COST OF PUMPS, CAPITAL, IN DOLLARS
0043               PUMP(I)=(1.87*(FLOWG(I)**.78152)*(HEAD(I)**
               *.69174)+7.75*(FLOWG(I)**.68914)*(HEAD(I)**.22625)+
               *29.1*(FLOWG(I)**.75655)+1.39*(FLOWG(I)**.80860)*
               *(HEAD(I)**.53109)+1.75*(FLOWG(I)**.77240)*(HEAD(I)
               ***.48164))
         C
         C
         C
         C  COST OF PUMPS, OPERATION AND MAINTENANCE, DOLLARS PER 1000 GALL...
         C
0044               PUMPOM(I)=.04*(FLOWG(I)*HEAD(I))+124.57*(FLOWG(I)
               ***.50443)+1.09*(FLOWG(I)**.85775)
0045     25        CONTINUE
         C
         C
         C
         C
         C
         C  COSTS OF TERTIARY FILTRATION, DOLLARS PER 1000 GALL...
         C
         C  GRAVITY FILTER CONSTRUCTION.....
0046               GRAVC=1799.56*(FLOWMT**.59901)+28863.05*(FLOWMT**.69806)
               *+13515.89*(FLOWMT**.5633)+8046.74*(FLOWMT**.55305)+
               *37857.49*(FLOWMT**.59019)+9521.09*(FLOWMT**.73684)+
               *17848.1*(FLOWMT**.54705)+15412.69*(FLOWMT**.77921)+
               *25605.56*(FLOWMT**.66069)
         C
0047               GRAVCA=CRF3*GRAVC
0048               GRAVTG=GRAVCA/(365000.*FLOWMT)
         C
         C  BACKWASH PUMPING FACILITIES, PEAK FACTOR IS 5
         C
0049               BACKC=2439.21*((5*FLOWMT)**.78004)+1024.83*((5*FLOWMT)**
               *.46432)+4508.27*((5*FLOWMT)**.48321)+8293.32*((5*FLOWMT)**
```

```
              $.31159)+1990.39*((5*FLOWMT)**.55613)
          C
0050              BACKCA=CRF3*BACKC
0051              BACKTG=BACKCA/(365000.*FLOWMT)
          C
          C  DUAL MEDIA FOR FILTER.....
          C
          C
0052              MEDIA=6469.83*(FLOWMT**.80912)
          C
0053              MEDIAA=CRF3*MEDIA
0054              MEDTG=MEDIAA/(365000.*FLOWMT)
          C
          C  SURFACE WASHING CONSTRUCTION FACILITIES....
          C
          C
          C
0055              SURFC=8683.26*(FLOWMT**.72415)+1034.23*(FLOWMT**
              $.73539)+2797.76*(FLOWMT**.57514)+14088.69*(FLOWMT**
              $.37436)+3711.72*(FLOWMT**.59754)
          C
0056              SURFCA=SURFC*CRF3
0057              SURCTG=SURFCA/(365000.*FLOWMT)
          C
          C
          C
          C
          C
          C  GRAVITY FILTER OPERATION AND MAINTENANCE....
          C
0058              GRAVOM=2436.5*(FLOWMT**.86331)+862.89*(FLOWMT**.72147)+
              $1001.07*(FLOWMT**.53384)
          C
0059              GRVMTG=GRAVOM/(365000.*FLOWMT)
          C
          C
          C  BACKWASH FILTER O&M
          C
0060              BACKOM=256.39*(FLOWMT**.13405)+200.42*(FLOWMT**1.0043)+
              $381.64*(FLOWMT**.40610)
          C
0061              BCKMTG=BACKOM/(365000.*FLOWMT)
          C
          C  SURFACE WASHING FACILITIES O&M....
          C
0062              SURFOM=79.51*(FLOWMT**.46826)+132.1*(FLOWMT**.97356)+
              $208.89*(FLOWMT**.2083)
          C
0063              SURMTG=SURFOM/(365000.*FLOWMT)
          CC
          C
          C
          C  COSTS FOR STORAGE DOLLARS PER 1000 GALLONS....
          C
          C
```

```
      IF (FLOWMT.GT.10.) GO TO 30
      STORC=16968.*(FLOWMT**.5884)
      STORL=25960.*(FLOWMT**.7750)
      STORCA=STORC*CRF4
      STOCTG=STORCA/(365000.*FLOWMT)
      STORLA=STORL*CRF4
      STOLTG=STORLA/(365000.*FLOWMT)
      STORE=21679.*(FLOWMT**.4072)
      STOREA=STORE*CRF3
      STOETG=STOREA/(365000.*FLOWMT)
C
      GO TO 38
30    STORC=12746.*(FLOWMT*.723)
      STORL=22306.*(FLOWMT**.8944)
      STORCA=STORC*CRF4
      STOCTG=STORCA/(365000.*FLOWMT)
      STORLA=STORL*CRF4
      STOLTG=STORLA/(365000.*FLOWMT)
      STORE=35132.*(FLOWMT**.4240)
      STOREA=STORE*CRF3
      STOETG=STOREA/(365000.*FLOWMT)
38    CONTINUE
C
C  REPLUMBING COSTS......
C
      REPLM=20*FLOWMT
      REPTG=.02
C
C  STORAGE O&M COSTS......
C
      IF (FLOWMT.GT.10) GO TO 45
      STOROM=549.*(FLOWMT**.3328)+202.*(FLOWMT**.5068)
      GO TO 50
45    STOROM=640.*(FLOWMT**.36974)+106.*(FLOWMT**.8853)
50    CONTINUE
      STOMTG=STOROM/(365000.*FLOWMT)
C
C
C
C
C  CHLORINATION COSTS......
C
C
C  CAPITAL....
      CHLORC=61102.*(FLOWMT**.6316)
      CHLOCA=CRF5*CHLORC
      CLOCTG=CHLOCA/(365000.*FLOWMT)
C
C  CHLORINATION O&M
C
      CHLORM=2250.*FLOWMT+1793.*(FLOWMT**.5322)+4473.*
     *(FLOWMT**.077)
      CLOMTG=CHLORM/(365000.*FLOWMT)
C  TOTAL TREATMENT COSTS....
C
```

```
        C
0098           TOTRC=GRAVC+BACKC+MEDIA+SURFC+STORL+STORC+CHLORC+STORE
        C
0099           TOTRCA=GRAVCA+BACKCA+MEDIAA+SURFCA+STORCA+STORLA+CHLOCA
             $+STORE+REPLM
0100           TOTRTG=TOTRCA/(365000.*FLOWMT)
        C
0101           TRTOM=GRAVOM+BACKOM+SURFOM+STOROM+CHLORM
0102           TRTMTG=TRTOM/(365000.*FLOWMT)
        C
0103           TTMTA=TOTRCA+TRTOM
0104           TTMTTG=TTMTA/(365000.*FLOWMT)
        C
        C  TOTAL COSTS, DOLLARS PER 1000 GALL......
0105           TPUMP=0.0
0106           TPIPE=0.0
0107           TPIPOM=0.0
0108           TPMPOM=0.0
0109           DO 100 I=1,N
0110           TPUMP=PUMP(I)+TPUMP
0111           TPIPE=PIPE(I)+TPIPE
0112           TPIPOM=PIPOM(I)+TPIPOM
0113           TPMPOM=PUMPOM(I)+TPMPOM
0114           TOTAL(I)=CRF1*PIPE(I)+PIPOM(I)+CRF2*PUMP(I)+
             $PUMPOM(I)
0115    100    CONTINUE
0116           TPIPEA=CRF1*TPIPE
0117           TPIPTG=TPIPEA/(365000.*FLOWMT)
0118           TPUMPA=CRF2*TPUMP
0119           TPMPTG=TPUMPA/(365000.*FLOWMT)
0120           TPOMTG=TPIPOM/(365000.*FLOWMT)
0121           TMPTG=TPMPOM/(365000.*FLOWMT)
0122           TOPLA=TPIPEA+TPUMPA+TPIPOM+TPMPOM
0123           TOPLTG=TOPLA/(365000.*FLOWMT)
        C
        C
0124           TOTA=TOPLA+TTMTA
0125           TOTATG=TOPLTG+TTMTTG
        C
0126           WRITE (3,305) REGION,I1,J1,K1,TIM
0127           WRITE (3,205)
0128           WRITE (3,200) AREATO
0129           WRITE (3,210) FLOWMT
0130           WRITE (3,220) GRAVC,GRAVCA,GRAVTG
0131           WRITE (3,222) BACKC,BACKCA,BACKTG
0132           WRITE (3,224) MEDIA,MEDIAA,MEDTG
0133           WRITE (3,226) SURFC,SURFCA,SURCTG
0134           WRITE (3,228) STORC,STORCA,STOCTG
0135           WRITE (3,230) STORL,STORLA,STOLTG
0136           WRITE (3,231) STORE,STOREA,STOETG
0137           WRITE (3,232) CHLORC,CHLOCA,CLOCTG
0138           WRITE (3,233) REPLM,REPTG
0139           WRITE (3,234) GRAVOM,GRVMTG
0140           WRITE (3,236) BACKOM,BCLMTG
0141           WRITE (3,238) SURFOM,SURMTG
```

```
              WRITE (3,240) STOROM,STOMTG
              WRITE (3,242) CHLORM,CLOMTG
              WRITE (3,244) TOTRC,TOTRCA,TOTRTG
              WRITE (3,246) TRTOM,TRTMTG
              WRITE (3,248) TTMTA,TTMTTG
              WRITE (3,250) TPIPE,TPIPEA,TPIPTG
              WRITE (3,252) TPIPOM,TPIPTG
              WRITE (3,254) TPUMP,TPUMPA,TPMPTG
              WRITE (3,256) TPMPOM,TMPTG
              WRITE (3,258) TOPLA,TOPLTG
              WRITE (3,260) TOTA,TOTATG
      C
              WRITE (3,305) REGION,I1,J1,K1,TIM
              WRITE (3,300)
              WRITE (3,302)
              WRITE (3,340)
              DO 138 I=1,N
      138     WRITE (3,330) PIPID(I),AREA(I),DIAM(I),DIST(I),PIPE(I),
             $PIPOM(I),PUMP(I),PUMPOM(I),TOTAL(I)
              WRITE (3,340)
      140     FORMAT (A60)
      145     FORMAT (1X,'*',1X,'PIPID',5X,'AREA',3X
             $'DIAM',3X,'DISTANCE'1X,'*',/)
      147     FORMAT (1X,36('*'))
      148     FORMAT (1X,('*'),37X,('*'))
      150     FORMAT (1X,'*',2X,A2,5X,F6.0,4X,F3.0,4X,F6.0,2X,'*')
      155     FORMAT (1X,A2,8X,F6.0,5X,F6.0)
      165     FORMAT ('1',3X,A60,//)
      168     FORMAT (F6.0)
      200     FORMAT (1X,'TOTAL AREA',T50,F12.2,' ACRES',/)
      205     FORMAT (1X,'ITEM',T55,'CAP. COST',T90,'AMZ. COST',T120,
             $'UNIT COST',//)
      210     FORMAT (1X,'TOTAL FLOW',T50,F12.2' MGD',/)
      220     FORMAT  (1X,'GRAVITY FILTER CONSTRUCTION COST',T50,F12.2,
             $'$',T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      222     FORMAT (1X,'BACKWASH FACILITIES COST',T50,F12.2,'$'
             $,T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      224     FORMAT (1X,'FILTRATION MEDIA MATERIALS COST',T50,F12.2,
             $'$',T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      226     FORMAT (1X,'SURFACE WASHING FACILITIES COST',T50,F12.2,
             $'$',T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      228     FORMAT (1X,'STORAGE CONSTRUCTION COST',T50,F12.2,'$',
             $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      230     FORMAT (1X,'STORAGE LINING COST',T50,F12.2,'$',
             $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      231     FORMAT (1X,'STORAGE EXCAVATION COST',T50,F12.2,
             $'$',T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      232     FORMAT (1X,'CHLORINATION FACILITIES COST',T50,F12.2,
             $'$',T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      233     FORMAT (1X,'REPLUMBING COSTS',T80,F12.2,
             $'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      234     FORMAT (1X,'GRAVITY FILTER OPERATING COST',T80,F12.2,
             $'$ PER YEAR',T110,F12.3,'$ PER TG',/)
      236     FORMAT (1X,'BACKWASH FACILITIES OPERATING COST',T80,F12.2,
             $'$ PER YEAR',T110,F12.3,'$ PER TG',/)
```

