APPLICATION OF THE WASTE RESOURCES ALLOCATION PROGRAM (WRAP) IN THE SEDGWICK-RENO-HARVEY COUNTY REGION

by

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Chapter One

INTRODUCTION

> From the earth and its atmosphere man takes ores, hydrocarbons, wood, oxygen and other substances in crude form and extracts, refines, purifies, and converts them into simple metals, chemicals, and other basic raw materials. He modifies these raw materials to alloys, ceramics, electronic materials, polymers, composites, and other compositions to meet performance requirements; from the modified materials he makes shapes or parts for assembly into products. The product, when its useful life is ended, returns to the earth or atmosphere as waste. Or it may be dismantled to recover basic materials that reenter the cycle.
>
> The materials cycle is a global system whose operation includes strong three-way interactions among materials, the environment, and energy supply and demand.[1]

A growing world community is extracting a finite supply of raw materials to meet the ever increasing consumer demands of a population that wants a higher standard of living. The demand for sources of energy to be used in the production process of the materials cycle will continue to rise into the twenty-first century.[2] Conversely, the solid waste by-

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[1] National Academy of Sciences, Mineral Resources and the Environment, COMRATE, (Washington: National Academy of Sciences, 1975), p.1.

[2] Ibid., p.1.

products of the materials cycle have, until recently, not found their way back into the cycle as readily as they might. This trend is changing in both North America and the remainder of the world, primarily Japan.

Increasingly, solid waste is being used as a source of energy in "waste-to-energy" facilities.

> In five years the number of waste-to-energy projects in the United States and Canada has tripled. In 1980, 60 projects had progressed at least as far as the advanced planning stage. Today 194 projects are under way. In Western Europe, Scandinavia, and Japan nearly 500 facilities are recovering energy from waste.[3]

The growth potential in the United States alone is expressed in billions of dollars. Alfred DelBello, President of Signal Environmental Systems, Inc., a waste-to-energy facility contractor and management firm, projects that capital investment could be between $15 billion to $30 billion in the next 15 years and 100 large and small facilities could be built.[4]

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[3] Nancy M. Petersen, ed., Waste-To-Energy Facilities: Decision Maker's Guide, (Alexandria: National Publishing, 1986), p.1.

[4] Ken Anderberg, ed., "Trash to Cash", American City & County, 100:8:28, August, 1985.

Problem Statement

Approximately 175 million tons of solid waste were generated by American consumers and commercial interests in 1980, (exclusive of the 250 million tons generated by industry). Of this 175 million tons, approximately 19 million tons will be recovered resources. By 1990 approximately 225 million tons of solid waste will be generated, with 58 million tons as recovered resources, a 205 percent increse in resource recovery over 1980 projections. Net disposal should increase by 6 percent, if projection are accurate, from 156 to 166 million tons per year.[5]

Solid waste and resource recovery projections do not, however, reflect the rising costs of disposal and collection, the increasing cost and decreasing supply of land, elimination of Resource Conservation and Recovery (RCRA) grants to states to aid in implementation and planning of comprehensive solid waste management programs, and the complex and confusing array of alternatives that solid waste and resource recovery planning impose on local decision-makers. These factors facing local decision makers

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[5] Office of Solid Waste, Fourth Report to Congress-Resource Recovery and Waste Reduction, Environmental Protection Agency, SW-600, (Washington: Government Printing Office, 1977), p. 20.

often give rise to strong pressures towards the regionalization of solid waste management functions.[6]

Attempting to resolve the issue through regionalization creates two significant problems: the complexity of designing a regional plan (technical), and consensus from participants over various choices (political). Each bears important incremental costs as alternative plans are considered before final selection. This relationship has been defined by Edward B. Berman as a state of political and technical feasibility.[7] Alternatives are defined by the availibility of the following: processes and transportation activities. As each alternative system is determined, the additional costs of moving from one design to another, and in particular the costs of moving from less political acceptability to greater political acceptability is illuminated.[8] This process is illustrated in Figure 1.1. The central problem is which of the alternatives acknowledges political and

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[6] Office of Solid Waste, WRAP: A Model for Regional Solid Waste Management Planning, Programmer's Manual, Environmental Protection Agency, SW-573, (Washington: Government Printing Office, 1977), p. 1.

[7] Office of Solid Waste, WRAP: A Model for Regional Solid Waste Management Planning, User's Guide, Environmental Protection Agency, SW-574, (Washington: Government Printing Office, 1977), p. 118.

[8] Ibid., p. 118.

technical issues and becomes the basis for an acceptable regional resource recovery plan, even though that plan may not be the least costly of those which are available.

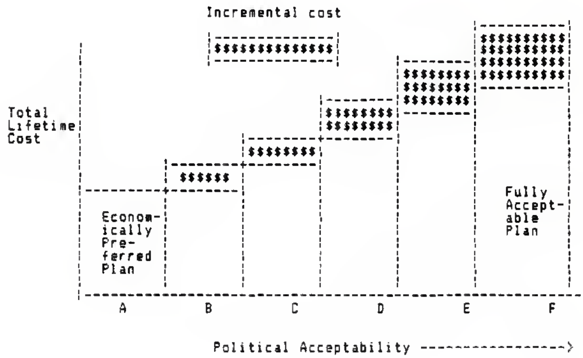

Figure 1.1

The Plan Set

Source: Office of Solid Waste, WRAP: A Model for Regional Solid Waste Management Planning, User's Guide, Environmental Protection Agency, SW-574, (Washington: Government Printing Office, 1977), p.119.

Scope

This report is about the use of a computer program that is a mathematical model that can be used by city planners to assist them in understanding the complex array of processes, transportation links, and their associated costs, and the increasing amounts of municipal solid waste that are generated in a given regional solid waste system. The focus is on the evaluation of alternatives. It is an attempt to learn about the program data requirements, the preparation of that input, and an explanation and analysis of the output in terms of the relative, rather than absolute, costs of an alternative plan. Selection of an alternative plan and implementation steps are beyond the scope of this report. It is also assumed that all environmental and regulatory standards would be dealt with in the implementation stage. Resource recovery alternatives of the region will be discussed in a later chapter.

A general study of systems is important because attention is directed towards all of the parts, how they interact, and their affect on one another. An analysis of the whole system, or a subsystem of the whole, can aid in the evaluation of alternatives in four ways:

1. The use of these methods leads to an increased capability for defining and evaluating possible alternatives and provides for a wider range of options at every level of decision-making.
2. There is an improved capacity for testing assumptions and data to estimate the effects of economic, hydrologic, political and technological uncertainties.

> 3. The use of systems analysis forces us to make explicit all assumptions and judgements, the consequences of which are available for all to see and question.
> 4. Systems analysis is a means of communication between all the participants such as planners, engineers, ecologists, hydrologists and economists, helping in understanding what each has to do.[9]

Mathematical modeling is important in the areas of socioeconomic and environmental planning.

> A mathematical model is a simplified and abstract view of some aspect of the urban system embodied in an explicit mathematical form, usually through a set of equations. These equations, operating on a massive set of urban data through the use of a computer, help ...., facilitate testing and evaluation of alternative sets of plans.[10]

Defining the parts and quantifying each alternative allows the planner to input data into a computer, process the results and isolate the needed information necessary to evaluate an alternative. To generate the complex results the program calculates would have been computationally impossible prior to the use of the computer. The mathematical technique used is linear programming. It will be briefly discussed in the next chapter.

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[9] Rolf A. Deininger, ed., Models For Environmental Pollution Control, (Ann Arbor: Ann Arbor Science Publishers Inc., 1973) p. 12.