```
0182     238      FORMAT (1X,'SURFACE WASHING FACILITIES OPERATING COST',
               $T80,F12.2,
               $'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0183     240      FORMAT (1X,'STORAGE OPERATING COST',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0184     242      FORMAT (1X,'CHLORINATION OPERATING COST',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0185     244      FORMAT (1X,'TREATMENT CAPITAL COSTS',T50,F12.2,'$',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0186     246      FORMAT (1X,'TREATMENT OP. MAIN. COSTS',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0187     248      FORMAT (1X,'TOTAL TREATMENT COSTS, AMZ.',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0188     250      FORMAT (1X,'PIPES, CONSTRUCTION COST',T50,F12.2,'$',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0189     252      FORMAT (1X,'PIPES, OP. MAIN. COSTS',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0190     254      FORMAT (1X,'PUMPS, CAP. COSTS',T50,F12.2,'$',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0191     256      FORMAT (1X,'PUMPS, OP. MAIN. COSTS',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0192     258      FORMAT (1X,'TOTAL PIPELINE COSTS, AMZ.',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0193     260      FORMAT (1X,'TOTAL COSTS',
               $T80,F12.2,'$ PER YEAR',T110,F12.3,'$ PER TG',/)
0194     300      FORMAT (1X,'PIPEID',6X,'AREA',2X,'DIAMETER',2X,
               $'DIST',10X,
               $'PIPE COST',10X,'PIPE OM COST',7X,'PUMP COST',9X,
               $'PMP OM COST',8X,'TOTCOST')
0195     302      FORMAT (12X,'AC',7X,'IN',7X,'FT',16X,'$',15X,
               $'$ PER YR',13X,'$',14X,'$ PER YR',10X,'$ PER YR',/)
0196     305      FORMAT ('1',9X,A60,T102,I2,'/',I2,'/',I2,5X,A8,//)
0197     330      FORMAT (1X,'*',1X,A3,5X,F5.0,5X,F3.0,5X,F6.0,4(8X,F10.0),8X,
               $F10.2,3X,'*',/)
0198     340      FORMAT (1X,128('*'))
0199              STOP
0200              END
```

PROGRAM SECTIONS

Number	Name	Size		Attributes
1	$CODE1	013052	2837	RW,I,CON,LCL
2	$PDATA	005006	1283	RW,D,CON,LCL
3	$IDATA	000140	48	RW,D,CON,LCL
4	$VARS	001026	267	RW,D,CON,LCL
5	$TEMPS	000010	4	RW,D,CON,LCL
8	.$$$$.	000052	21	RW,D,OVR,GBL,SAV

VARIABLES

Name	Type	Address	Name	Type	Address	Name	Type	Address	Name	Type	Address	Name	Type	Address
AREATO	R*4	4-000452	BACKC	R*4	4-000512	BACKCA	R*4	4-000516	BACKOM	R*4	4-000532	BACKTG	R*4	4-000522
BCKHTG	R*4	4-000556	C	R*4	4-000466	CHLOCA	R*4	4-000662	CHLORC	R*4	4-000656	CHLORM	R*4	4-000672
CLOCTG	R*4	4-000666	CLOMTG	R*4	4-000676	CRF1	R*4	4-000416	CRF2	R*4	4-000422	CRF3	R*4	4-000426
CRF4	R*4	4-000432	CRF5	R*4	4-000436	FLOWGT	R*4	4-000456	FLOWMT	R*4	4-000462	GRAVC	R*4	4-000476
GRAVCA	R*4	4-000502	GRAVOM	R*4	4-000542	GRAVTG	R*4	4-000506	GRVHTG	R*4	4-000546	HSTAT	R*4	4-000472
I	I*2	4-000442	I1	I*2	4-000444	J1	I*2	4-000446	K1	I*2	4-000450	MEDIA	R*4	4-000240
MEDIAA	R*4	4-000244	MEDTG	R*4	4-000250	N	I*2	8-000050	REGION	CHR	4-000300	REPLM	R*4	4-000636
REPTG	R*4	4-000642	STOCTG	R*4	4-000606	STOETG	R*4	4-000632	STOLTG	R*4	4-000616	STOMTG	R*4	4-000652
STORC	R*4	4-000572	STORCA	R*4	4-000602	STORE	R*4	4-000622	STOREA	R*4	4-000626	STORL	R*4	4-000576
STORLA	R*4	4-000612	STOROM	R*4	4-000646	SURCTG	R*4	4-000536	SURFC	R*4	4-000526	SURFCA	R*4	4-000532
SURFOM	R*4	4-000552	SURMTG	R*4	4-000566	TIM	CHR	4-000374	TMPTG	R*4	4-001002	TOFLA	R*4	4-001006
TOFLTG	R*4	4-001012	TOTA	R*4	4-001016	TOTATG	R*4	4-001022	TOTRC	R*4	4-000702	TOTRCA	R*4	4-000706
TOTRTG	R*4	4-000712	TPIPE	R*4	4-000742	TPIPEA	R*4	4-000756	TPIPOM	R*4	4-000746	TPIPTG	R*4	4-000762
TPMPOM	R*4	4-000752	TPMPTG	R*4	4-000772	TPOMTG	R*4	4-000776	TPUMP	R*4	4-000736	TPUMPA	R*4	4-000766
TRIMTG	R*4	4-000722	TRTOM	R*4	4-000716	TTHTA	R*4	4-000726	TIMTTG	R*4	4-000732			

ARRAYS

Name	Type	Address	Size		Dimensions
AREA	R*4	8-000000	000024	10	(5)
DIAM	R*4	8-000024	000024	10	(5)
DIST	R*4	4-000254	000024	10	(5)
FLOWG	R*4	4-000170	000024	10	(5)
FLOWM	R*4	4-000144	000024	10	(5)
HEAD	R*4	4-000120	000024	10	(5)
PIPE	R*4	4-000000	000024	10	(5)
PIPID	CHR	4-000404	000012	5	(5)
PIPOM	R*4	4-000214	000024	10	(5)
PUMP	R*4	4-000024	000024	10	(5)
PUMPOM	R*4	4-000050	000024	10	(5)
TOTAL	R*4	4-000074	000024	10	(5)

LABELS

Label	Address	Label	Address	Label	Address	Label	Address	Label	Address

5	**	10	**	20	1-001654	22	1-002256	25	**
30	1-006010	38	1-006266	45	1-006436	50	1-006530	100	**
138	**	140'	2-000000	145'	2-000004	147'	2-000064	148'	**
150'	2-000076	155'	2-000132	165'	2-000152	158'	**	200'	2-000164
205'	2-000222	210'	2-000304	220'	2-000340	222'	2-000456	224'	2-000564
226'	2-000700	228'	2-001014	230'	2-001122	231'	2-001222	232'	2-001326
233'	2-001440	234'	2-001526	236'	2-001632	238'	2-001742	240'	2-002062
242'	2-002156	244'	2-002260	246'	2-002364	248'	2-002464	250'	2-002566
252'	2-002674	254'	2-002770	256'	2-003066	258'	2-003162	260'	2-003262
300'	2-003344	302'	2-003520	305'	2-003620	330'	2-003652	340'	2-003726

FUNCTIONS AND SUBROUTINES REFERENCED

IDATE   OPEN$ OPTIM   TIME

Total Space Allocated = 021330 4460

```
              SUBROUTINE OPTIM
              COMMON AREA,DIAM,N
       C      SUBROUTINE OPTIM (MODIFIED)
       C  THIS SUBROUTINE PICKS AN OPTIMUM DIAMETER OF A PIPELINE, USING
       C  OPTIMIZATION TECHNIQUES TO PERFORM THE TRADEOFF BETWEEN LARGER
       C  DIAMETER PIPES WITH HIGHER CONSTRUCTION COSTS AND LOWER PUMPING
       C  COSTS; AND SMALLER DIAMETER PIPES WITH LOWER CONSTRUCTION COSTS,
       C  AND HIGHER PUMPING COSTS.......
              DIMENSION DIAM(5),DIAM5(5),AREA(5),FLOWG(5)
              R=2
              DO 1000 I=1,N
              FLOWG(I)=AREA(I)*R*2.6937
              DIAM(I)=5
       C  DIAM1 IS THE TOTAL COST OF THE PIPELINE, AND DIAM2 IS THE
       C  SECOND DERIVATIVE....
       C
       C  FIRST, FOR PVC PIPE.....
       C
       50     DIAM1=.0101*(DIAM(I))**(-.7413)+.03265*(DIAM(I))**.7832-
          $2.07E-4*FLOWG(I)**2.85*(DIAM(I))**(-5.86)
              DIAM2=-.00749*(DIAM(I))**(-1.7413)+.02557*(DIAM(I))**-.2168+
          $1.213E-3*(FLOWG(I)**2.85)*DIAM(I)**-6.86
              DIAM5(I)=DIAM(I)-(DIAM1/DIAM2)
       C
       C  EPS IS THE ERROR TERM, EPSILON
       C
              EPS=ABS(DIAM5(I)-DIAM(I))
              IF (EPS.LT..00001) GO TO 100
              DIAM(I)=DIAM5(I)
              GO TO 50
       100    IF (DIAM(I).GT.12) GO TO 200
              GO TO 500
       200    DIAM(I)=DIAM5(I)
       C
       C  FOR DUI PIPE.....
       C
       C
       300    DIAM1=.04382*(DIAM(I))**(-.11168)+.06254*(DIAM(I))**.5549
          $+.03924*(DIAM(I))**(-.11018)-2.90E-4*FLOWG(I)**2.85*(DIAM(I))
          $**(-5.86)
              DIAM2=-.00489*(DIAM(I))**(-1.11168)+.03470*(DIAM(I))**(-.4451)-
          $.00432*(DIAM(I))**(-1.11018)+1.699E-3*FLOWG(I)**2.85*
          $(DIAM(I)**(-6.86))
              DIAM5(I)=DIAM(I)-(DIAM1/DIAM2)
              EPS=ABS(DIAM5(I)-DIAM(I))
              IF (EPS.LT..00001) GO TO 500
              DIAM(I)=DIAM5(I)
              GO TO 300
       500    DIAM(I)=DIAM5(I)
              IF (DIAM(I).LT.5) DIAM(I)=4.
              IF (DIAM(I).GE.5 .AND. DIAM(I).LT.7) DIAM(I)=6.
              IF (DIAM(I).GE.7 .AND. DIAM(I).LT.9) DIAM(I)=8.
              IF (DIAM(I).GE.9 .AND. DIAM(I).LT.11) DIAM(I)=10.
              IF (DIAM(I).GE.11 .AND. DIAM(I).LT.13) DIAM(I)=12.
              IF (DIAM(I).GE.13 .AND. DIAM(I).LT.15) DIAM(I)=14.
```