[10] Benjamin Reif, Models in Urban and Regional Planning, (New York: Intertext Educational Publishers, 1973), p.53.

A resource recovery region will be considered a subsystem of a total solid waste management system that would affect a given region. This total system might look like the one in Figure 1.2.

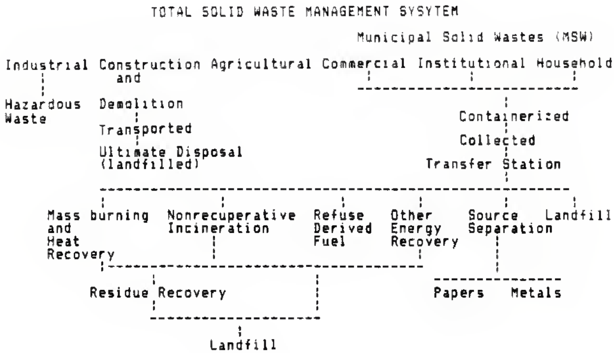

Figure 1.2

Components of a Total Solid Waste Management System

Source: Martin Grayson, ed., Recycling, Fuel and Resource Recovery: Economic and Environmental Factors, (New York: John Wiley and Sons, 1974), p. 109.

In this report, any alternarive that might be the basis for a regional resource recovery plan will be concerned with the municipal solid waste (MSW) branch of Figure 1.2. Commercial, household and institutional wastes are not differentiated.

Industrial, agricultural, and construction and demolition wastes will not be considered. The total tonnage of wastes generated in the region is a function of the total population. Per capita wastes generated differ from region to region and affect the overall solution. The basic unit of measurement is that amount generated on a per capita, per year, basis which is found by dividing total waste (in tons) by total population of the region.

The costs of transportation are also important and are generally divided into vehicle and labor costs. Such items as fuel, maintenance, insurance, and equipment are vehicle costs. Labor costs are based on driver and crew size and salaries. When combined, these are the haul costs of the transportation network for the region. Haul costs are a function of the distance and time from a source, which generates wastes, to a process and then to ultimate disposal (landfilling). Haul costs are expressed as the cost per ton/minute of operation. The door to door costs of collection within the region are important, but are not considered as a cost in the subsystem and are beyond the scope of this report.

Processing costs include capital and operating costs. Capital costs are sometimes called "first" or "fixed" costs. These include site development, construction and administrative costs such as legal and engineering fees. Operating costs are "variable" costs and include maintenance of the process, grounds and buildings. The cost of labor is also included in operating costs. Capital and operating costs are combined into an annual cost. The cost per ton is a function of the total annual costs divided by the total wastes processed. Revenues generated by a process are deducted from the operating costs.

Process capacity is important because of economies of scale in facility size. Operating and capital costs are also a function of the facility size and the amount and manner by which wastes are processed. Travel distance to the process and the amount of wastes generated at each source will increase transportation costs if processes are not properly sited throughout the region.

Resource recovery and recycling are different and must be defined. Resource recovery is defined as

> procedures and processes for recovery of useful energy and for recyclable materials from mixed or segregated MSW (often restricted to centralized recovery from mixed waste, but more properly applied to all types of recovery.[11]

More specifically, energy recovery is defined as capturing the heat value from organic wastes, either by direct combustion or by first converting it into an intermediate fuel product.[12] Recycling is defined as the reprocessing of used products into new basic materials of commerce, in which the identity and utility of the original product are lost.[13] Recycling will not be considered. Only those processes that produce useful (saleable) energy will be considered.

Method

The computer program, WRAP (Waste Resources Allocation Program) was obtained free of charge from the Environmental Protection Agency and will be used to

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[11] U.S. Congress, Materials and Energy from Municipal Waste, Office of Technology Assessment, (Washington: Government Printing Office, 1975), p. 283.

[12] Office of Solid Waste. Fourth Report to Congress-Resource Recovery and Waste Reduction, Environmental Protection Agency, SW-600, (Washington: Government Printing Office, 1977), p.1.

[13] Ibid., p. 283.

evaluate the Sedgwick, Reno and Harvey County region of Kansas. This area was chosen because of two reports: Technical Assistance To Reno County, Kansas prepared by PEDCo Environmental and the Sedgwick County, Kansas Resource Recovery Feasibility Report, 1982, compiled by the Sedgwick County Department of Environmental Resources. These two reports indicated the need to study resource recovery as an alternative to landfilling of solid wastes. In reality the political and municipal boundaries between the various counties, cities and other jurisdictions would, in all likelihood, preclude the successful implementation of a regional resource recovery plan. It is assumed that these boundaries have no affect on this study. It is further assumed that the base year for this report is 1982.

WRAP has been used in various cities and regions around the country. An analysis of the application of WRAP in those areas was conducted to better understand the program inputs and outputs.

Interviews and communications with public officials in the region were conducted to gain insight into the nature of solid waste activities. Additionally, staff at the Kansas Department of Health and Environment, Solid Waste Division, were interviewed. They provided valuable insight into solid waste activities in the region.

The data requirements of WRAP are considerable. Waste volumes, capital and operating costs of processes and transportation costs are accounted for in many ways. Accounting systems vary among the three counties. When data is not available, then process costs and other data generated in previous studies are assumed to be appropriate. Assumptions used in determining input data will be noted when used.

Structure of the Report

This paper is divided into six chapters. Chapter twos contains a brief description of the region and the resource recovery objectives each county considered. Also, there is a description of the various processes and general site plans of each. The regulatory processes required to implement a modular incinerator and a landfill are briefly discussed. The WRAP model is discussed in chapter three. Emphasis is given to describing the system, data requirements and the process, transportation and source balance equations. Linear programming will be briefly discussed. All data requirements and assumptions are considered in chapter four. Analysis of output and comparison of alternative plans will be discussed in chapter five. Maps are an important tool in the analysis of WRAP output. Source to process to ultimate disposal are easily depicted on maps and will be used extensively in the analysis of results. Chapter six will contain summary and concluding remarks. Computer inputs and outputs will be appended as well as data calculations and assumptions on that data.

Chapter Two

REGION, ALTERNATIVES, PROCESSES AND REGULATORY DESCRIPTION

This chapter will present a brief description of the region in terms of population, per capita densities, population centers, the transportation network and other information. The solid waste management processes each study suggested will also be discussed. Finally, a brief overview of the regulatory process will be presented.

Description of the Region

The Sedgwick-Reno-Harvey County region is located in south-central Kansas, Figure 2.1. The total population of the region in 1980 was 462,045 persons, with total population by county being 366,531, 64,983 and 30,531, respectively.

The main population centers are Wichita in Sedgwick County, Hutchinson in Reno County and Newton in Harvey County. In 1980 each had populations of 279,272, 40,284 and 16,332, respectively.

The total square mileage of the three county region is 2807 square miles with a density of 165 persons per square mile. Square mileage/density characteristics are, by county, 1007/364, 1259/51.6 and 541/56.4, respectively.

Major highways that interconnect the region are I-135, US-50, US-54, K-61 and K-96. I-35 and I-235 are also major access routes surrounding Wichita.

The Arkansas River flows southeast from Reno County into Sedgwick County and Wichita. Another major body of water is Cheney Reservoir in southeast Reno County. The area is characterized by gently rolling hills to generally flat terrain.