```
      IF (DIAM(I).GE.13 .AND. DIAM(I).LT.17) DIAM(I)=16.
      IF (DIAM(I).GE.17 .AND. DIAM(I).LT.19) DIAM(I)=18.
      IF (DIAM(I).GE.19 .AND. DIAM(I).LT.22) DIAM(I)=20.
      IF (DIAM(I).GE.22 .AND. DIAM(I).LT.27) DIAM(I)=24.
      IF (DIAM(I).GE.27 .AND. DIAM(I).LT.33) DIAM(I)=30.
      IF (DIAM(I).GE.33 .AND. DIAM(I).LT.39) DIAM(I)=36.
      IF (DIAM(I).GE.39 .AND. DIAM(I).LT.45) DIAM(I)=42.
      IF (DIAM(I).GE.45 .AND. DIAM(I).LT.48) DIAM(I)=48.
      IF (DIAM(I).GE.48 .AND. DIAM(I).LT.51) DIAM(I)=43.
      IF (DIAM(I).GE.51) DIAM(I)=0.
C THIS LAST LINE MAKES IT POSSIBLE TO CHECK IF TWO PIPELINES NEED
C TO SERVE THE AREA, BECAUSE IT WILL BE THE ONLY CASE IF THE COSTS
C EQUAL ZERO WITH LARGE AREAS.....
1000  CONTINUE
      RETURN
      END
```

PROGRAM SECTIONS

Number	Name	Size		Attributes
1	$CODE1	004370	1148	RW,I,CON,LCL
2	$PDATA	000164	58	RW,D,CON,LCL
3	$IDATA	000040	16	RW,D,CON,LCL
4	$VARS	000072	29	RW,D,CON,LCL
5	$TEMPS	000010	4	RW,D,CON,LCL
8	.$$$$.	000052	21	RW,D,OVR,GBL,SAV

ENTRY POINTS

Name	Type	Address	Name	Type	Address	Name	Type	Address	Name	Type	Address	Name	Type	Address
OPTIM		1-000000												

VARIABLES

Name	Type	Address	Name	Type	Address	Name	Type	Address	Name	Type	Address	Name	Type	Address
DIAM1	R*4	4-000056	DIAM2	R*4	4-000062	EPS	R*4	4-000066	I	I*2	4-000054	N	I*2	8-000050
R	R*4	4-000050												

ARRAYS

Name	Type	Address	Size		Dimensions
AREA	R*4	8-000000	000024	10	(5)
DIAM	R*4	8-000024	000024	10	(5)
DIAM5	R*4	4-000000	000024	10	(5)
FLOWG	R*4	4-000024	000024	10	(5)

LABELS

Label	Address	Label	Address	Label	Address	Label	Address	Label	Address
50	1-000222	100	1-001150	200	1-001220	300	1-001254	500	1-002336
1000	**								

Total Space Allocated = 004770 1276

ROYAL PALM BEACH 201 SUBREGION, CEN. P.B. REG., ALL

PIPID	AREA	DIAM	DISTANCE
A	386.	12.	6200.
B	175.	8.	1220.
C	211.	10.	9920.
D	170.	8.	1700.
E	41.	4.	9920.

ROYAL PALM BEACH 201 SUBREGION, CEN. P.B. REG., ALL　　　　11/14/83　　10:18:24

ITEM	CAP. COST	AMZ. COST	UNIT COST
TOTAL AREA	386.00 ACRES		
TOTAL FLOW	2.99 MGD		
GRAVITY FILTER CONSTRUCTION COST	320669.31$	37665.82$ PER YEAR	0.034$ PER TG
BACKWASH FACILITIES COST	68646.51$	8063.22$ PER YEAR	0.007$ PER TG
FILTRATION MEDIA MATERIALS COST	15714.49$	1845.82$ PER YEAR	0.002$ PER TG
SURFACE WASHING FACILITIES COST	55178.14$	6481.22$ PER YEAR	0.006$ PER TG
STORAGE CONSTRUCTION COST	32352.11$	3431.91$ PER YEAR	0.003$ PER TG
STORAGE LINING COST	60737.88$	6443.07$ PER YEAR	0.006$ PER TG
STORAGE EXCAVATION COST	33884.45$	3980.07$ PER YEAR	0.004$ PER TG
CHLORINATION FACILITIES COST	122153.20$	16059.97$ PER YEAR	0.015$ PER TG
REPLUMBING COSTS		59.89$ PER YEAR	0.020$ PER TG
GRAVITY FILTER OPERATING COST		9981.97$ PER YEAR	0.009$ PER TG
BACKWASH FACILITIES OPERATING COST		1495.79$ PER YEAR	0.001$ PER TG
SURFACE WASHING FACILITIES OPERATING COST		779.66$ PER YEAR	0.001$ PER TG
STORAGE OPERATING COST		1143.02$ PER YEAR	0.001$ PER TG
CHLORINATION OPERATING COST		14819.14$ PER YEAR	0.014$ PER TG
TREATMENT CAPITAL COSTS	709336.06$	113935.38$ PER YEAR	0.104$ PER TG
TREATMENT OP. MAIN. COSTS		28219.57$ PER YEAR	0.026$ PER TG
TOTAL TREATMENT COSTS, AMZ.		142154.95$ PER YEAR	0.130$ PER TG
PIPES, CONSTRUCTION COST	279584.94$	29487.82$ PER YEAR	0.027$ PER TG
PIPES, OP. MAIN. COSTS		1118.34$ PER YEAR	0.027$ PER TG
PUMPS, CAP. COSTS	121644.66$	19033.74$ PER YEAR	0.017$ PER TG
PUMPS, OP. MAIN. COSTS		41464.01$ PER YEAR	0.038$ PER TG
TOTAL PIPELINE COSTS, AMZ.		91103.91$ PER YEAR	0.083$ PER TG
TOTAL COSTS		233258.88$ PER YEAR	0.213$ PER TG

ROYAL PALM BEACH 201 SUBREGION, CEN. P.B. REG., ALL   11/14/83   10:18:24

PIPEID	AREA AC	DIAMETER IN	DIST FT	PIPE COST $	PIPE OM COST $ PER YR	PUMP COST $	PMP OM COST $ PER YR	TOTCOST $ PER YR
A	396.	12.	6200.	141254.	565.	39065.	12657.	34232.83
B	175.	8.	1220.	8167.	33.	15682.	5579.	8927.16
C	211.	10.	9920.	96505.	386.	31672.	10639.	26159.04
D	170.	8.	1700.	11380.	46.	16997.	5866.	9771.30
E	41.	4.	9920.	22280.	89.	18229.	6722.	12013.58

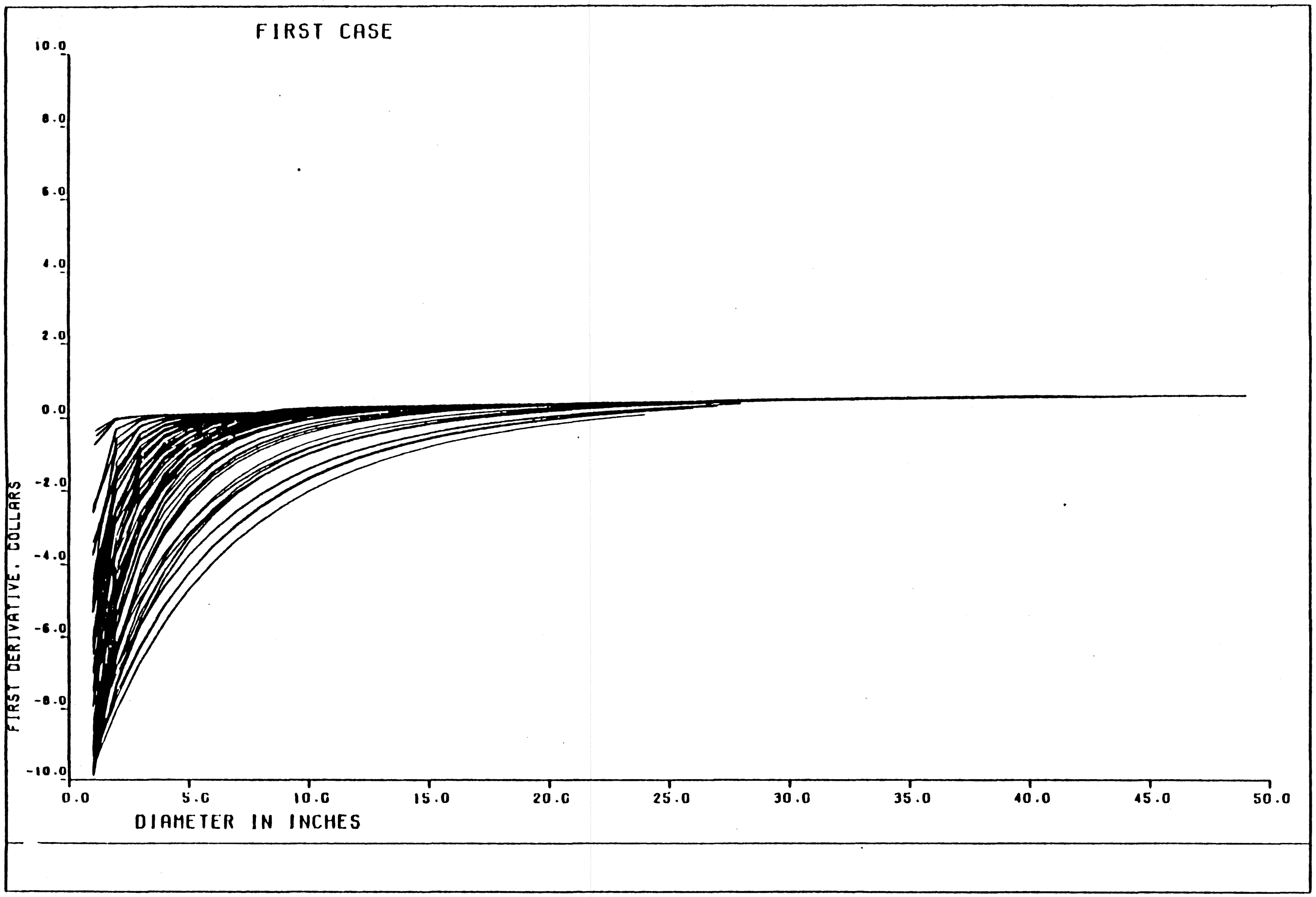

FIGURE B-1: FIRST DERIVATIVE OF COST EQUATION VS. DIAMETER OF PIPE, FIRST CASE

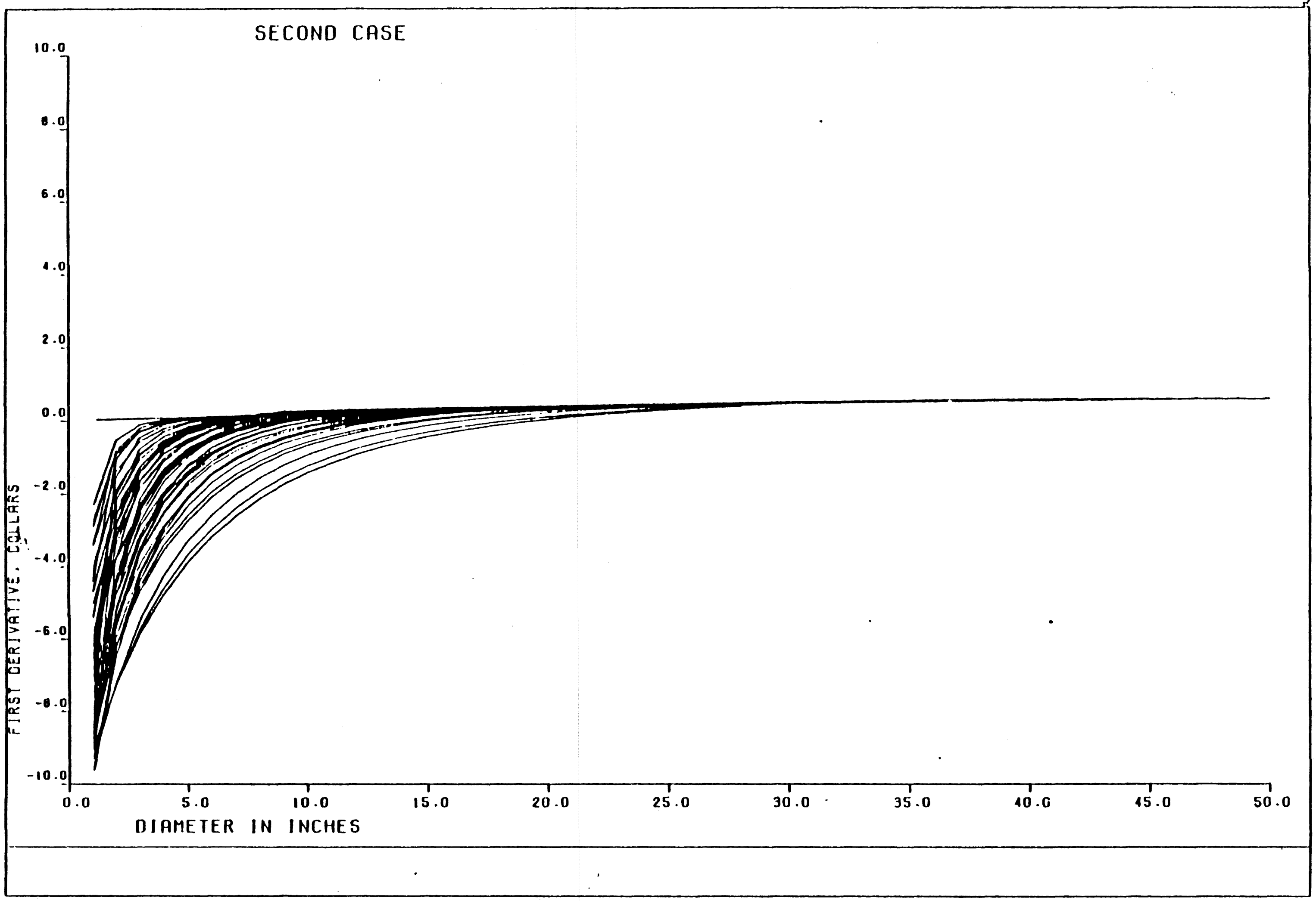

FIGURE B-2: FIRST DERIVATIVE OF COST EQUATION VS. DIAMETER OF PIPE, SECOND CASE

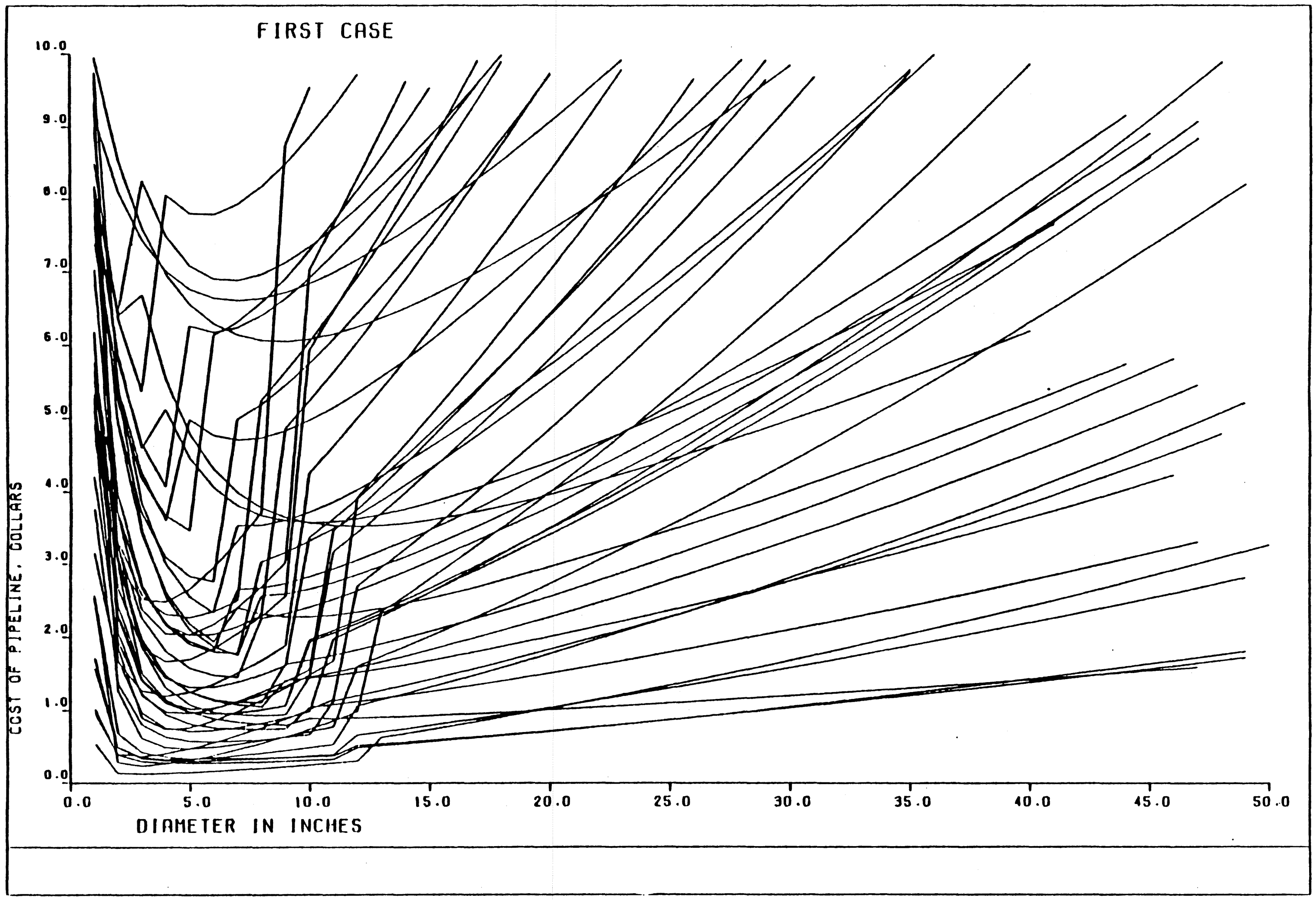

FIGURE B-3: COST OF PIPE FROM COST EQUATION VS. DIAMETER OF PIPE, FIRST CASE

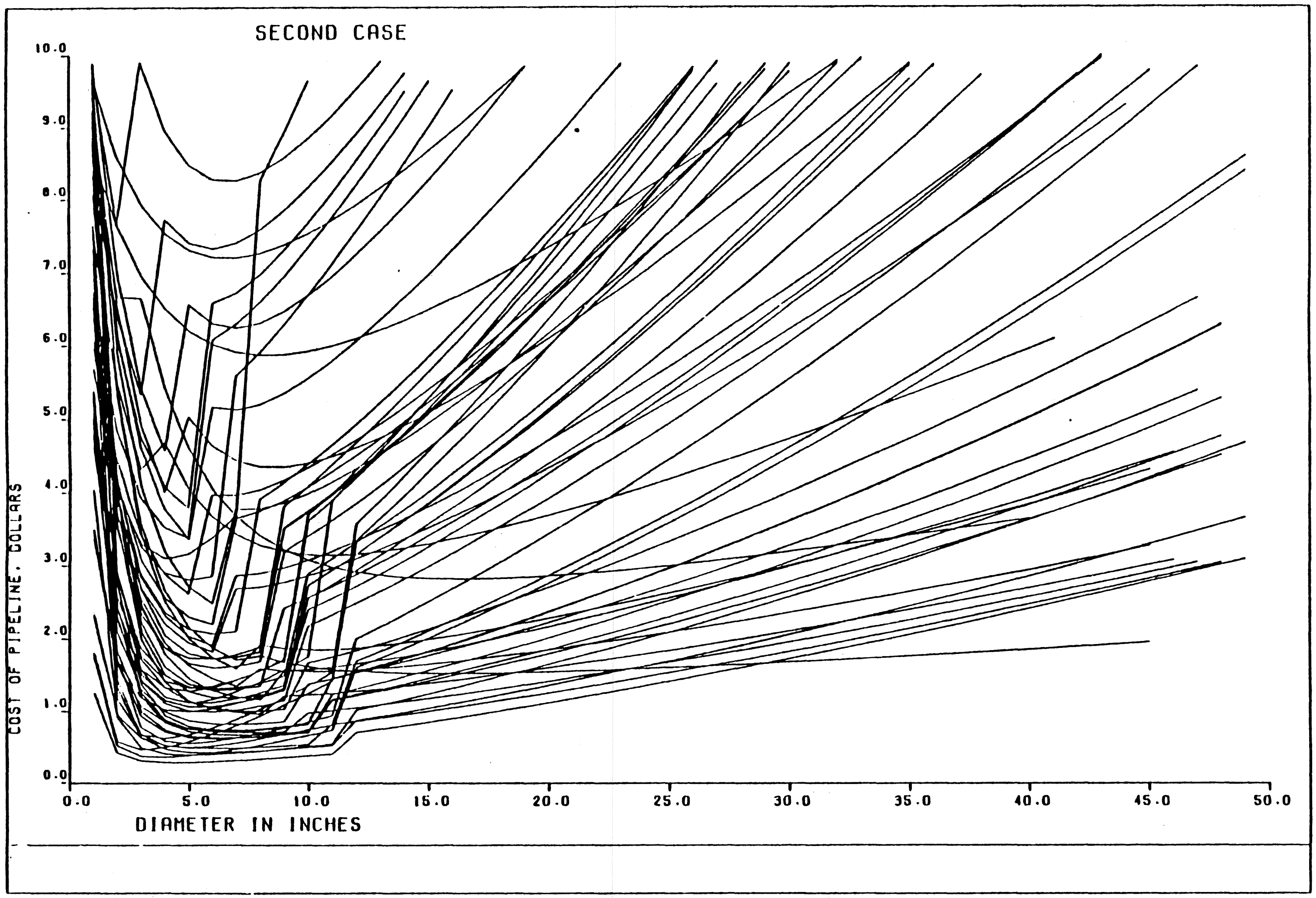

FIGURE B-4: COST OF PIPE FROM COST EQUATION VS. DIAMETER OF PIPE, SECOND CASE

APPENDIX C:

MPOS PROGRAMS

AND SAMPLE OUTPUT

```
REGULAR
VARIABLES
GC77,PK66,GC79,GC31,GC78,PK85,GC20,PK20,PK19,GC57
MAXIMIZE
GC77
CONSTRAINTS
PK66 + GC79 .LE. 204332.96
GC57 + PK19 .LE. 133878.78
GC57 + PK20 .LE. 133697.62
PK19 + PK20 .LE.  69205.16
GC79 + GC57 .LE. 178932.61
GC57 + PK19 + PK20 .LE. 156222.95
PK66 +GC79 + GC77+ GC31 + GC78 .LE. 659675.75
GC79 + GC77 + GC31 + GC78 .LE. 418533.46
GC31 + GC79 + GC78 .LE. 402842.42
PK65 + GC79 + GC57 + PK19 .LE. 245375.42
PK66 + GC79 + GC57 + PK20 .LE. 245333.22
GC79 + GC57 + PK20 + PK19 .LE. 215626.87
GC57 + PK20 + PK19 + GC20 .LE. 167952.22
GC77 + PK66 + GC57 + PK19 + PK20 + GC20 .LE. 436489.06
GC57 + PK19 + PK20 + GC20 +  PK85 + GC78 + GC79 + GC31 .LE. 484607.40
GC57 + PK19 + PK20 + GC20 + PK85 + GC78 + GC79 + GC31
 + GC77 + PK66 = 727136.21
GC77 + PK66 + GC57 + PK19 + PK20 + GC20 .LE. 661062.27
BOUNDS
PK66 .LE. 144257.08
GC79 .LE. 89662.58
GC57 .LE. 101545.00
PK19 .LE. 45602.55
GC57 .LE. 116776.50
PK20 .LE. 45421.40
RNGOBJ
RNGRHS
PRINT
OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     **************************************
     *                                    *
     *              M P O S               *
     *                                    *
     *            VERSION 4.0             *
     *                                    *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM  *
     *                                    *
     **************************************

***** PROBLEM NUMBER  1 *****

        REGULAR
        VARIABLES
        GC22,GC60,GC70
        MAXIMIZE
        GC22
        CONSTRAINTS
    1.  GC22 + GC60 .LE. 69739.10
    2.  GC22 + GC70 .LE. 139851.53
    3.  GC60 + GC70 .LE. 158013.89
    4.  GC22 + GC60 + GC70 = 197740.10
    5.  GC22 .LE. 81949.04
    6.  GC60 .LE. 73725.59
    7.  GC70 .LE. 59479.06
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
   MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

***** PROBLEM NUMBER 23 *****

        REGULAR
        VARIABLES
        CM9,GC23,GC25,GC24,CM5,GC34,CM4,GC64,CM8,GC33,GC43,GC36
        GC32,GC59,GC54,G4262,CM6,CM7,GC65,GC51,GC50,GC1A2,GC21,GC71,GC35
        MAXIMIZE
        GC36
        CONSTRAINTS
   1.   GC32 + GC33 .LE. 197312.55
   2.   GC59 + GC54 .LE. 60043.33
   3.   GC64 + G4262 .LE. 356914.11
   4.   GC64 + GC43 .LE. 77469.41
   5.   GC36 + GC64 + GC43 .LE. 110061.90
   6.   GC59 +  GC54 + CM6 + CM7 .LE. 195233.41
   7.   GC24 + GC23  + GC25 .LE. 270506.24
   8.   GC33 + GC32 + CM5 + CM6 .LE. 243406.62
   9.   GC34 + GC21 + GC50 + CM4 .LE. 547366.55
  10.   GC1A2 + CM9 .LE. 267435.70
  11.   GC65 + GC51 + GC71 .LE. 655154.30
  12.   G4262 + GC35 .LE. 495798.61
  13.   GC24 + GC23  + GC25 + GC33 + GC32 + CM5 + CM6 .LE. 412610.35
  14.   GC59 +  GC54 + CM6 + CM7 + GC33 + GC32 + CM5 + CM6 .LE. 372994.77
  15.   GC36 + GC64 + GC43 + G4262 + GC35 .LE. 523657.67
  16.   GC36 + GC64 + GC43 + GC65 + GC51 + GC71 .LE. 665753.93
  17.   GC36 + GC64 + GC43 + GC65 + GC51 + GC71 +
        GC34 + GC21 + GC50 + CM4 .LE. 1122267.75
  18.   GC36 + GC64 + GC43 + GC65 + GC51 + GC71 +
        G4262 + GC35 .LE. 1662464.20
  19.   GC59 +  GC54 + CM6 + CM7 + GC24 + GC23  + GC25 +
        GC33 + GC32 + CM5 + CM6 .LE. 1130811.80
  20.   GC34 + GC21 + GC50 + CM4 + GC1A2 + CM9 +
        GC65 + GC51 + GC71 + GC36 + GC64 + GC43 .LE. 1459292.02
  21.   GC34 + GC21 + GC50 + CM4 + GC1A2 + CM9 +
        GC65 + GC51 + GC71 + GC36 + GC64 + GC43 + G4262 + GC35 .LE. 1807776.71
  22.   GC24 + GC23  + GC25 + GC34 + GC21 + GC50 + CM4 + GC65 + GC51 + GC71 +
        G4262 + GC35 + GC36 + GC64 + GC43 + GC33 + GC32 + CM5 +
        CM6 .LE. 1744032.86
  23.   GC59 +  GC54 + CM8 + CM7 + GC24 + GC23  + GC25 +
        GC34 + GC21 + GC50 + CM4 + GC1A2 + CM9 + GC65 + GC51 + GC71 +
        G4262 + GC35 + GC36 + GC64 + GC43 + GC33 + GC32 + CM5 + CM6 =1657094.03
        BOUNDS
        GC64 .LE. 52801.52
        GC43 .LE. 55606.24
        GC36 .LE. 44940.65
        G4262 .LE. 342261.52
        GC59 .LE. 43445.19
        GC54 .LE. 56252.30
        GC33 .LE. 156554.66
        GC32 .LE. 79436.61
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     *************************************
     *                                   *
     *              M P O S              *
     *                                   *
     *            VERSION 4.0            *
     *                                   *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM *
     *                                   *
     *************************************

***** PROBLEM NUMBER  1 *****

        REGULAR
        VARIABLES
        GC75,GC80
        MINIMIZE
        GC75
        CONSTRAINTS
    1.  GC80 + GC75 = 268780.07
    2.  GC75 .LE. 81326.68
    3.  GC80 .LE. 228755.68
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
     MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

***** PROBLEM NUMBER  2 *****

        REGULAR
        VARIABLES
        CM1,GC30,GC29
        MINIMIZE
        CM1
        CONSTRAINTS
    1.  GC29 + GC30 .LE. 174226.20
    2.  CM1  + GC30 .LE. 118590.87
    3.  CM1  + GC30 + GC29 = 198380.15
        BOUNDS
        CM1 .LE. 49476.28
        GC30 .LE. 124722.41
        GC29 .LE. 90751.42
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     ****************************************
     *                                      *
     *               M P O S                *
     *                                      *
     *             VERSION 4.0              *
     *                                      *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM    *
     *                                      *
     ****************************************

***** PROBLEM NUMBER  1 *****

       REGULAR
       VARIABLES
       GC63,GC45
       MINIMIZE
       GC63
       CONSTRAINTS
   1.  GC45 + GC63 = 56675.34
   2.  GC63 .LE. 36133.72
   3.  GC45 .LE. 74670.30
       RNGOBJ
       RNGRHS
       PRINT
       OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     **************************************
     *                                    *
     *              M P O S               *
     *                                    *
     *            VERSION 4.0             *
     *                                    *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM  *
     *                                    *
     **************************************

***** PROBLEM NUMBER  1 *****

        REGULAR
        VARIABLES
        GC74,GC64,GC58
        MAXIMIZE
        GC74
        CONSTRAINTS
    1.  GC64 + GC58 .LE. 191206.03
    2.  GC74 + GC64 .LE. 66445.77
    3.  GC74 + GC64 + GC58 = 129779.61
        BOUNDS
        GC74 .LE. 56156.93
        GC64 .LE. 64065.67
        GC58 .LE. 174239.87
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     **************************************
     *                                    *
     *              M P O S               *
     *                                    *
     *            VERSION 4.0             *
     *                                    *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM  *
     *                                    *
     **************************************

***** PROBLEM NUMBER  1 *****

        REGULAR
        VARIABLES
        GC18,GC19
        MINIMIZE
        GC18
        CONSTRAINTS
    1.  GC19 + GC18 = 108292.69
    2.  GC18 .LE. 91670.06
    3.  GC19 .LE. 38183.25
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     ***************************************
     *                                     *
     *               M P O S               *
     *                                     *
     *             VERSION 4.0             *
     *                                     *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM   *
     *                                     *
     ***************************************

***** PROBLEM NUMBER  1 *****

        REGULAR
        VARIABLES
        CM2,GC13,GC14,GC47,GC81,GC17,GC10,GC68,GC67,GC15,GC46
        MAXIMIZE
        CM2
        CONSTRAINTS
    1.  GC67 + GC68 .LE. 209637.61
    2.  GC81 + GC47 .LE. 211136.70
    3.  GC81 + GC17 .LE. 226976.49
    4.  GC47 + GC17 .LE. 170002.64
    5.  CM2 +  GC13 .LE. 102931.90
    6.  GC14 + GC13 .LE. 153171.50
    7.  GC81 + GC47 + GC17 .LE. 263540.33
    8.  GC67 + GC68 + GC10 .LE. 218053.62
    9.  GC15 + GC13 + GC14 .LE. 171820.22
   10.  GC13 + GC14 + GC46 .LE. 216023.96
   11.  GC46 + GC15 + GC13 + GC14 .LE. 310520.62
   12.  CM2  + GC46 + GC15 + GC13 + GC14 .LE. 318138.91
   13.  GC10 + GC68 + GC67 + GC81 + GC47 + GC17 .LE. 421840.30
   14.  GC10 + GC17 + GC47 + GC67 + GC68 + GC81 + GC46 +
        GC15 + GC14 + GC13 + CM2 = 672027.09
   15.  GC17 + GC47 + GC67 + GC68 + GC81 + GC46 +
        GC15 + GC14 + GC13 + CM2 .LE. 650852.18
   16.  GC17 + GC47 + GC67 + GC68 + GC81 + GC46 + GC15 +
        GC14 + GC13 .LE. 644197.76
   17.  GC17 + GC47 + GC67 + GC68 + GC81 + GC46 + GC14 + GC13 .LE. 610589.94
   18.  GC17 + GC47 + GC67 + GC68 + GC81 + GC14 + GC13 .LE. 464865.00
        BOUNDS
        CM2 .LE. 30351.81
        GC13 .LE. 97988.71
        GC14 .LE. 102136.62
        GC47 .LE. 101701.85
        GC81 .LE. 164752.57
        GC17 .LE. 113789.93
        GC10 .LE. 35572.82
        GC68 .LE. 130191.66
        GC67 .LE. 125685.86
        GC15 .LE. 57563.45
        GC46 .LE. 182455.90
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

***** PROBLEM NUMBER  4 *****

       REGULAR
       VARIABLES
       GC4,GC9
       MAXIMIZE
       GC9
       CONSTRAINTS
   1.  GC9 + GC4 = 92691.02
   2.  GC4 .LE. 41183.90
   3.  GC9 .LE. 72626.37
       RNGOBJ
       RNGRHS
       PRINT
       OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     ***************************************
     *                                     *
     *               M P O S               *
     *                                     *
     *             VERSION 4.0             *
     *                                     *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM   *
     *                                     *
     ***************************************

***** PROBLEM NUMBER  1 *****

        REGULAR
        VARIABLES
        GC73,GC38
        MINIMIZE
        GC73
        CONSTRAINTS
    1.  GC73 + GC38 = 138687.14
    2.  GC38 .LE. 73005.01
    3.  GC73 .LE. 96827.70
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
MPOS VERSION 4.0          NORTHWESTERN UNIVERSITY

     **************************************
     *                                    *
     *              M P O S               *
     *                                    *
     *            VERSION 4.0             *
     *                                    *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM  *
     *                                    *
     **************************************

***** PROBLEM NUMBER  1 *****

        REGULAR
        VARIABLES
        GC6,PK10,PK8
        MAXIMIZE
        GC6
        CONSTRAINTS
    1.  GC6 + PK8 .LE. 57974.42
    2.  GC6 + PK10 .LE. 64790.35
    3.  PK8 + PK10 .LE. 92118.13
    4.  GC6 + PK8 + PK10 = 95423.67
        BOUNDS
        GC6 .LE. 18941.02
        PK10 .LE. 58436.18
        PK8 .LE. 58504.31
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

```
MPOS VERSION 4.0        NORTHWESTERN UNIVERSITY

     ***************************************
     *                                     *
     *              M P O S                *
     *                                     *
     *            VERSION 4.0              *
     *                                     *
     * MULTI-PURPOSE OPTIMIZATION SYSTEM   *
     *                                     *
     ***************************************

***** PROBLEM NUMBER  1 *****

       REGULAR
       VARIABLES
       PK66,GC37,GC83,PK67,GC8,GC7,GC5,GC41,GC39,GC40,GC82
       MAXIMIZE
       PK86
       CONSTRAINTS
  1.   PK67 + GC8 .LE. 65000.21
  2.   GC5  + GC7 .LE. 80913.78
  3.   GC39 + GC40 .LE. 251790.28
  4.   GC83 + PK66 .LE. 117637.38
  5.   GC82 + GC39 + GC40 .LE. 302962.51
  6.   GC8 + PK67 + GC83  .LE. 115977.30
  7.   GC41 + GC39 + GC40 + GC82 .LE. 715878.85
  8.   GC5 + GC7 + GC8 + PK67 .LE. 194003.18
  9.   GC41 + GC37 + GC39 + GC40 + GC82 .LE. 744951.80
 10.   GC5 + GC7 + GC8 + PK67 + GC83 + PK66 .LE. 229370.99
 11.   PK66 + GC83 + PK67 + GC8 + GC41 + GC39 + GC40 .LE. 517202.94
 12.   PK66 + GC83 + PK67 + GC8 + GC41 + GC39 + GC40 + GC82
         .LE. 766763.14
 13.   GC7  + PK66 + GC83 + PK67 + GC8 + GC41 + GC39 + GC40 +
       GC82 .LE. 809665.96
 14.   GC37 + GC7 + PK66 + GC83 + PK67 + GC8 + GC41 + GC39 +
       GC40 + GC82 .LE. 903914.55
 15.   GC5 + GC37 + GC7 + PK66 + GC83 + PK67 + GC8 + GC41 + GC39 +
       GC40 + GC82 = 907402.85
       BOUNDS
       PK66 .LE. 93774.55
       GC37 .LE. 159693.30
       GC83 .LE. 47662.14
       PK67 .LE. 26379.04
       GC8 .LE. 77467.03
       GC7 .LE. 79539.97
       GC5 .LE. 23951.51
       GC41 .LE. 357992.82
       GC39 .LE. 155972.34
       GC40 .LE. 158033.40
       GC82 .LE. 232539.84
       RNGOBJ
       RNGRHS
       PRINT
       OPTIMIZE
```

```
     MPOS VERSION 4.0          NORTHWESTERN UNIVERSITY

***** PROBLEM NUMBER 10 *****

        REGULAR
        VARIABLES
        PR06,GC37,GC63,PR07,GC8,GC7,GC5,GC41,GC39,GC40,GC62
        MAXIMIZE
        GC7
        CONSTRAINTS
   1.   PR07 + GC8 .LE. 83880.21
   2.   GC5  + GC7 .LE. 88913.78
   3.   GC39 + GC40 .LE. 251798.28
   4.   GC63 + PR06 .LE. 117837.58
   5.   GC62 + GC39 + GC40 .LE. 382982.51
   6.   GC8 + PR07 + GC63  .LE. 115977.30
   7.   GC41 + GC39 + GC40 + GC62 .LE. 715878.85
   8.   GC5 + GC7 + GC8 + PR07 .LE. 194883.18
   9.   GC41 + GC37 + GC39 + GC40 + GC62 .LE. 744951.86
  10.   GC5 + GC7 + GC8 + PR07 + GC63 + PR06 .LE. 229370.99
  11.   PR06 + GC63 + PR07 + GC8 + GC41 + GC39 + GC40 .LE. 517262.94
  12.   PR06 + GC63 + PR07 + GC8 + GC41 + GC39 + GC40 + GC62
          .LE. 788755.14
  13.   GC7  + PR06 + GC63 + PR07 + GC8 + GC41 + GC39 + GC40 +
        GC62 .LE. 809885.98
  14.   GC37 + GC7 + PR06 + GC63 + PR07 + GC8 + GC41 + GC39 +
        GC40 + GC62 .LE. 903914.55
  15.   GC5 + GC37 + GC7 + PR06 + GC63 + PR07 + GC8 + GC41 + GC39 +
        GC40 + GC62 = 907902.03
        BOUNDS
        PR06 .LE. 93774.55
        GC37 .LE. 159693.38
        GC63 .LE. 47882.14
        PR07 .LE. 28379.04
        GC8 .LE. 17457.83
        GC7 .LE. 79539.97
        GC5 .LE. 23951.51
        GC41 .LE. 387992.82
        GC39 .LE. 155972.34
        GC40 .LE. 158833.48
        GC62 .LE. 232539.84
        RNGOBJ
        RNGRHS
        PRINT
        OPTIMIZE
```

MPOS VERSION 4.0 NORTHWESTERN UNIVERSITY

****
* PROBLEM NUMBER 10 *
****

USING REGULAR

SUMMARY OF RESULTS

VAR NO	VAR NAME		ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
1	PROD		--	UB	93774.5500000	0.0000000	0.0000	93774.5500
2	GC37		--	UB	159693.5600000	0.0000000	0.0000	159693.5600
3	GC63		--	B	23033.0100000	0.0000000	0.0000	47602.1400
4	PRE7		--	UB	26579.0400000	0.0000000	0.0000	26579.0400
5	GC8		--	B	2100.0900000	0.0000000	0.0000	77467.6300
6	GC7		--	UB	79539.9700000	1.0000000	0.0000	79539.9700
7	GC5		--	B	3466.3300000	0.0000000	0.0000	25951.5100
8	GC41		--	UB	367992.8200000	0.0000000	0.0000	367992.8200
9	GC39		--	B	2667.4300000	0.0000000	0.0000	155972.3400
10	GC40		--	LB	0.0000000	0.0000000	0.0000	156033.4600
11	GC62		--	B	146076.0600000	0.0000000	0.0000	232539.6400
12	SLACK--	U-	1	B	54975.0600000	0.0000000	0.0000	INF
13	SLACK--	U-	2	B	5053.4600000	0.0000000	0.0000	INF
14	SLACK--	U-	3	B	246950.8500000	0.0000000	0.0000	INF
15	SLACK--	U-	4	LB	0.0000000	0.0000000	0.0000	INF
16	SLACK--	U-	5	B	222017.0000000	0.0000000	0.0000	INF
17	SLACK--	U-	6	B	63409.1600000	0.0000000	0.0000	INF
18	SLACK--	U-	7	B	156746.3200000	0.0000000	0.0000	INF
19	SLACK--	U-	8	B	62946.7500000	0.0000000	0.0000	INF
20	SLACK--	U-	9	B	66919.9700000	0.0000000	0.0000	INF
21	SLACK--	U-	10	LB	0.0000000	0.0000000	0.0000	INF
22	SLACK--	U-	11	LB	0.0000000	0.0000000	0.0000	INF
23	SLACK--	U-	12	B	101564.1200000	0.0000000	0.0000	INF
24	SLACK--	U-	13	B	55664.9700000	0.0000000	0.0000	INF
25	SLACK--	U-	14	LB	0.0000000	0.0000000	0.0000	INF
26	ARTIF--	U-	15	LB	0.0000000	0.0000000	0.0000	INF

MAXIMUM VALUE OF THE OBJECTIVE FUNCTION = 79539.970000

CALCULATION TIME WAS .0490 SECONDS FOR 12 ITERATIONS.