Reno and Harvey County

In 1980, Reno County requested assistance to study the economic feasibility of implementing modular incineration as an alternative method of processing solid waste. PEDCo Environmental Inc., of Cincinnati, Ohio, under contract with the Environmental Protection Agency's Technical Assistance Panels Program, prepared a report that covered the Reno, Rice, Harvey, McPherson and Sedgwick County area. The conclusions of the report focused primarily on Reno County, and to a

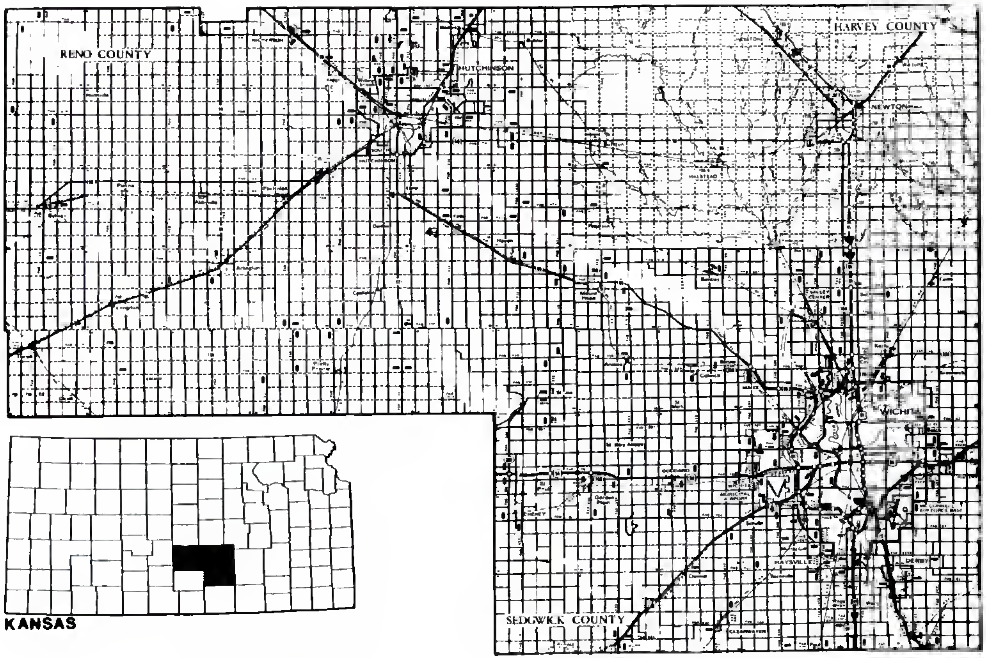

Figure 2.1

Regional Location Map

much lesser extent on the other counties. The report did not consider Sedgwick County in the final conclusions, because a concurrent report was already in progress for that county. Harvey County was added to the study area to increase the waste base generated yearly, and to expand the transportation network of the region.

The report suggested the construction of modular incinerators at a number of sites in Reno County, specifically in Hutchinson, but none in Harvey County. These incinerators would be sited adjacent to the potential users of steam that would be produced by the incinerators. The interested markets cited were three salt companies that would use the steam in a drying process.

The resource recovery alternatives selected by PEDCo for Reno County were to continue landfilling as currently practiced, use transfer stations to centrally distribute the wastes from distant areas to the landfill and to build modular incinerators with landfilling.

Unnamed vendors supplied financial information on total capital and operating costs, net revenues from the sale of steam and annual capital and operating costs of 125 and 250 ton per day (TPD) modular incinerators. Public and private financing mechanisms were not differentiated.

<u>Sedgwick County</u>

In 1980 the Sedgwick County Commissioners authorized the Sedgwick County Department of Environmental Resources to conduct a thorough study of solid waste activities in the county and prepare a set of resource recovery alternatives based on that study. The Wichita City Commission also voted in 1980 to support the study and prevent duplication of effort. A task force of private citizens was formed to gather the information and prepare a report. Their efforts were to be coordinated by the Sedgwick County Department of Environmental Resources.

The report addressed the following solid waste components: the waste stream, collection system, markets, public attitudes towards resource recovery, regulatory impact, and technical and financial analyses. Without appendices the report was approximately one thousand pages long which is indicative of the complexity of the subject.

In 1982 the <u>Sedgwick County, Kansas Resource Recovery Feasibility Report</u> was sent to the governing bodies. The resource recovery alternative suggested in the report was modular incineration, with revenue to be generated from the sale of low pressure steam, and landfilling.

A detailed financial analysis of modular incinerators at 50, 100 and 200 TPD processing capacities was prepared with the assistance of Consumat, a manufacturer of modular incinerator systems. This analysis was submitted to the City and County Commissioners in 1983. Information contained in the addendum included average annual capital and operating costs, net revenues from the sale of steam and total debt service based on either public or private financing mechanisms for each of the process capacities. Modular incinerators that would, in total, process 700-900 TPD were considered to have the most "economic viability".

Landfilling

The two basic methods for landfilling of solid waste are the area and trench types as illustrated in Figure 2.2.

The area landfill is used on flat surfaces or in existing quarries or ravines. The wastes are spread in thin layers, and compacted and covered by varying levels of soil. The trench method uses an excavated trench into which the wastes are dumped and compacted and then covered with the excavated soil.[14] Wastes are compacted into cells. The depth of a cell is significant because it sets a limitation on the ultimate capacity of the landfill. Cell depths vary and are dependent on site specific criteria.

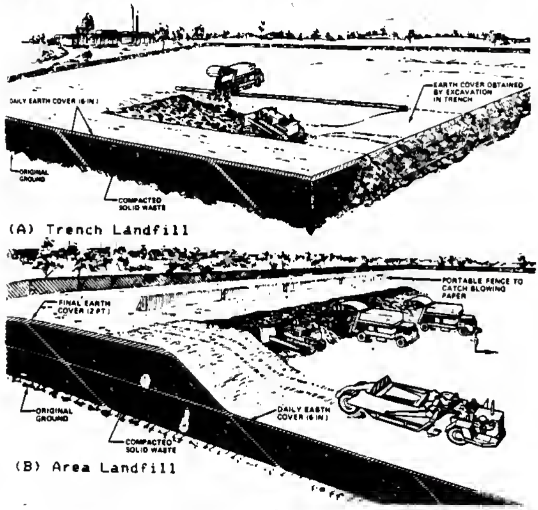

Figure 2.2

Types of Landfills (A) Trench and (B) Area

Source: David Gordon Wilson, ed., Handbook of Solid Waste Management, (New York: Van Nostrand Reinhold Company, 1977), p. 241.

(A) Trench Landfill (B) Area Landfill

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[14] Sedgwick County Department of Environmental Resources, Sedgwick County, Kansas Resource Recovery Feasibilty Report, 1982, (Wichita: Department of Environmental Resources, 1982), p. 8-7.

Landfills are regulated in Kansas by the Kansas Department of Health and Environment, Solid Waste Section as well as by various federal and local agencies. The costs of landfilling vary from locale to locale and reflect a combination of economic (capital and operating), technical, and regulatory costs that make each locale's site unique.

Transfer Stations

Transfer stations are an intermediate process between the sources of solid waste and either some sort of process or landfills. Two basic types of transfer stations have been developed: direct dump and hydraulic compaction.[15]

The direct dump station is the simplest and least costly to operate; however, the costs of transporting the wastes after dumping are higher since the wastes are less densely compacted and as a consequence more trips are required to haul the wastes to a site. A simple open trailer system is illustrated in Figure 2.3.

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[15] Michael D. Brown, Thomas D. Vence, and Thomas C. Reilly, Solid Waste Transfer Fundamentals, (Ann Arbor: Ann Arbor Science, 1981), p. 16.