APPENDIX D:

COST ANALYSIS OUTPUT TABLES

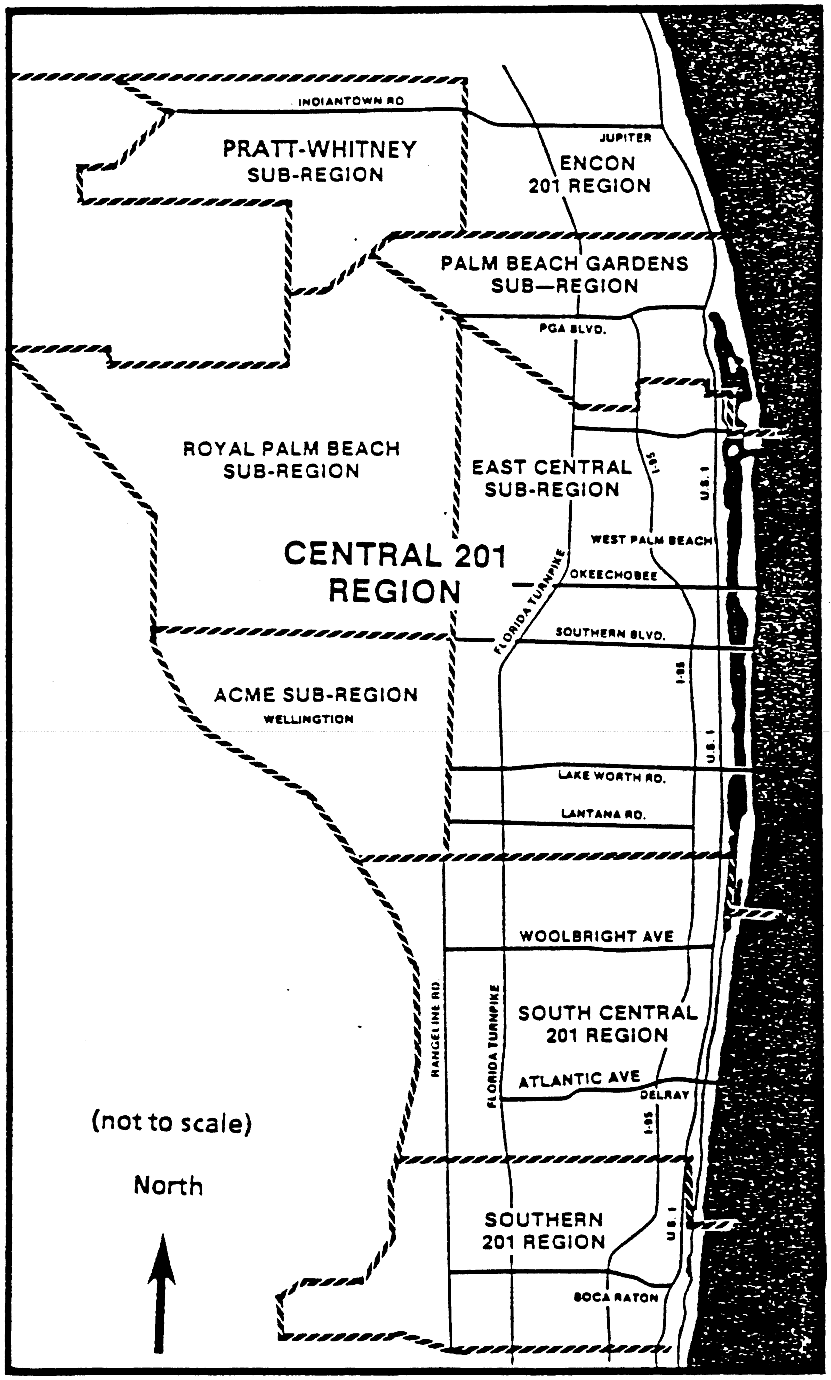

FIGURE D-1: "201" WASTEWATER PLANNING REGIONS FOR EASTERN PALM BEACH COUNTY, FLA.

TABLE D-1: USER'S UNIT COST INFORMATION ENCON 201 REGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Jupiter Beach	ENCON	20PK		36	26380	A,E,L,N,P,Q	7	14	5	18	153	135
Carlin Park Park	ENCON	19PK		36	25180	A,E,L,N,O	7	14	5	18	153	135
Loxahatchee Bend Park	ENCON	66PK		188	21120	A,B,C,	7	10	5	14	5	-9
Jonathan's Landing	ENCON	57GC	50-00237	120	22180	A,E,L,M	7	12	5	16	5	-11
Turtle Creek	ENCON	79GC	43-00140	105	29220	A,E,F,H	7	13	5	17	5	-12
Jupiter Dunes	ENCON	20GC		30	25180	A,E,L,N,P	7	13	5	17	5	-12
Tequesta C. C	ENCON	31GC	50-00273	100	33820	A,E,F,G	7	15	5	19	5	-14
Jupiter Hills	ENCON	78GC	43-00054	298	41520	A,E,F,H,I,K	7	19	5	23	5	-18
Unknown Park	ENCON	85PK		51	44720	A,E,F,H,I,J	7	21	5	25	5	-20
Ranch Colony	ENCON	77GC	43-00138	230	41640	A,B,D	7	22	5	26	5	-21

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

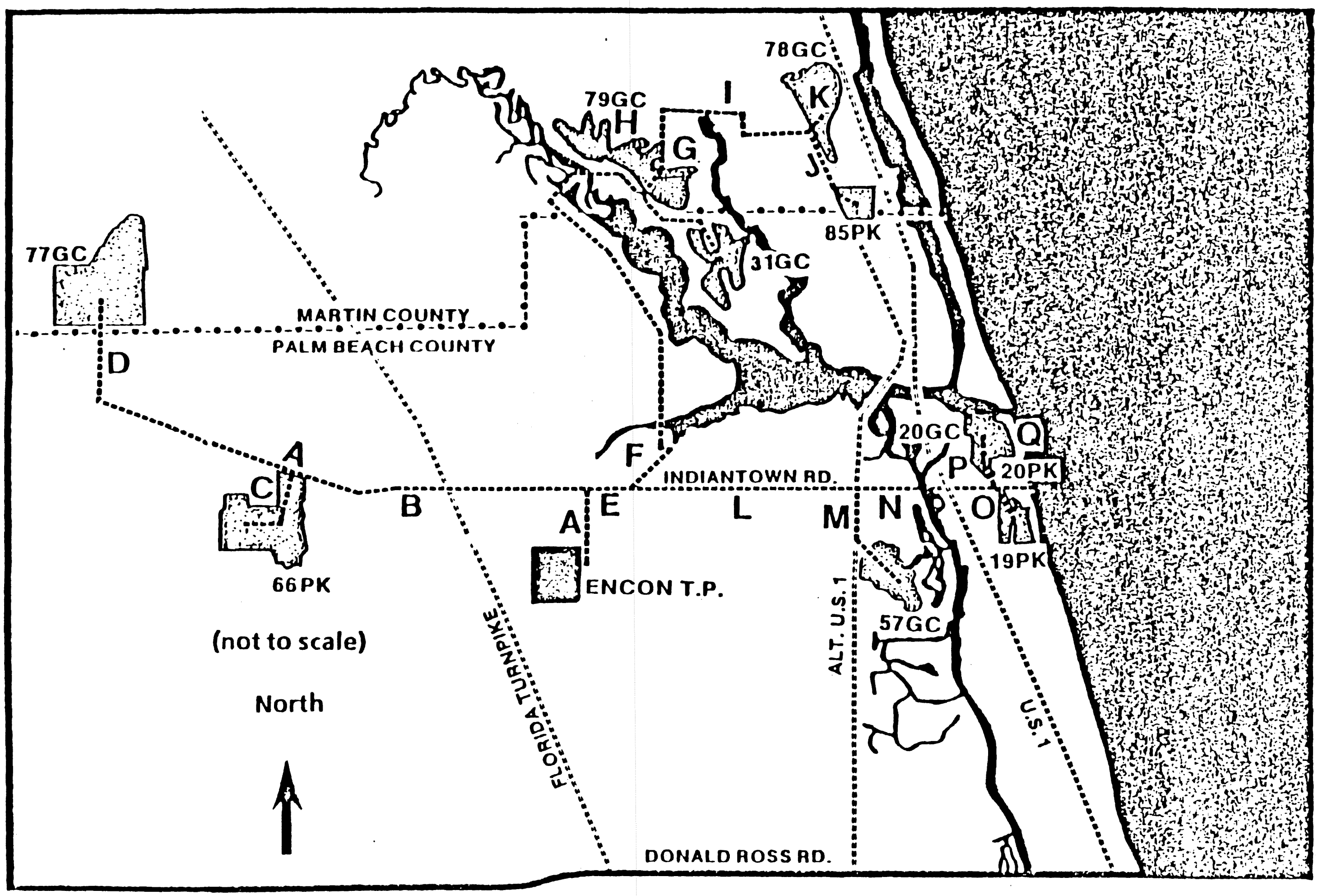

FIGURE D-1: ENCON 201 REGION

TABLE D-2:
USER'S UNIT COST INFORMATION
CENTRAL 201 REGION-PALM BEACH COUNTY, N. CEN. SUBREGION (PALM BEACH GARDENS)

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Frenchmen's	Cabana	52GC	50-00091	168	7680	B	13	5	10	10	5	-5
Eastpointe C. C.	PBG	49GC	50 00111 50-00941	502	10040	A	9	5	4	12	5	-7
N.P.B. C. C.	Anch.	22GC	50-00084	160	5580	C	10	3	0	15	5	-10
Lost Tree Club	Anch.	60GC	50-00421	130	16980	C,D,E	10	10	0	22	5	-17
Seminole G. C.	Anch	70GC	50-00394	105	20760	C,D,F	10	11	0	23	5	-18

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

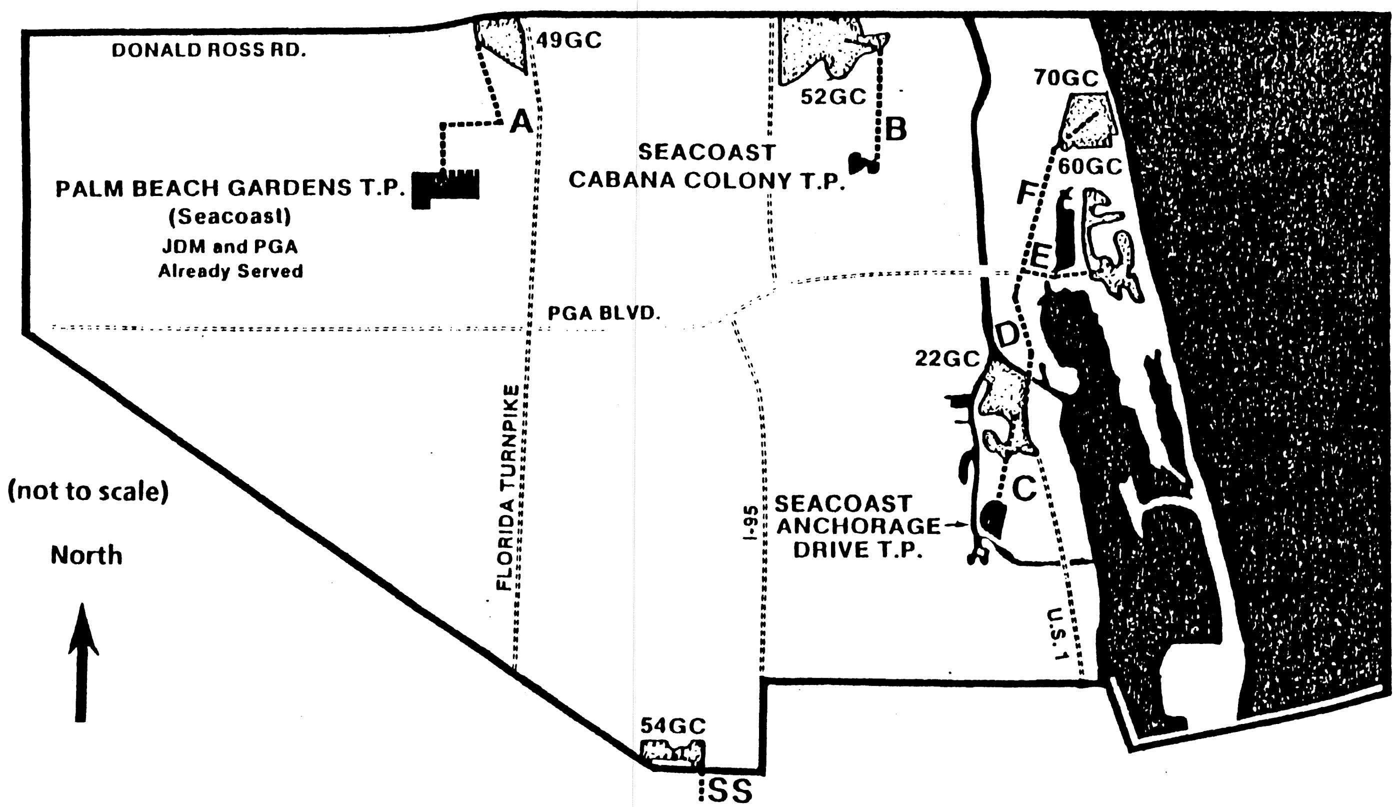

FIGURE D-3: CENTRAL 201 REGION,
NORTH-CENTRAL SUBREGION

TABLE D-3
USER'S UNIT COST INFORMATION
CENTRAL PALM BEACH COUNTY-201 REGION-EAST CENTRAL SUBREGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Cemetery	E C.	9CM		23	70,220	A,B,D,I,K,L,M,U, V	6	30	3	35	88	53
Breakers C. C.	E C.[2]	23GC		100	38,000	A,CC,DD,FF,HH, JJ,LL,NN	6	22	3	21	55	28
Palm Beach C. C.	E C.[2]	25GC		79	46,280	A,CC,DD,FF,HH, JJ,LL,OO	6	26	3	31	55	24
Everglades C. C.	E C.[2]	24GC		86	44,800	A,CC,DD,FF,HH LL,NN,MM	6	30	3	35	55	20
Cemetery	E C	5CM		9	33960	A,CC,DD,FF,HH,II	6	23	3	6	44	38
West Palm Beach C. C.	E C.	34GC		197	79,420	A,B,D,I,KL,M,U, X,Y	6	32	3	37	44	7
Cemetery	E.C	4CM		34	79,460	A,B,D,I,KL,M, U,X,Y,Z	6	34	3	39	44	5
Country Village	E C.	84GC	50-00890	61	14,820	A,B,C	6	8	3	13	5	-8
Cemetery	E C.	8CM		8	35,960	A,CC,PP,RR,TT,U U	6	4	3	29	5	-24

[1] 2¢/1000 gallons was added for conversion and set-up costs.
[2] indicates an ocean outfall group.

TABLE D-3-CONTINUED
USER'S UNIT COST INFORMATION
CENTRAL PALM BEACH COUNTY-201 REGION-EAST CENTRAL SUBREGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
The Presidential	E C	33GC	50-00224		16,780	A,CC,DD,EE	6	9	3	14	5	-9
Meadowbrook	E C	43GC	50-00120	247	24,160	A,B,D,I,J	6	9	3	14	5	-9
Belvedere G. C.	E C	36GC	50-00899	41	28,300	A,B,D,I,K	6	10	3	18	5	-10
Palm Beach Lakes	E C	32GC	50-00257	25	21,340	A,CC,DD,FF,GG	6	12	3	17	5	-12
Lone Pine G. C.	E C	59GC	50-00954	95	18,320	A,CC,PP,QQ	6	13	3	18	5	-13
Holiday C. C.	E C	54GC		40	24,540	A,CC,PP,RR,SS	6	17	3	22	5	-17
Breaker's/Flagler Mayacoo Lakes	E C	42GC 62GC	50-00203 50-00537	48	43,220	A,B,D,F,E	6	20	3	25	5	-20
Woodlawn Cemetery	E C	6CM	50-00257	200	37,980	A,CC,DD,FF,HH,JJ,KK	6	23	3	28	5	-23

[1] 2¢/1000 gallons was added for conversion and set-up costs.
[2] indicates an ocean outfall group.

TABLE D-3-CONTINUED
USER'S UNIT COST INFORMATION
CENTRAL PALM BEACH COUNTY-201 REGION-EAST CENTRAL SUBREGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Royal P. B. Mem.	E C	7CM	50-00218	81	38,600	A,CC,PP,RR,TT,V V	6	24	3	29	5	-24
Palm Beach Nat'l	E C.	65GC	50-00268	70	92,160	A,B,D,I,K,L,N,O	6	27	3	32	5	-27
The Fountains	E.C.	51GC	50-00440	285	107,700	A,B,D,I,L,N,P,S	6	28	3	33	5	-28
Forest Hills Golf	E C	50GC	50-00099	25	66,600	A,B,D,I,K,L,M,U, X	6	27	3	32	5	-27
Atlantis Golf & CC	E C	1/2GC	50-00452	100	90,280	A,B,D,I,K,L,M,U, V	6	30	3	35	5	-30
Lake Worth Mun.	E C.	21GC	50-00866	97	93,320	A,B,D,I,L,M,U,X, Y,BB	6	39	3	44	5	-39
Sherbrooke	E C	71GC		150	86,040	A,B,D,I,K,L,N,P,T	6	42	3	47	5	-42
Banyan G. C.	E C.	35GC	50-00443	140	65,480	A,B,D,F,G	6	35	3	40	5	-45

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

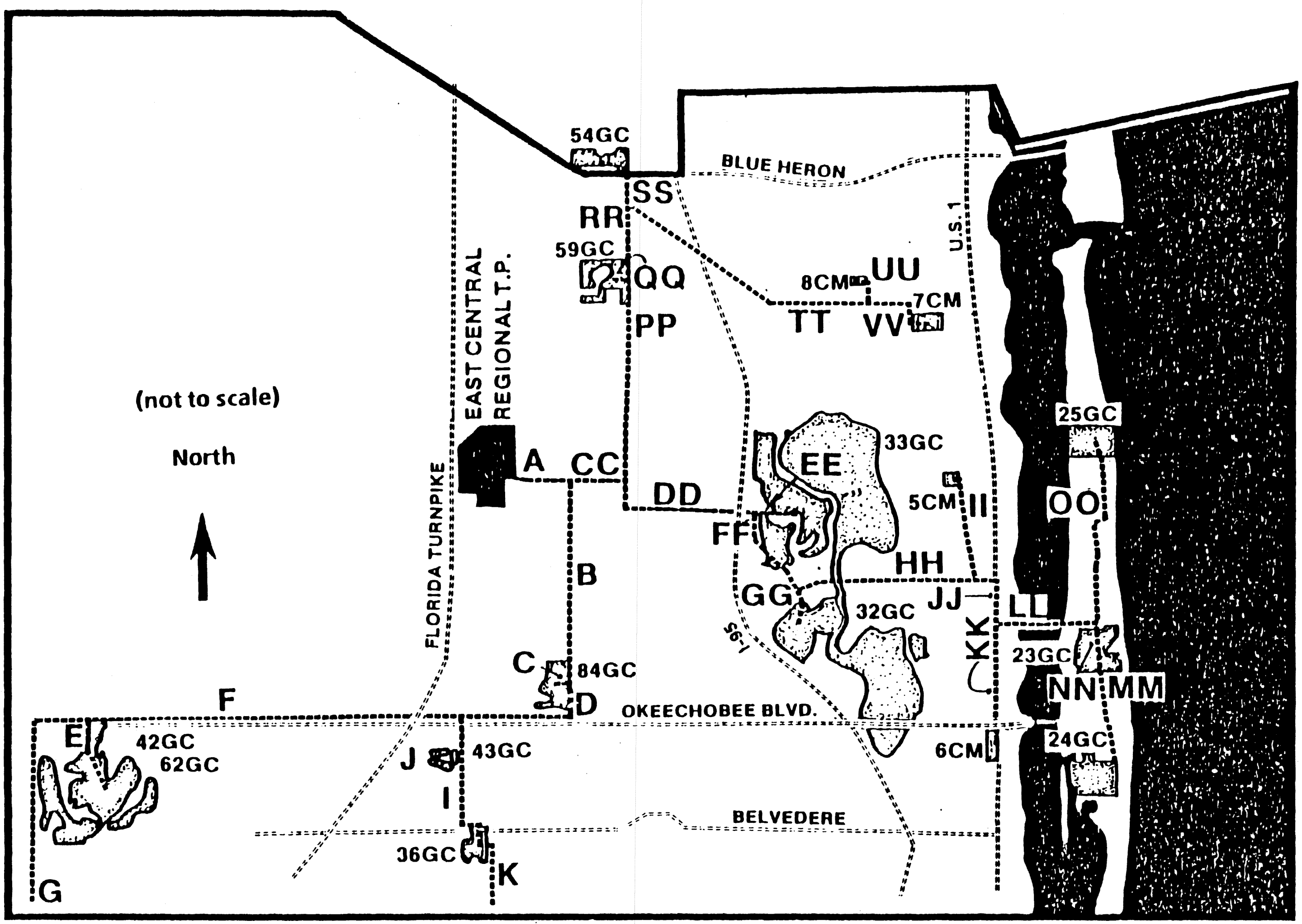

FIGURE D-4: CENTRAL 201 REGION, EAST CENTRAL SUBREGION, NORTH HALF

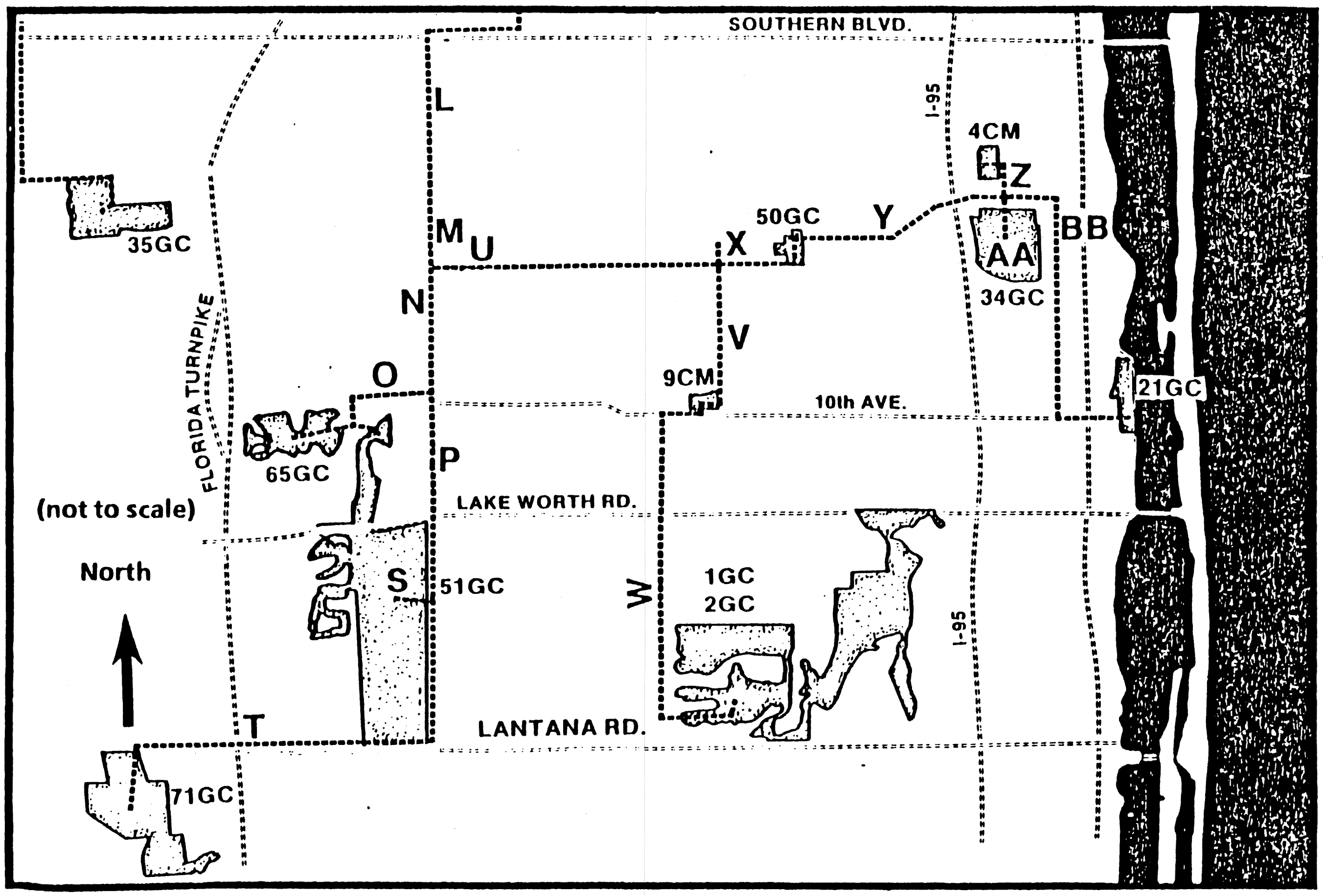

FIGURE D-5: CENTRAL 201 REGION, EAST-CENTRAL SUBREGION, SOUTH HALF

TABLE D-4
USER'S UNIT COST INFORMATION
CENTRAL 201 REGION-PALM BEACH COUNTY-ROYAL PALM BEACH SUBREGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Cemetery	RPB	1CM		41	26,040	A,C,E	10	15	7	20	5	-15
Royal Palm C C	RPB	30GC	50-00561	170	17,820	A,C,D	10	10	7	12	5	-7
Indian Trail C C	RPB	29GC	50-00269	175	7,420	A,B	10	4	7	9	5	4

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

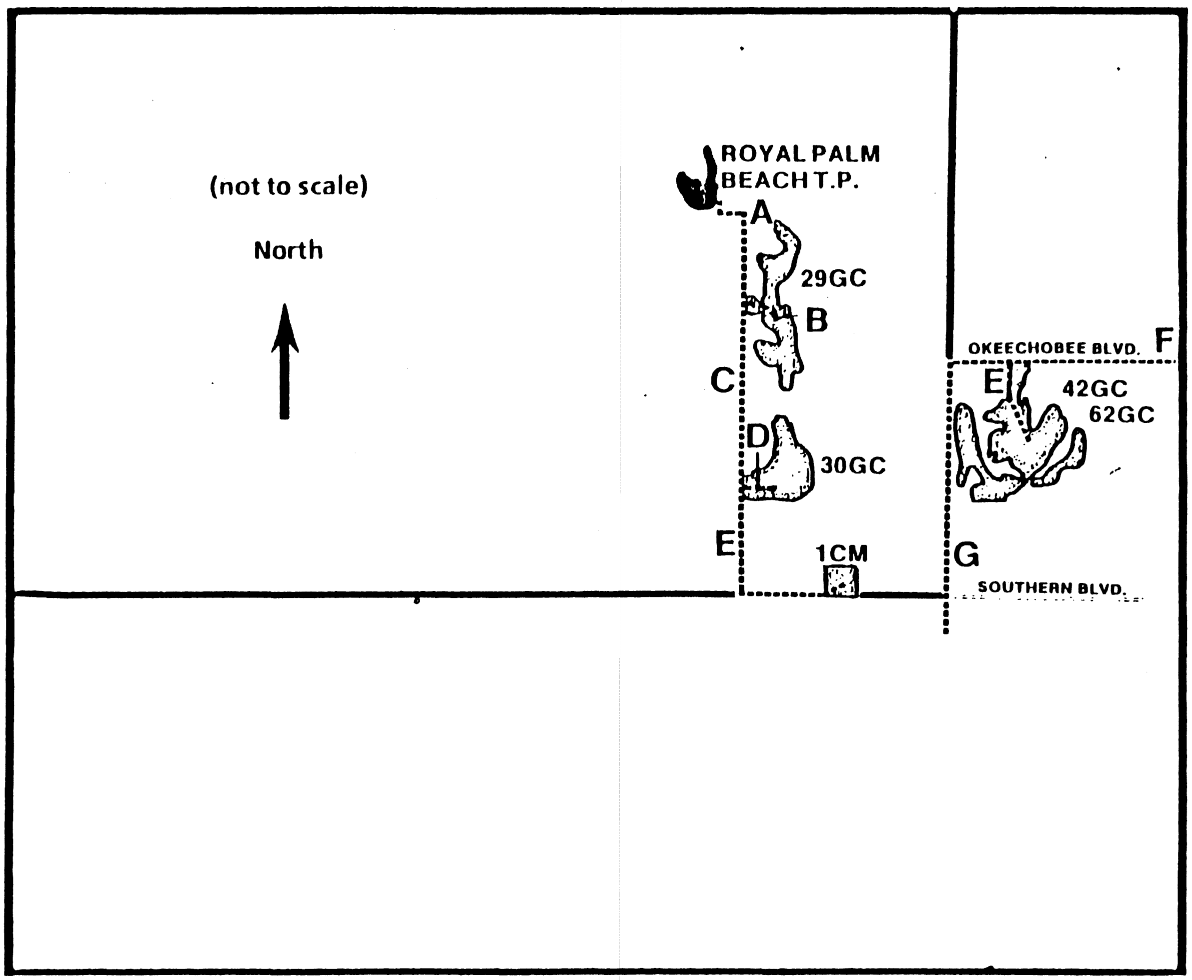

FIGURE D-6: CENTRAL 201 REGION, ROYAL PALM BEACH SUBREGION

TABLE D-5
USER'S UNIT COST INFORMATION
CENTRAL 201 REGION-PALM BEACH COUNTY-ACME IMPROVEMENT DISTRICT SUBREGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Gould Prop. (Polo C.)	Acme	80GC	50 00883	632	10,180	A,B	8	4	6	8	5	-3
Wellington Country Club	Acme	75GC		150	5,980	A,C	8	4	6	8	5	-3