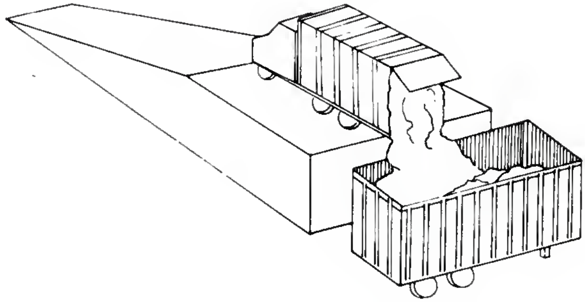

Figure 2.3

Transfer Station: Direct Dump with Trailer

Source: Michael D. Brown, Thomas D. Vence, and Thomas C. Reilly, Solid Waste Transfer Fundamentals, (Ann Arbor: Ann Arbor Science Publishers, Inc., 1981), p. 17.

The hydraulic compaction system uses a chamber into which wastes are dumped from above and are then compacted and forced into the rear openings of trailers or other containers which can be transported to other sites.[14] Transportation costs are lower because wastes are more densely compacted and the number of trips to other sites are reduced. Capital costs of this type of system are the highest. The major drawback to this system is that if the compactor fails then it is likely that the flow of all wastes into the transfer station and to other sites will halt. The reason being that the compaction/loading method would be the only available method at the site. A compactor and direct to hopper method is illustrated in Figure 2.4.

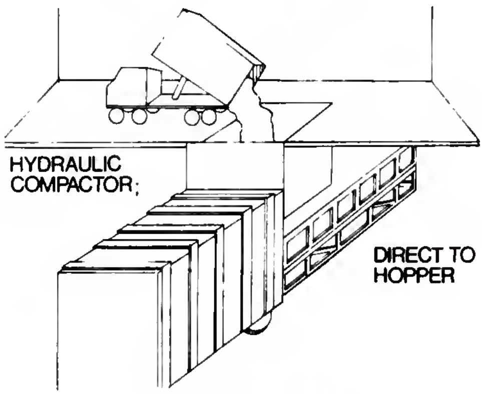

Figure 2.4

Transfer Station: Hydraulic Compactor with Direct to Hopper Transfer

Source: Michael D. Brown, Thomas D. Vence, and Thomas C. Reilly, Solid Waste Transfer Fundamentals, (Ann Arbor: Ann Arbor Science Publishers, Inc., 1981), p. 19.

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[14] Ibid, p. 19.

Simple site plans to accommodate local waste haulers, private or public, and transfer trailers are illustrated in Figure 2.5. As with landfills, transfer stations are regulated by various federal, state and local agencies.

Modular Incinerators

"Modular incineration refers to a process in which municipal solid waste, or some other fuel, is mass burned in small, self-contained, prefabricated combustion units."[17] The self-contained units are manufactured in various individual unit sizes that process from two to four tons per day to as much as one hundred tons per day.[18] The units are assumed to process wastes twenty four hours per day.

Units are usually assembled in combinations of two or more units. "Two or more modules in a single facility provide for continued operation of some of the modules in the facility in the event a module is shut down for maintenance or repair."[19] This system also

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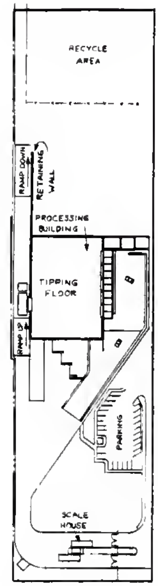
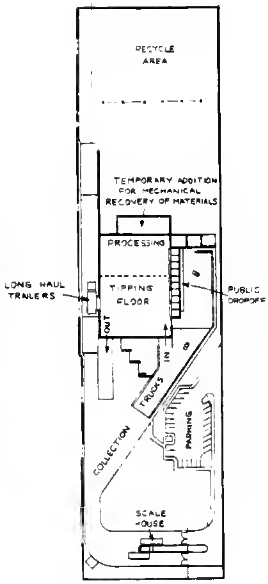
[17] Department of Environmental Resources, op. cit., p. 8-246.

[18] PEDCo Environmental, Technical Assistance to Reno County, Kansas, (Washington: Government Printing Office, 1980), p. 3-15.

[19] Department of Environmental Resources, op. cit., p. 8-249.



TRANSFER
AND
HAULING



TRANSFER
WITH
MECHANICAL
RECOVERY

Figure 2.5

Site Plans for Transfer Stations

Source: Michael D. Brown, Thomas D. Vence, and Thomas C. Reilly, Solid Waste Transfer Fundamentals, (Ann Arbor: Ann Arbor Science Publishers, Inc., 1981), p. 63.

accommodates add-on units if demand is increased.

Modular incinerators consist of a tipping (dumping) floor, primary and secondary combustion chambers, heat or electricity recovery, ash recovery and dump stacks. An incinerator with steam recovery is illustrated in Figure 2.6.

All modular incinerators are controlled air systems: starved air or excess air incinerators.[20] Wastes are dumped directly onto the tipping floor and loaded into the primary chamber where it is either burned under reduced oxygen or excess air conditions. Unburned wastes and gases pass into the secondary chamber where the remainder is completely burned. "Temperatures in the chambers are in the range of 1300° to 1600°F."[21] Heat dump stacks remove hot gases if an electrical or steam recovery process is not part of the system. "If heat recovery is desired, heat exchangers are positioned to recover heat directly from flue gases as they exit the secondary chamber."[22] A boiler system would be attached and produce steam that would go directly to an end user.

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[20] Ibid., p. 8-254.

[21] PEDCo Environmental, op. cit., p. 3-16.

[22] Department of Environmental Resources, op. cit., p. 8-257.

Ash is a by-product of wastes burned in the primary chamber.

> In one method, the hot dry ash exits the primary chamber through a chute into an air lock chamber or the ash moves through the primary chamber to be dumped through a quillotine door into a water-sealed quenching pit. The wet cooled ash is then conveyed into a container for disposal in a landfill or other suitable disposal area.[22]

For illustration purposes, a site plan for a 100 TPD modular incinerator is shown in Figure 2.7.

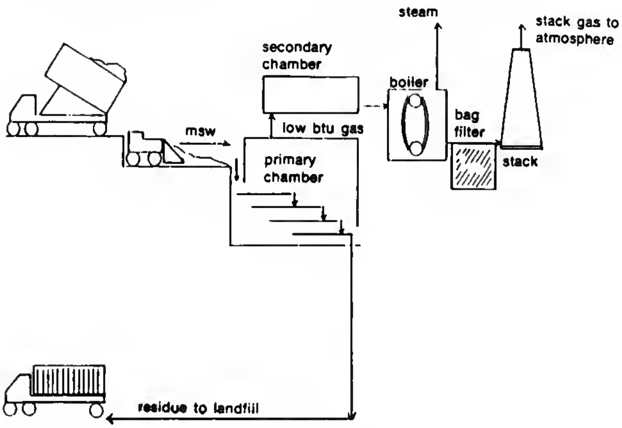

Figure 2.6

Modular Incinerator

Source: Michael D. Brown, Thomas D. Vence, and Thomas C. Reilly, Solid Waste Transfer Fundamentals, (Ann Arbor: Ann Arbor Science Publishers, Inc., 1981), p. 43.

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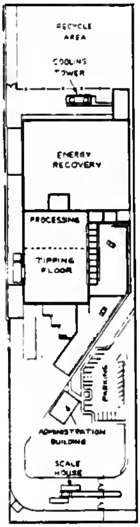
[22] Ibid., p. 8-258.



ENERGY

RECOVERY

Figure 2.7

Site Plan for Energy Recovery Plant

Source: Michael D. Brown, Thomas D. Vence, and Thomas C. Reilly, Solid Waste Transfer Fundamentals, (Ann Arbor: Ann Arbor Science Publishers, Inc., 1981), p. 63.

Regulatory Requirements

Landfills and resource recovery projects are required to meet local, state and federal regulatory standards. This step is usually in the implementation process and may require more time than the actual construction step. Any step in the regulatory phase has the potential to stall the project. The reader should consult current local, state and federal regulatory standards for specific steps to be followed.

If a landfill was selected as an alternative process for handling solid wastes in the study region, then the following general site selection and design considerations would be followed:

1. Site selection is dependent upon local zoning ordinances, land use plans and subdivision platting requirements.
2. Site design is dependent on Kansas Department of Health and Environment and local city and/or county building codes. Regulatory criteria of the Environmental Protection Agency may also have to be followed.
3. A building permit may have to be obtained to construct the landfill and a certificate of occupancy may have to be issued prior to opening the landfill.
4. A solid waste disposal facility permit has to be obtained from the Kansas Department of Health and Environment (KDHE) prior to operation and the landfill must follow Kansas Solid Waste Management Regulations.
5. If federal funding is involved, an environmental

impact statement may be required under the National Environmental Policy Act.

The regulatory process for a modular incinerator alternative is specified according to the type of system selected. In general, the following are required:

1. Determine the local ownership of the waste stream prior to implementing the alternative's system development plan.
2. Air quality standards of federal and state regulations must be met and are dependent on the size of the system.
3. KDHE requires multiple chambered systems unless another type can be shown to meet applicable air quality standards.
4. Federal and state water quality standards may have to be met, depending on what is done with the water used in the incinerator process or for grounds maintenance.
5. Ash and residue must meet federal and state quality control standards prior to disposal.
6. Meet steps 1-5 as described in the landfill process above.
7. Have long term contracts for sale of recovered energy reviewed by the Kansas Attorney General.

Chapter Three

WRAP MODEL STRUCTURE

WRAP (Waste Resources Allocation Program) was developed by the MITRE Corp., the Environmental Protection Agency and others. It is a fixed-charge linear programming computer model that determines a minimum cost solution for a centralized resource recovery plan. Alternatives reflect the minimum costs of any given combination of transportation and process activities, the flow of solid waste through the system to an indeterminant number of locations and the capacity of the system to handle that flow. This is accomplished through a series of mathematical equations. The model balances the economies of scale of centralization of capacitated processes versus the costs of transportation which increase relative to the size of the region.[24]

General System Structure

WRAP is written in FORTRAN IV and contains 7000

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[24] Office of Solid Waste, WRAP: A Model for Regional Solid Waste Management Planning, User's Guide, Environmental Protection Agency, SW-574, (Washington: Government Printing Office, 1977), p.1

source statements and 99 subroutines. The standard size for a matrix is up to 90 rows and 360 columns, if required. The model can be expanded to fit larger problems. Constraint values are assigned to the rows and decision variable values are assigned to columns.

There are two modes of operation in the WRAP model: static and dynamic. In the dynamic mode, two to four model periods can be designated. The dynamic mode will not be used because it has been used infrequently and the proper method of implementing it is not clearly understood by the writer.

The static mode will be used. This mode has a single planning period with a "look ahead capability". "This is an ability to anticipate problems (primarily associated with land shortage) and adjust to them in a timely manner."[23] For example, "land availability and land use are both evaluated over the entire planning period so that, if land-conservative measures are required, they are initiated immediately and at a relatively low cost."[24]

Data is collected and input by the user (basic

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[23] E. B. Berman, "A Model for Selecting, Sizing, and Locating Regional Solid Waste Processing and Disposal Facilities", M73-111, (Bedford: The MITRE Corporation, 1973), p.20.

[24] Ibid, p. 20.

data requirements will be explained in the next section). The data is checked for accuracy and completeness. If an error is found the program aborts and an error message is issued. Error messages are numbered, listed in the Programmer's Manual and explain to the user what should be happening at that point in the program and what the user must do to correct the error. If no errors are found the program matrix is created and an initial feasible solution is calculated. If the user is seeking an optimum solution, the initial feasible solution is used as a starting basis for the Walker algorithm and a solution is generated. The program aborts if no solution is found. If one is found a variety of outputs are available. Matrix information can be output which includes starting basis data for the next run. More important to the user is the report information which includes the solid waste tonnage volumes handled at the source, site processing and ultimate disposal levels. The objective value, or the total cost per year for the region, is reported as well as the total number of tons of solid wastes generated in the region and the average cost per ton. The above two cost items can be compared to those found in other solutions and represent incremental costs of moving from less to more politically acceptable solutions. A flow chart of the WRAP system is presented in Figure 3.1.

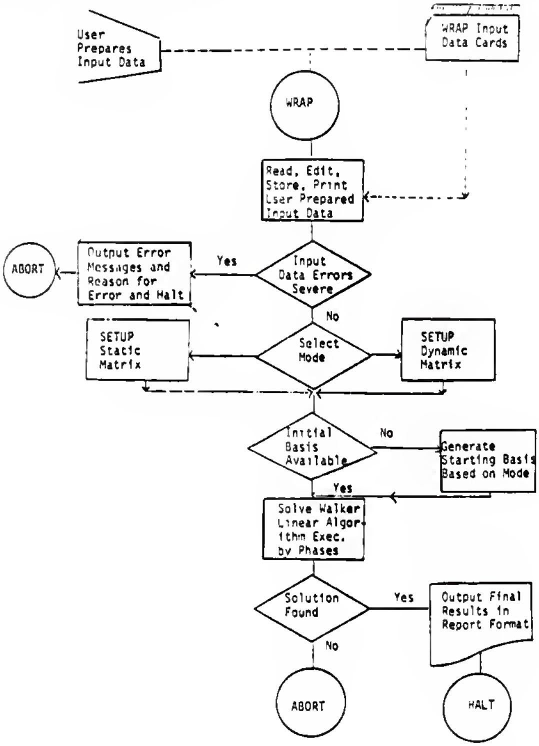

Figure 3.1

WRAP System Flow Chart

Source: Office of Solid Waste, WRAP: A Model For Solid Waste Management Planning, Programmer's Manual, Environmental Protection Agency, SW-573, (Washington: Government Printing Office, 1977), p. 8.

Modules and Subroutines

In WRAP terminology, a "module" is a group of subroutines. The model consists of ten functional modules and one "MAIN" module. The MAIN controls the initialization of data and invokes the other modules. Besides MAIN, the other modules are EDIT1, EDIT2, LINKAGE, CROWFLY, FRONTOUT, COLUMN, MATRIX, BASIS, LINEAR and OUTPUT. The following is a listing and brief explanation of each module:

MAIN	main FORTRAN program, data initialization and invoke remaining modules
EDIT1	reads user data and checks for validity
EDIT2	checks consistency of data
LINKAGE	assures transportation activity sources to sites are linked and complete
CROWFLY	a user option that creates an automatic transportation file, travel distance and time are calculated if not user supplied
FRONTOUT	prints user information as requested
COLUMN	structures the matrix based on user information
MATRIX	model equations create a matrix
BASIS	generates an initial starting basis which the user can use in proceeding runs
LINEAR	uses the Walker linear programming subroutines to find an optimal solution; the objective function is the minimum cost solution, the activity level is in tons of solid waste and selected activities are

calculated

OUTPUT uses LINEAR solutions in printout form

WRAP Data Requirements

Basic data supplied by the user is transportation related and includes geographic coordinates for origins and destinations, called source and site processes in WRAP terminology, and which are defined by longitude and latitude values. Time and distance values are also input for all origin-destination combinations. The associated tonnage of solid wastes for each origin are supplied by the user as well as the associated haul costs to a destination. Site process costs, operating and capital costs, revenues, if any, constraints on the number of trucks that can enter a site, if any, and any constraint on the number of tons processed at a particular site, if any, are supplied by the user. A more detailed description of data requirements is contained in Figure 3.2.