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

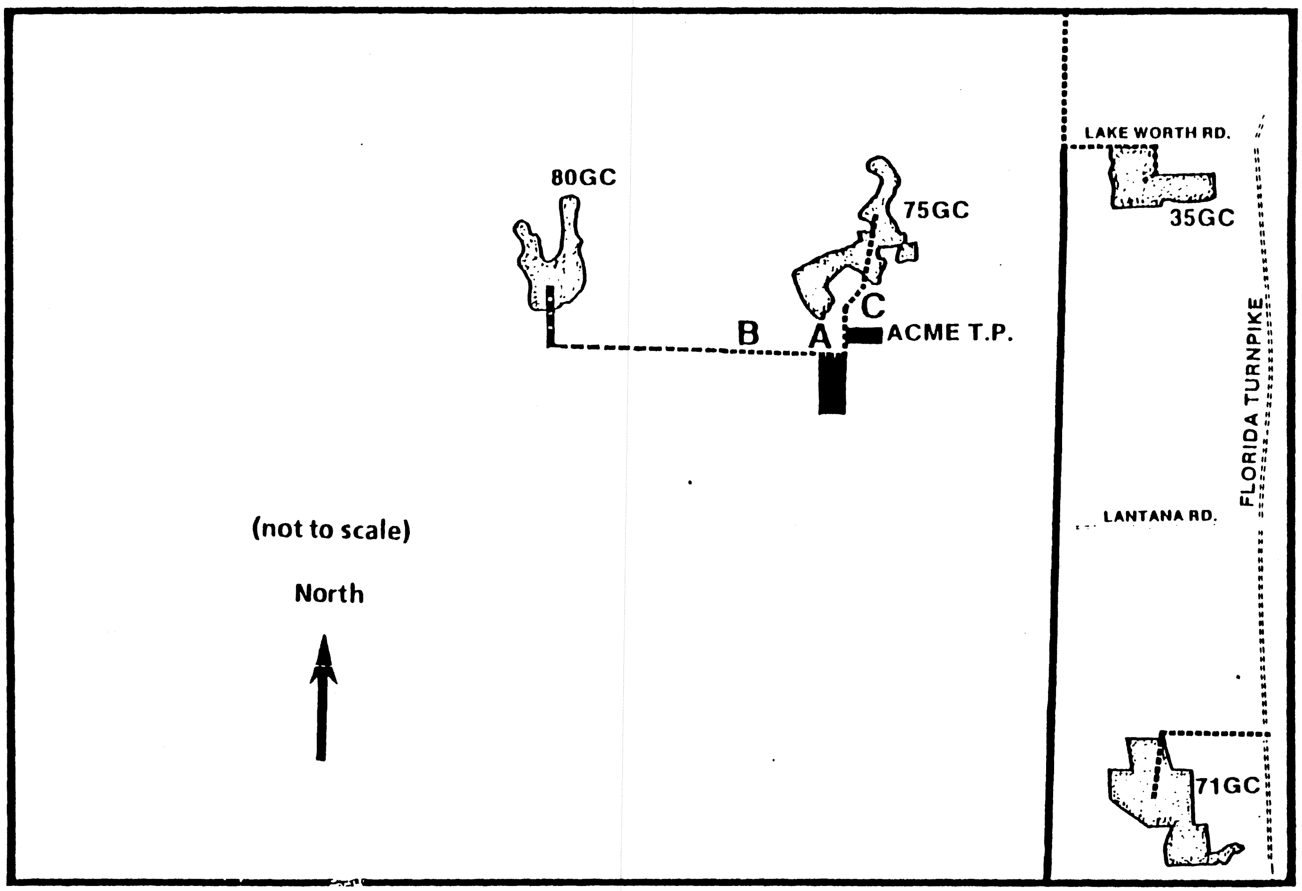

FIGURE D-7: CENTRAL 201 REGION, ACME SUBREGION

TABLE D-6
USER'S UNIT COST INFORMATION
SOUTH CENTRAL PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Indian Springs	SCR1	56GC	50-00981	155	18,260	A	14	11	9	18	5	-13
Villa Del Ray	SCR2	74GC	50-00898 50-00859	110	1,820	B	9	11	4	8	5	-3
Oriole Golf & Tennis	SCR2	64GC	50-00078	101	9,480	C,D	9	5	4	12	5	-7
King's Point	SCR2	58GC	50-00971 50-00975	315	13,300	C,E	9	6	4	13	5	-8
Military Trail	Golf	63GC		50	1,840	F	5	1	9	-1	5	6
Cypress Creek	Golf	45GC	50-00394	115	7,600	G	5	6	9	4	5	1
Cemetery	SC	2CM		22	28,840	H,R,S	6	11	0	19	30	11
Village of Golf	SC	17GC		175	37,140	H,I,N,O	6	6	0	14	5	-9
Hunter's Run G.C.	SC	81GC	50-00636	314	26,820	H,I,N,P	6	6	0	14	5	-9

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-6-CONTINUED
USER'S UNIT COST INFORMATION
SOUTH CENTRAL PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Quail Ridge	SC	68GC	50-00419	197	28,940	H,I,J,L	6	8	0	16	5	-11
Leisureville G. C.	SC	10GC		29	39,780	H,I,J,K	6	9	0	17	5	-12
Delray Dune G. C.	SC	47GC	50-00851	120	26,340	H,I,N,Q	6	9	0	17	5	-12
Delray C. C.	SC	13GC	50-00944	120	23,920	H,R,T,V	6	10	0	18	5	-13
Pine Tree G. C.	SC	67GC	50-00535	160	33,600	H,I,J,L,M	6	11	0	19	5	-14
Hamlet Golf & Tennis	SC	14GC	50 00284	114	29,000	H,R,T,V,W	6	12	0	20	5	-15
Lakeview G. C.	SC	15GC		50	35,880	H,R,T,V,X,Y	6	15	0	23	5	-18
Del-Aire G. C.	SC	46GC	50-00534	190	36,240	H,R,T,V,X,Z	6	17	0	25	5	-20
Gulfstream G. C.	SC[2]	18GC	50-00377	160	3,660	AA,BB	13	5	0	21	5	-16
Little Club G. C.	SC[2]	19GC	50-00434	33	11,100	AA,CC	13	9	0	24	5	-19

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

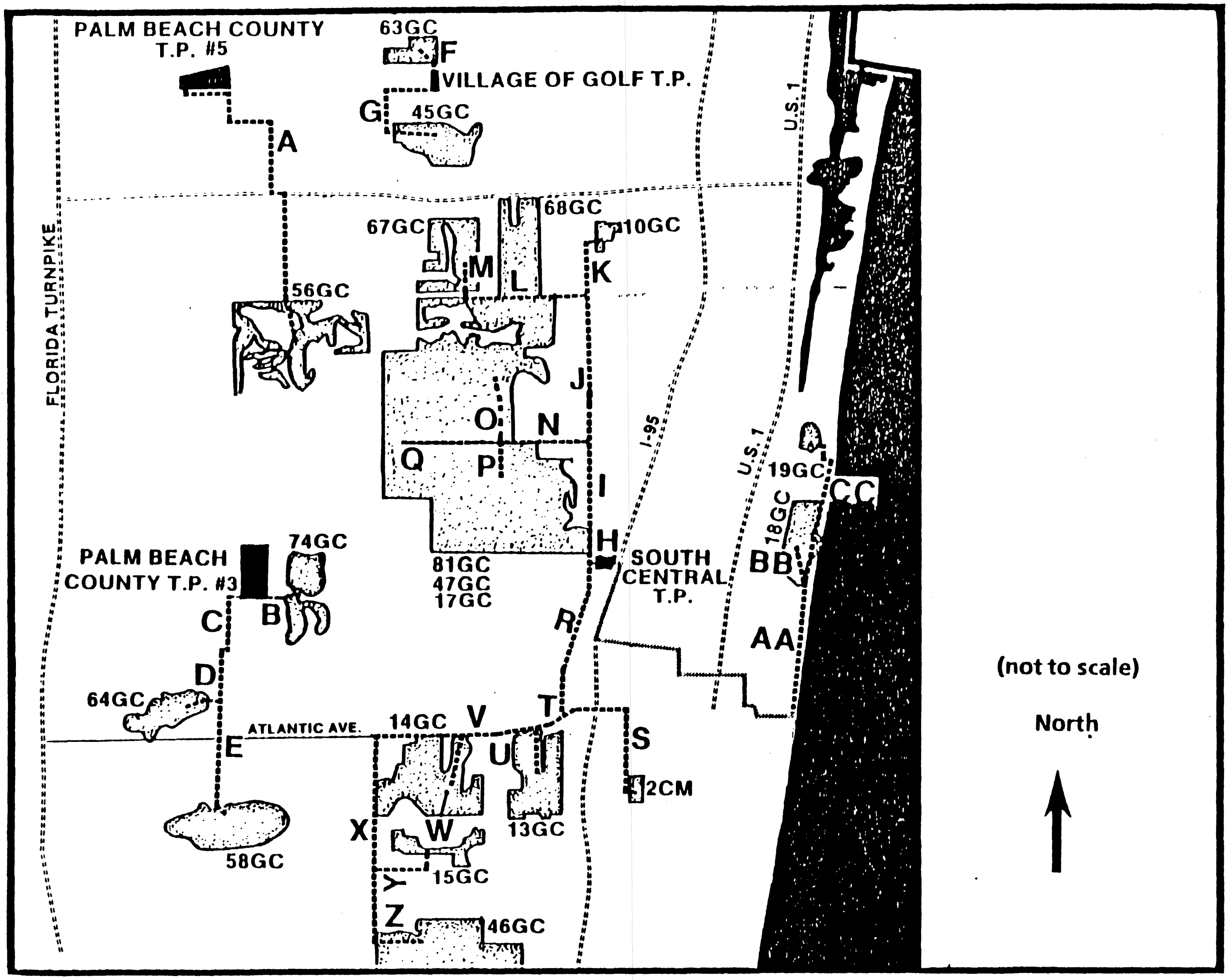

FIGURE D-8: SOUTH CENTRAL 201 REGION

TABLE D-7
USER'S UNIT COST INFORMATION
SOUTHERN PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Boca Greens	SR2	38GC	50 00632	140	3,860	A,C	11	3	4	12	5	-7
Southern Manor	SR2	73GC		160	10,800	A,B	11	6	4	15	5	-10
Sandalfoot Cove	SR1	69GC	50 00411	64	0		19	0	9	10	5	-5
Boca Raton Hotel & Club	SR[2]	4GC	50-00328	163	2,140	Y	9	1	0	12	44	32
Royal Palm Yacht	SR[2]	9GC	50 00159	131	4,640	Y,Z	9	3	0	14	44	30
South Beach Park	SR[2]	8PK		98	2,540	AA	9	2	0	13	44	31
Spanish River Park	SR[2]	10PK		79	12,220	A,BB,CC	9	8	0	19	50	31
Red Reef Ex.	SR[2]	6GC		13	3,660	AA,BB	9	3	0	19	44	30
Cemetery	SR[2]	3CM		23	4,580	X	33	4	0	39	44	5
Fla. Atlantic	SR	86PK	50 00655	240	2,200	E	6	1	0	9	5	-4

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-7-CONTINUED
USER'S UNIT COST INFORMATION
SOUTHERN PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	SFWMD PERMIT #	AREA (AC)	DIST. (FT)	PIPE ID'S	T.P. COST ¢/1000 gallons	PIPE COST ¢/1000 gallons	ALT. DISP. COST ¢/1000 gallons	MAX.[1] SUP. CHG. ¢/1000 gallons	MAX. USER CHG. ¢/1000 gallons	NET SAVINGS ¢/1000 gallons
Univ. Park	SR	83PK	50-00119	60	9,180	F,P,Q	6	5	0	13	5	-7
Boca West	SR	41GC	50-00992	913	17,000	F,G,I,J	6	6	0	14	5	-9
Boca del Mar	SR	37GC	50-00054 50-00055	258	17,240	F,G,H	6	9	0	17	5	-12
Boca Lago	SR	39GC	50-00888	203	22,640	F,G,I,K,L	6	10	0	18	5	-13
Boca Teeca	SR	7GC	50-00088	100	20,580	F,P,R,V	6	10	0	18	5	-13
Broken Sound	SR	8GC	50-00489	90	21,440	F,P,R,S,V	6	11	0	19	5	-11
IBM Park	SR	87PK		15	20,840	F,P,R,S,T	6	11	0	19	5	-14
Boca Woods	SR	82GC	50-00737	200	41,000	F,G,I,K,M,O	6	13	0	21	5	-16
Boca Raton at Hidden Valley	SR	5GC	50-00970	10	26,840	F,P,R,V,W	6	17	0	25	5	-20
Boca Rio	SR	40GC	50-00292	163	27,540	F,G,I,K,M,N	6	20	0	28	5	-23

[1] 2¢/1000 gallons was added for conversion and set-up costs.
[2] indicates an ocean outfall group.

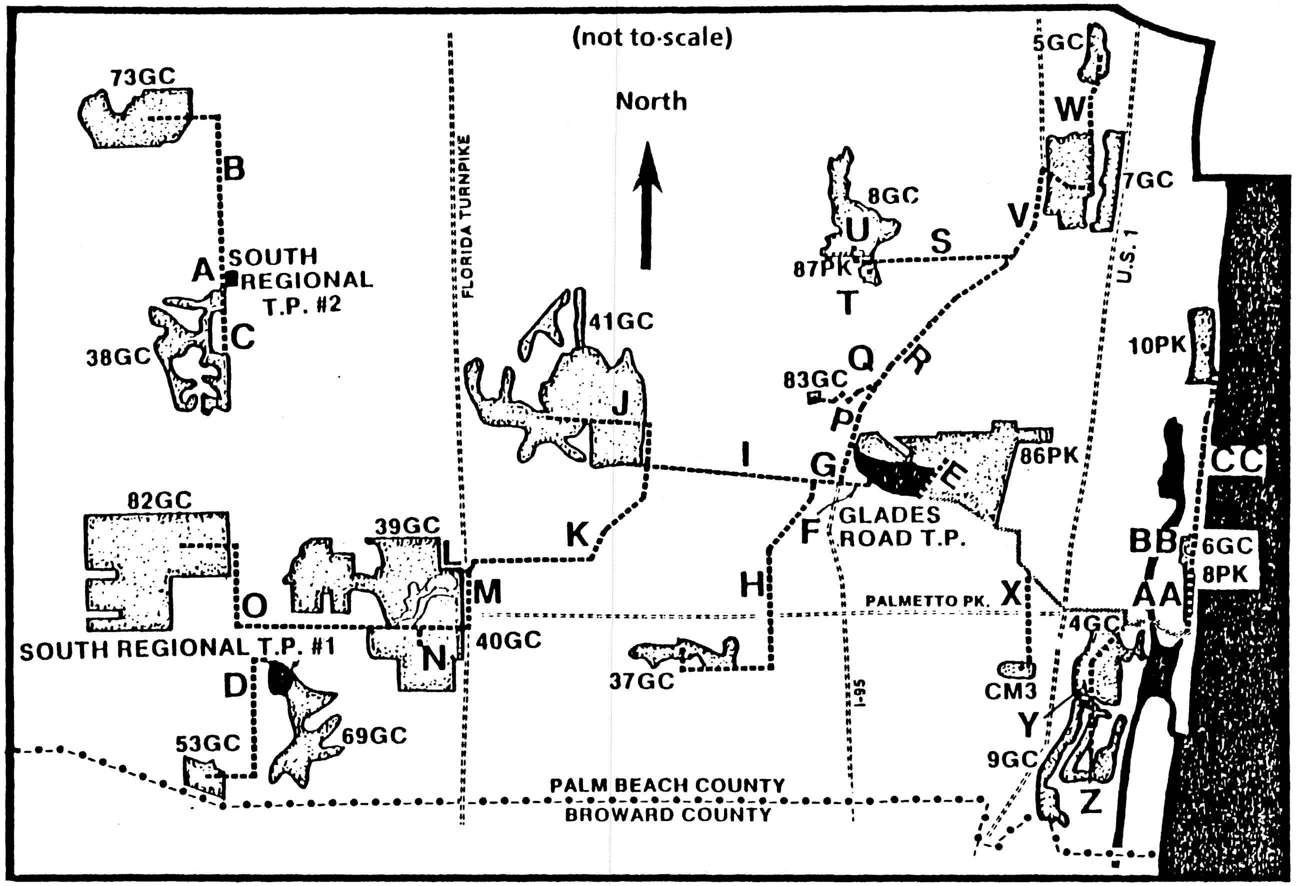

FIGURE D-9: SOUTHERN 201 REGION

TABLE D-8
USER'S UNIT COST INFORMATION USING LP
ENCON 201 REGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		$\beta(i)$	$X(i)$		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Jupiter Beach	ENCON	20PK	0 00	45421 40	0226	13185.81	15	5	10	153	143	145771.67
Carlin Park	ENCON	19PK	45421 40	45602 55	0001	45473 91	47	5	44	153	109	256962.82
Tequesta C.C.	ENCON	31GC	0 00	320261.73	.1594	14816.89	7	5	2	5	3	265463.67
Loxahatchee Bend Park	ENCON	66PK	0.00	144257 08	0718	41879 54	10	5	5	5	0	265463 67
Turtle Creek	ENCON	79GC	0 00	89662.58	.0446	26033.23	11	5	6	5	-1	262488.37
Jonathan's Landing	ENCON	57GC	0 00	116776 50	0581	33903.88	12	5	7	5	-2	255687.69
Jupiter Hills	ENCON	78GC	0 00	320261 73	.1594	93008 83	4	5	-1	5	-6	205022 61
Ranch Colony	ENCON	77GC	98271.73	418533 46	1594	191249 22	31	5	26	5	-21	27694 83
Jupiter Dunes	ENCON	20GC	0 00	167952 22	0836	48758 34	59	5	54	5	-49	-13959 35
Unknown park	ENCON	85PK	0 00	484607 40	2411	14069 46	99	5	94	5	-89	-14286 47