CONTROL	describes the WRAP control switches, options, planning periods, number of sources, sites, and processes
SOURCE	describes original source with name and number and geographic location in coordinates, waste tonnage per year
SITE	describes intermediate and ultimate sites with name and number and geographic location in coordinates, number of processes at a site
PROCESS	describes general waste processing facilities with name and number, percent output weight and density, haul costs, cost slopes and intercepts
SITE-PROCESS	describes a particular process at a site with site and process numbers, linear segments, waste capacity, revenue per period, and process level code
TRANSPORTATION	describes travel activities between locations, time, distance, and speed
STARTING BASIS	describes an initial feasible solution from a problem matrix
TRUCK	describes truck constraints at a site, identification number and number of trucks per period

Figure 3.2

User Supplied Data for WRAP

Source: Office of Solid Waste, <u>WRAP: A Model for Regional Solid Waste Management Planning, Programmer's Manual</u>, Environmental Protection Agency, SW-573, (Washington: Government Printing Office, 1977), pp.5-6.

WRAP Processing Levels

There are four levels of processing (A,B,C and

D) or points through which wastes flow. A modified version of the processing levels is shown in Figure 3.3.

SITE LEVEL	SOURCE AND PROCESSING LEVEL	MSW INPUT FROM	MSW OUTPUT TO
	SOURCE		
A	TRANSFER	SOURCE,A	A,B,D
B	PRIMARY	SOURCE,A	C,D
C	SECONDARY	B,C	C,D
D	LANDFILL	SOURCE,A,B,C	NONE

Figure 3.3

WRAP Processing Levels

Source: Edward B. Berman and William M. Stein, "The MITRE Solid Waste Planning Model: A Status Report", Energy from Solid Waste, (Westport: TECHNOMIC Publishing Co.,Inc., 1976), p.103.

All wastes originate at a source. From the source, wastes can be shipped to intermediate sites or ultimate disposal (landfill). Transfer stations receive raw refuse and total input is equal to total output. Wastes can be received from source packer (garbage) trucks and transferred to larger transfer trailer vans or the wastes can be transferred to rail or barge. Primary processes also receive raw refuse, but total output is less than total input. Primary processes include modular incineration, mass burning or shredded fuel processing. Secondary processes receive refined wastes from primary or other secondary processes, and total output is less than total input. Refuse derived fuel (RDF), a supplementary fuel to coal or oil, is an example of product refined at a secondary process. In WRAP terminology, intermediate sites are called "transshipment" points and can be collocated.[27] A processing flow chart, Figure 3.4, illustrates the flow of wastes through the various levels.

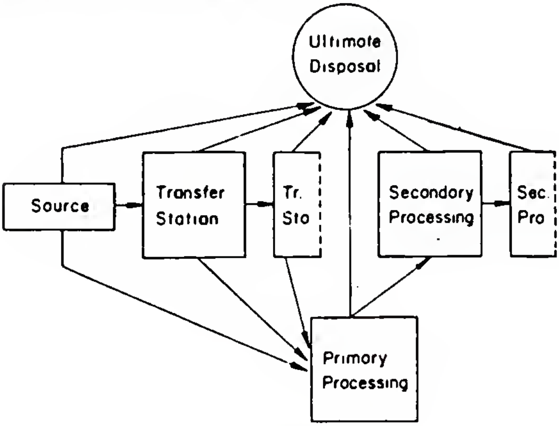

Figure 3.4

WRAP Process Level Flow Chart

Source: Yakir Hasit and Dennis B. Warner, "Regional Solid Waste Management Planning with WRAP", Journal of Environmental Engineering Division, A.S.C.E., EE3, (1981), p. 517.

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[27] Yakir Hasit and Dennis B. Warner, "Regional Solid Waste Planning with WRAP", Journal of Environmental Engineering Division, A.S.C.E., EE3 (June, 1981), 517.

Linear Programming and WRAP

Linear programming is a mathematical technique that is most often used to find a minimum cost or maximum profit solution for a given application. "The most common situations in which linear programming is applied today are finding the least-cost means of meeting product specifications, determining optimal production processes and/or products, finding least-cost transportation routes, and determining the best schedules for production and sales."[28] "It is also applicable in the analysis and planning of various urban and regional programs when an effort is made to maximize or minimize some goals."[29]

The classic linear programming problem takes the form:

Maximize or minimize $Z = c_1x_1 + \ldots + c_kx_k \leq b_1$

subject to:

$$
\begin{aligned}
a_{11}x_1 + \ldots + a_{1k}x_k &\leq b_1 \\
\vdots \qquad\qquad \vdots \quad &\quad \vdots \\
a_{m1}x_1 + \ldots + a_{mk}x_k &\leq b_m \\
x_i \geq 0 \qquad \text{for } i &= 1,\ldots,k
\end{aligned}
$$

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[28] Michael R. Greenburg, Applied Linear Programming for the Socioeconomic and Environmental Sciences, (New York: Academic Press, 1978), p.16.

[29] John W. Dickey and Thomas M. Watts, Analytic Techniques in Urban and Regional Planning, (New York: McGraw-Hill Book Company, 1978), p.371.

where $x_1, \ldots, x_k$ are k decision variables, $c_1, \ldots, c_k$ are their coefficients in the objective function, and a_{ji}, $i = 1, \ldots, k, j = 1, \ldots, m$, are their coefficients in the m constraints. The parameters $b_1, \ldots, b_m$ are nonnegative limiting values of the constraints. "The m constraints determine the feasible region and the point that maximizes or minimizes the objective function is one of the corner points of the region."[30]

The objective function is a mathematical expression and is the quantity that is being maximized or minimized. The decision variables are those values that are manipulated in the search for a solution. "These variables reflect the decision choices available."[31] The solution to the objective function would, however, be unlimited unless the decision variables are restricted or "constrained". "Constraints are relationships among variables that restrict the values assignable to the decision variables."[32] The decision variables and constraints are ≥ 0 and cannot be negative since negative

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[30] Ibid, pp.383-384.

[31] Hamed Kamal Eldin and Hooshang M. Beheshtia, Management Science Application: Computing and Systems Analysis, (New York: Elsevier North Holland, Inc., 1981), p. 141.

[32] Ibid, p.141.

quantities cannot be produced or used.

In WRAP terminology the solution to the objective function is called the "objective value". The value is arrived at by solving for one of two optimal values, a "local" and a "global" optimum solution. These two are calculated by the Walker algorithm through a set of "phases". Phase 1 generates a feasible solution. Phase 2 generates an optimum solution. Phase 3 generates a "local" optimum which is arrived at by improving on phase 2. Phase 4 generates a "global" solution that is an attempt to improve on the solution found in phase 3.

> Although all four phases are built into the optimizer, WRAP as presently configured enters phase 3 in all circumstances, thus bypassing phases 1 and 2. This bypass requires an advance starting point, or initial feasible basis. The user may provide a basis, but an advanced starting point algorithm is built into WRAP and is brought into operation whenever the user signals that a basis has not been provided.[22]

It is beyond the scope of this paper to discuss the appropriateness of either a "local" or "global" solution to the objective function. It is assumed that either solution is acceptable. This was substantiated by Hasit and Warner who found that 80% - 85% of the

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[22] Office of Solid Waste, <u>WRAP: A Model for Regional Solid Waste Management Planning, User's Guide</u>, Environmental Protection Agency, SW-574, (Washington: Government Printing Office, 1977), p. 8.

time "phase 4" did not improve on "phase 3" indicating that a "good" solution was reached at "phase 3". "Though the 'phase 3' solution is not computationally time consuming, 'phase 4' is; therefore, a 'phase 3' search may be sufficient for initial, exploratory runs in planning."[24] Phase 4, however, takes complete advantage of all of the mathematical techniques of the algorithm that drives the model and is used in all model runs.

Mathematical Equation Structure of WRAP

This section is added to give brevity to the program explanation. It is not necessary for most user's to understand the mathematics to implement the program. Equations are presented for the static mode only. The entire section is taken from Hasit and Warner's article entitled "Regional and Solid Waste Planning with WRAP".

The objective function of the static mode is the sum of the transportation costs, capital and operating costs, site preparation costs, and revenues, if any. The objective value in the output is the total

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[24] Yakir Hasit and Dennis B. Warner, "Regional Solid Waste Planning with WRAP", Journal of Environmental Engineering Division, ASCE, EE3, June 1981, p.523.

cost of the system for the given time period. The decision variables are transportation and processing activities. Constraints consist of "source balance equations", intermediate and ultimate site processing constraints, land, intermediate and ultimate site input equations, intermediate facility output balance equations, and truck constraints. The equations, in order, are:

(1) Source Balance:

$$\sum_{k} T_{ik} + \sum_{j} T_{ij} = G_i$$

and ensures that all waste generated at source i = all waste that is transported away. T_{ik} = waste transported from source i to ultimate site k, in tons per year. T_{ij} = waste transported from source i to intermediate site j, in tons per year. G_i = waste generated at source i, in tons per year.

(2) Intermediate and Ultimate Site Processing:

$$P_{jp} \leq K_{jp} \text{ and } P_{kp} \leq K_{kp} \text{ for all } j,p \text{ and } k,p$$

This constraint ensures that the amount of MSW processed at an intermediate site will be $\leq$ to the capacity of process. P_{jp} = waste processed by process p at intermediate site j, in tons per year. P_{kp} = waste processed by process p at ultimate site k other than a landfill, in tons per year. K_{jp} = capacity of

process p at intermediate site j, in tons per year.
K_{kp} = capacity of process p at ultimate site k other than a landfill, in tons per year.

(3) Land:

$$\sum_{t} dP_k \leq L_k$$

This constraint replaces the ultimate site constraint in (2) if the ultimate site is a landfill. d = land requirements for a landfill in acre-feet per ton. P_k = waste processed at a landfill in tons per year. L_k = available land at landfill k, in acre-feet per year.

(4) Intermediate and Ultimate Site Input:

$$\sum_{i} T_{ij} + \sum_{\hat{j} \neq j} \sum_{p} T_{\hat{j}pj} = \sum_{p} P_{\hat{j}p} \text{ for all } j$$

$$\sum_{i} T_{ik} + \sum_{j} \sum_{p} T_{jpk} = \sum_{p} P_{kp} \text{ for all } k$$

These equations state that the amount transported from sources and intermediate sites to a certain intermediate or ultimate site is the total amount processed at that site. T_{ij}, T_{ik} from formula (1). $T_{\hat{j}pj}$ = waste processed from process p at other intermediate site $\hat{j}$ to intermediate site j, in tons per year. T_{jpk} = waste transported from process p at intermediate site j to ultimate site k, in tons per year. $P_{\hat{j}p}$ = waste processed by process p at intermediate site j, in tons per year. P_{kp} = waste processed at landfill k, in tons per year.

(5) Intermediate Output Facility Balance:

$$\sum_{k} T_{jpk} + \sum_{\hat{j} \neq j} T_{jp\hat{j}} = b_p P_{jp} \text{ for all } j, p$$

This equation ensures that the waste transported from a certain intermediate site to another intermediate or ultimate site is the total nonusable output which is the amount processed less the recovered resources at that site. T_{jpk}, P_{jp} defined in (4). $T_{jp\hat{j}}$ = waste transported from process p at intermediate site j to other intermediate site $\hat{j}$, in tons per year. b_p = coefficient of P_{jp} or tons of nonusable output per ton of input.[35]

Nonlinear and Piecewise Linear Approximations

As previously stated, WRAP is able to reduce costs due to economies of scale at centralized resource recovery facilities, but can be offset by increasing transportation costs. It was also stated that WRAP is a fixed-charged linear programming model. "The fixed-charge capability of the model permits the representation of economies of scale in process costs."[36]

Some solid waste activities are linear by nature. An example is an established landfill from

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[35] Ibid, pp.514-516.

[36] Office of Solid Waste, op. cit., p.5.

which the cost to process a ton of solid waste is a function of the total operating costs divided by the total tons processed in a year. Not all solid waste activities are so easily determined. When fixed-charges are included the assumptions of linearity do not hold as in the case of economies of scale in processing and disposal. Two examples of these situations are when new transfer stations and landfills are introduced. "In these cases, there are increasing returns to scale (or decreasing costs with scale), or what is known as the concave cost function."[37]

Figure 3.5 is an example of a two segment piecewise linear approximation of a concave cost function. In this example, capital costs are fixed and are the intercept of each linear segment. "Operating costs are variable and are the slopes of each segment. In static mode applications, the differentiation between capital and operating costs is arbitrary, since they are merely added together to obtain a combined slope and a combined intercept."[38] This combination is the total processing cost and is represented by the

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[37] E. B. Berman, "A Model for Selecting, Sizing, and Locating Regional Solid Waste Processing and Disposal Facilities", M73-11, (Bedford: The MITRE Corporation, 1973), p. 28.

[38] Office of Solid Waste, op. cit., p.51.

curve TC. C_1 is the fixed charge or capital cost associated with the process. O_1 is the slope or operating cost of the first linear segment. C_2 and O_2 are the intercept and slope of the second linear segment. T_1 is the amount processed and represents the maximum or minimum size constraint of each segment.

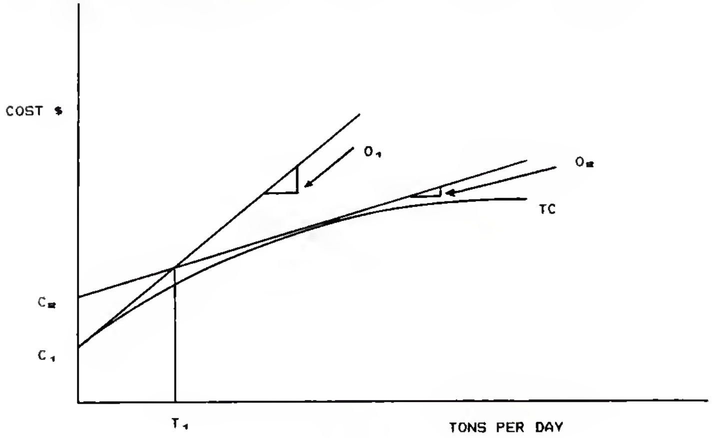

Figure 3.5

Two Segment Piecewise Linear Approximation of a Concave Cost Curve

Source: Office of Solid Waste, WRAP: A Model For Solid Waste Management Planning, User's Manual, Environmental Protection Agency, SW-574, (Washington: Government Printing Office, 1977), p. 8.

Source: Rolf Deninger, Models for Environmental Pollution Control, (Ann Arbor: Ann Arbor Science Publisher's Inc., 1973), pp. 341-342.