Note: Non separable costs totalled $583443 08/year for ENCON.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-9:
USER'S UNIT COST INFORMATION USING LP
CENTRAL 201 REGION-PALM BEACH COUNTY, N. CEN. SUBREGION (PALM BEACH GARDENS)

SITE NAME	T.P.	APB #	BOUNDS, $/year		$\beta(i)$	$X(i)$		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Frenchmen's	Cabana	52GC	37743 34	37743.34	1 0000	37743.34	30	10	20	5	-15	-71356.76
Eastpointe C.C.	PBG	49GC	202038 64	202038 64	1 0000	202038 64	16	4	12	5	-7	-94503 04
N.P.B.C.C.	Anch	22GC					15	0	15	5	-10	-45305.88
Lost Tree Club	Anch.	60GC					22	0	22	5	-17	-107884.62
Seminole G.C.	Anch.	70GC					23	0	23	5	-18	-161402.19

Note: The single member treatment plant/golf course groups remain unchanged in their relative cost allocations. The Anchorage Drive treatment plant has no feasible solution--i.e., with the constraint set given, there is no core. Relaxing the conditions proved unavailing as the problem would have been changed too drastically. C(N) for the total coalition equalled $197740.10 $/year.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-10
USER'S UNIT COST INFORMATION USING LP
CENTRAL PALM BEACH COUNTY-201 REGION-EAST CENTRAL SUBREGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		$\beta(i)$	$X(i)$		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Breakers C.C.	E C.[2]	23GC	0 00	27506 24	.0351	58156.38	23	3	20	55	35	99106 61
Everglades C.C.	E C.[2]	24GC	0 00	270506 24	0351	58156 38	26	3	23	55	32	177032.72
Palm Beach C.C.	E C.[2]	25GC	0 00	270506.24	.0351	58156 38	28	3	25	55	30	244142.06
West Palm Beach	E C	34GC	0 00	547368 55	0710	117679.26	23	3	20	44	34	433803.79
The Presidential	E.C.	33GC	0 00	156554 88	.0203	33657.88	7	3	4	5	1	440797.89
Cemetery	E C	9CM	0 00	267435 70	.0347	57496.24	90	3	87	88	1	441449.16
Palm Beach Lakes	E C	32GC	0 00	79458 61	.0103	17082.88	8	3	5	5	0	441449.16
Country Village	E C.	84GC	0.00	52801.52	.0069	11351 85	9	3	6	5	-1	439721.87
Breakers/Flagler Mayacoo Lakes	E C.	4GC 62GC	0 00	342261 52	.0444	73583 11	9	3	6	5	-1	429528 05

Note: Non-separable costs totalled $1,657,094 03/year for the entire E.C. system.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-10-CONTINUED
USER'S UNIT COST INFORMATION USING LP
CENTRAL PALM BEACH COUNTY-201 REGION-EAST CENTRAL SUBREGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		$\beta(i)$	$X(i)$		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Lone Pine G.C.	E.C.	59GC	0.00	43445.19	.0056	4340.32	10	3	7	5	-2	428272.85
Holiday C.C.	E.C	54GC	0.00	58252.30	.0076	12523.71	11	3	8	5	-3	423185.22
Meadowbrook	E.C.	43GC	0.00	55608.24	.0072	11955.27	12	3	9	5	-4	418541.37
Belvedere G.C.	E.C.	36GC	0.00	44948.85	.0058	9663.59	16	3	13	5	-7	413586.04
Atlantis Golf & C.C.	E.C.	1/2GC	0.00	267435.70	.0347	57496.24	21	3	16	5	-11	382438.25
The Fountains	E.C	51GC	0.00	655154.30	.0850	140852.21	19	3	16	5	-11	293667.04
Banyan G.C.	E.C	35GC	0.00	495798.81	.0643	106592.23	29	3	26	5	-21	210417.49
Sherbrooke	E.C	71GC	0.00	655154.30	.0850	140852.21	35	3	32	5	-27	95736.98

Note: Non-separable costs totalled $1,657,094.03/year for the entire E.C. system.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-10-CONTINUED
USER'S UNIT COST INFORMATION USING LP
CENTRAL PALM BEACH COUNTY-201 REGION-EAST CENTRAL SUBREGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		β(i)	X(i)		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Lake Worth Mun.	E C.	21GC	0 00	547368.55	.0710	117679.26	45	3	42	5	-37	-5889.77
Cemetery	E C.	4CM	0 00	547368.55	0710	117679.26	109	3	106	44	-62	65580.26
Palm Beach Nat'l	E C	65GC	0.00	655154.30	0850	140852.21	73	3	70	5	-65	-104418.86
Woodlawn Cem	E C	6CM	0 00	243408 62	.0316	52330 64	105	3	102	5	-97	-243858.90
Forest Hills Golf	E.C	50GC	0 00	547368 55	.0710	117679 26	168	3	165	5	-160	-357123.59
Cemetery	E C.	5CM	0.00	243408 62	.0316	52330.64	207	3	204	44	-160	-397898 88
Cemetery	E.C.	8CM	0.00	195233 41	0253	41973.41	187	3	184	5	-179	-438447.65
Royal P.B. B. Mem.	E C.	7CM	0 00	195233 41	.2563	424657.21	187	3	184	5	-179	-849003.86

Note: Non-separable costs totalled $1,657,094.03/year for the entire E.C. system.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-11
USER'S UNIT COST INFORMATION USING LP
CENTRAL 201 REGION-PALM BEACH COUNTY-ROYAL PALM BEACH SUBREGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		β(*i*)	X(*i*)		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Royal Palm C.C.	Royal	30GC	58152.45	94436.92	5000	7694.69	18	7	11	5	-6	-28882.50
Indian Trail C.C.	Royal	29GC	79789.28	90751.42	1511	85270.35	19	7	12	5	-7	-63568.10
Cemetery	Royal	1CM	24153.95	49476.28	3489	36815.12	24	7	27	5	-22	-89111.00

Note: Non-separable costs totalled $36284.47/year.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-12
USER'S UNIT COST INFORMATION USING LP
CENTRAL 201 REGION-PALM BEACH COUNTY-ACME IMPROVEMENT DISTRICT SUBREGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		β(*i*)	*X*(*i*)		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Gould Prop. (Polo Club)	Acme	80GC	187453.39	228755.68	.5000	60675.54	5	6	-1	5	-6	-107374.93
Wellington Country Club	Acme	75GC	40024.39	81326.68	.5000	208104.44	51	6	45	5	-40	-277271.48

Note: Non-separable costs totalled $41302.29/year.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-13
USER'S UNIT COST INFORMATION USING LP
SOUTH CENTRAL PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		β(*i*)	X(*i*)		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Indian Springs	SCR#1	56GC	55522 70	55522 70	1 0000	55522 70	27	9	18	5	-13	-23559 06
Villa Del Ray	SCR#2	74GC	0 00	56156 93	.3008	19989 41	8	4	4	5	1	3114 78
Oriole Golf & Tennis	SCR#2	64GC	0 00	64065 67	.3432	22804 58	10	4	6	5	-1	-254.85
King's Point C.C.	SCR#2	58GC	63333 38	129779 61	.3560	86985 63	12	4	8	5	-3	26503.94
Cypress Creek C.C.	Golf	45GC	20541 62	56675 34	.5000	38608 48	14	9	5	5	0	0 00
Military Trail G C	Golf	63GC	0 00	36133 72	5000	18066 86	15	9	6	5	-1	-1415.981
Cemetery	S C	2CM	0 00	30351.81	0267	15036 37	26	0	26	30	4	2491 82
Hunter's Run	S C.	81GC	0 00	164752.57	.1449	83618.88	11	0	11	5	-6	50855.85
Village of Golf	S C.	17GC	0 00	113789.93	.1001	56371 85	13	0	13	5	-8	-90498 49

Note: Non separable costs totalled $563,367 65/year for the S C. main system, 36133.72$/year for the Golf system, 31145 57$/year for the SCR#2, and SCR#1 was the same as before.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-13-CONTINUED
USER'S UNIT COST INFORMATION USING LP
SOUTH CENTRAL PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		$\beta(i)$	$X(i)$		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Quail Ridge G.C.	S C	68GC	0 00	130191 66	1145	64497 31	16	0	16	5	-11	-151859.64
Delray CC	S C	13GC	0.00	92988 71	.0818	46066.86	16	0	16	5	-11	-189236.99
Pine Tree G C.	S C.	67GC	0.00	125685.86	.1105	62265.12	16	0	16	5	-11	-239073.46
Delray Dunes G C	S C	47GC	0 00	101701 85	.0894	50383 38	17	0	17	5	-12	-279848.75
Hamlet Golf & Tennis	S C.	14GC	0 00	102136 62	.0898	50598.76	18	0	18	5	-13	-321813.32
Lakeview G C.	S.C	15GC	3810 51	57563 45	.0473	304439 87	23	0	23	5	-18	-347297.88
Del-Aire G C	S C.	46GC	83674 091	182455 90	.0869	132610 83	27	0	27	5	-22	-465659.49
Leisureville G C.	S C	10GC	21174 91	35572 82	.0127	28306.67	36	0	36	5	-31	-49145.73
Gulfstream G C.	S C[2]	18GC	79709 94	91670 06	.4929	81041.18	20	0	20	5	-15	-67958.82
Little Club G C	S C[2]	19GC	16622 63	38183 25	.5071	27250 70	31	0	31	5	-26	-92254.70

Note: Non separable costs totalled $563,367 65/year for the S C main system, 36133.72$/year for the Golf system, 31145 57$/year for the SCR# 2, and SCR# 1 was the same as before.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-14
USER'S UNIT COST INFORMATION USING LP
SOUTHERN PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		β(*i*)	X(*i*)		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Boca Greens	SR#2	38GC	41859 44	73005 01	5000	57432 23	16	4	12	5	-7	-27749 85
Southern Manor	SR#2	73GC	65682 13	96829 10	.5000	81254 92	20	4	16	5	-11	-77586 31
Sandalfoot Cove	SR#1	69GC	30579 03	30579 03	1 0000	30579 03	19	9	10	5	-5	-9601.18
Boca Raton Hotel & Club	Glades[2]	4GC	20064 65	41183.90	.5000	30624.28	9	0	9	44	35	161543.77
Royal Palm Yacht Club	Glades[2]	9GC	51507.12	72626 37	.5000	62066.75	169	0	169	5	-164	-446800.92
Spanish River Park	Glades[2]	10PK	30633 32	54668.88	.3962	40157.35	20	0	20	50	30	67109.33
South Beach park	Glades[2]	8PK	37449 25	58436 18	.3460	45765.27	18	0	18	44	26	139258.95
Red Reef Ex.	Glades[2]	6GC	51507 12	72626 37	.5000	62066 65	169	0	169	44	16	145148.71
Cemetery	Glades[2]	3CM	25208 66	25208 66	1.0000	25208.66	39	0	139	44	5	3256.36
Fla. Atlantic	Glades	86PK	0 00	93774 55	.0879	48513.39	9	0	9	5	-4	-27183.53

Note: Non-separable costs totalled $55180 70/yr for the main system, 31145.56$/yr. for SR#2, 21119.25$/yr. for the 2 member outfall group, and 24635.56$/yr. for the 3 member outfall group.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

TABLE D-14-CONTINUED
USER'S UNIT COST INFORMATION USING LP
SOUTHERN PALM BEACH COUNTY-201 REGION

SITE NAME	T.P.	APB #	BOUNDS, $/year		β(i)	X(i)		ALT. DISP. COST ¢/1000 gallons	MAX. SUPP. CHRG. ¢/1000 gallons	MAX USER CHRG. ¢/1000 gallons	NET SAV-INGS ¢/1000 gallons	CUM SAVINGS $/year
			LOWER	UPPER		$/year	¢/1000 gallons[1]					
Boca West	Glades	41GC	135975.82	367992.82	2174	256007.65	12	0	12	5	-7	-208152.22
Boca del Mar	Glades	37GC	0.00	159093.56	.0801	117812.60	18	0	18	5	-13	-419022.75
Univ. Park	Glades	83PK	0.00	47602.14	.0446	24626.52	16	0	16	5	-11	-290070.89
Boca Lago	Glades	39GC	0.00	155972.34	.1461	80690.83	16	0	16	5	-11	-271382.22
Boca Teeca	Glades	7GC	0.00	79539.97	.0745	41149.26	17	0	17	5	-12	-324050.30
Broken Sound	Glades	8GC	0.00	77487.63	0726	40087.50	18	0	18	5	-13	-452152.67
Boca Rio	Glades	40GC	0.00	158033.46	.1481	81757.13	20	0	20	5	-15	-521385.72
IBM Park	Glades	87PK	0.00	26579.04	.0249	13750.42	34	0	34	5	-29	-533703.26
Boca Woods	Glades	82GC	142192.62	232539.64	.0846	188932.81	35	0	35	5	-30	-703600.36
Boca Raton at Hidden Valley	Glades	5GC	3488.33	32951.51	0192	14074.76	52	0	52	5	-47	-716908.90

Note: Non separable costs totalled $55180.70/yr. for the main system, 31145.56$/yr. for SR#221119.25$/yr. for the 2 member outfall group, and 24635.56$/yr. for the 3 member outfall group.

[1] 2¢/1000 gallons was added for conversion and set-up costs.

[2] indicates an ocean outfall group.

BIOGRAPHICAL SKETCH

The author of this Master's thesis, David James Sample, was born in Daytona Beach, Florida on July 20, 1958. He attended elementary school at Highlands Elementary and Westside Elementary, High school at Campbell Jr. High, and Mainland Senior High (all are located in Daytona Beach), graduating *Magna cum laude* in 1976. David attended his freshman year of college at the University of Central Florida in Orlando, Florida, and transferred to the University of Florida, where he received a B.S. in Environmental Engineering Sciences in June of 1981. He was admitted to graduate school in the same department that year. The next year, he was married and moved to South Florida, where he began working for the South Florida Water Management District (September, 1982), on the subject of this thesis. He is now currently residing in Atlanta, and works for the J.C. Taulmann Corporation.