"This technique requires that each segment be treated as a separate facility. The two sites are really only one since 'one or the other, but not both' would exist."[39] This means that T_1 is the maximum size constraint of a site with a linear cost plus a fixed cost (C_1) or T_1 is a minimum size constraint on a site with a linear cost and a fixed cost (C_2). Also, "since the model is a cost minimizing model, the model will select the activity which is lowest cost for the scale required ..., and also use no more than one of the alternative activities in the optimal solution."[40]

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[39] Rolf Deninger, Models for Environmental Pollution Control, (Ann Arbor: Ann Arbor Science Publishers, Inc., 1973), pp. 341-342.

[40] Berman, op. cit., p.29.

Chapter Four

DATA INPUT AND DEVELOPMENT

Chapter Two described the region and the solid waste management alternatives that each county considered appropriate for a resource recovery study. Basic WRAP data input was explained in Chapter Three.

In this chapter, the data necessary to run the program will be formulated. This data consists of the following:

1. location by coordinate and tonnage of waste generated at a source;
2. haul costs from a source to a site process which are based on the cost per ton minute of operation of a typical packer (garbage) truck divided by the average load, in tons;
3. identification of sites by level of process, location by coordinates and acre-feet available, if the level is landfilling;
4. costs for processes at each site level selected, and transportation input (origin) and output (destination) links as wastes move through the system;

5. specific site-process information such as site capacity, revenue and the linear segments representative of the site-process; and
6. transportation data consisting of one-way times and distances and average speed from origin to destination.

Source Data

The WRAP model identifies a source as a "waste centroid" which is a division of the region into a subregion. Each source, or "centroid", has a specific population base associated with it "and hence waste generation". The source represents the "geographic impact" of wastes generated in that subregion. The User's Guide suggests that the number of sources be kept small, no more than thirty, and preferably less. Thirteen sources were identified for this report.

Sources should represent an ideal compromise between locational weight of population and be at, or adjacent, to a major transportation intersection or route. Previous applications of the model centered on urban settings such as St. Louis, Chicago or very densely populated areas of Massachusetts and North Carolina. Dispersed rural areas like Reno and Harvey County, and parts of Sedgwick County are not as densely populated. Consequently, the ideal and reality have to be compromised even further. Transportation routes were used as the rationale for division of sources, to include Wichita. Also, since sources in the rural areas contain more square miles and less population than urban areas, those sources were assigned a larger area in an attempt to provide an adequate waste generation base.

Reno County was divided into three sources, Harvey County into two sources and Sedgwick County into four sources. Wichita was further divided into four sources. The map of the region and sources is illustrated in Figure 4.1. A stripped down version of the map will be used in the analysis of the results.

Each source is assigned an identification number between 100 and 499, given a source name, identified by longitude and latitude coordinates and the number of tons, in thousands per year, of wastes generated at the source.

Longitude and latitude coordinates of each source were determined by overlaying a 2.5 by 2.5 minute grid, drawn on vellum, on a 7.5 minute USGS map. The 2.5 by 2.5 grid was divided into 5 second intervals

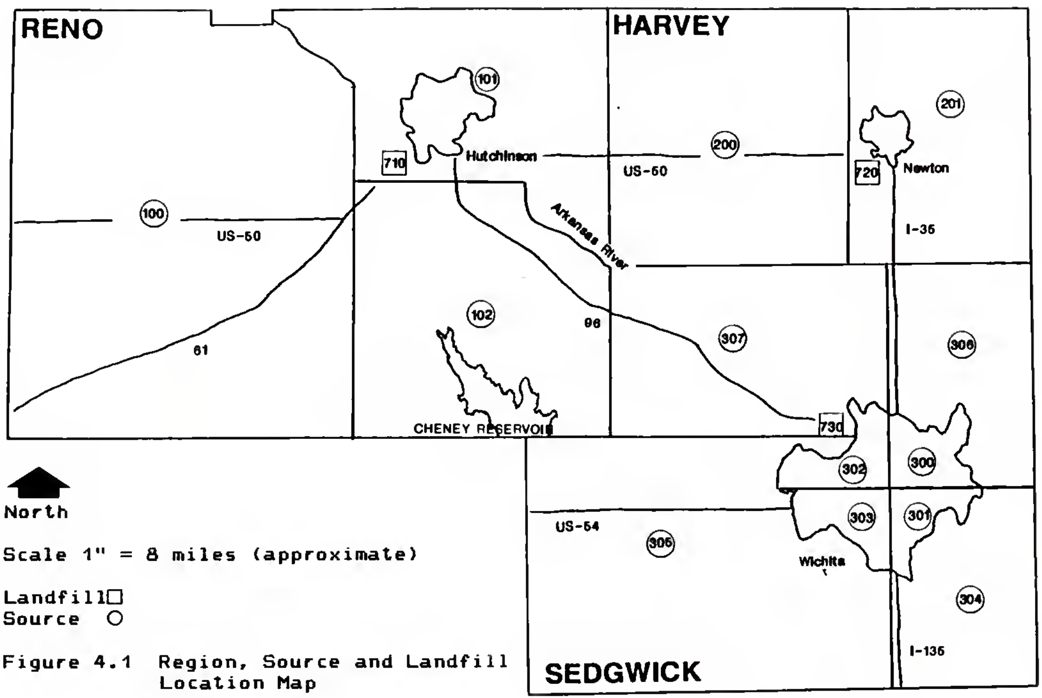

Figure 4.1 Region, Source and Landfill Location Map

for more detailed location of sources. All site-processes were also located using the above method.

Source tons, in thousands per year, of wastes generated in a source are calculated based on the average waste generated per capita per day. This is a difficult and important value to identify. The amounts of wastes generated by source will affect the overall solution.

The Sedgwick County report indicated a value of 5.27 lbs./person and the PEDCo report indicated a value of 3.5 lbs./person in Reno County and 3.0 lbs./person in Harvey County as values assumed to be representative of that population. Accurate waste amounts have not been determined for that area as they were in the Sedgwick report. Source information is contained in Table 4.1.

Haul-Cost Data

Source haul-costs per ton-minute of operation are also assigned to each source, (Appendix A). In the scope of this report, haul-costs were explained to consist of an assumed set of maintenance and operating budget amounts that are assumed to be available. If a collection system is publicly operated, those figures would be available. However, in the study-region all

Table 4.1

Source and Haul-Cost Information

COUNTY	SOURCE NAME	POPULATION (1)	WRAP CODE	LONGITUDE (Deg)	(Min) (1/10)	LATITUDE (Deg)	(Min) (1/10)	PER CAPITA WASTES	WASTE GENERATED (1000 tons/yr.)	SOURCE HAUL COSTS (per ton/min.)
RENO	N RENO CO	8465	100	98	15.0	37	58.1	3.5	5407	.10
	HUTCHINSON	40284	101	97	55.0	38	02.3	3.5	25731	.10
	SE RENO CO.	6234	102	97	46.5	37	54.1	3.5	3982	.10
HARVEY	N HARVEY CO.	10618	200	97	30.0	38	00.0	3.0	5813	.12
	NEWTON	19913	201	97	15.0	38	02.3	3.0	10902	.12
SEDGWICK	NE WICHITA	61064	300	97	17.3	37	42.3	5.27	58730	.12
	SE WICHITA	44915	301	97	17.3	37	40.0	5.27	43198	.12
	NW WICHITA	67182	302	97	22.3	37	42.3	5.27	64614	.12
	SW WICHITA	57090	303	97	22.3	37	40.0	5.27	54908	.12
	DERBY CITY	45955	304	97	16.1	37	32.3	5.27	44198	.12
	GODDARD	43911	305	97	34.3	37	40.0	5.27	42233	.12
	NE SEDG. CO.	18498	306	97	15.0	37	52.1	5.27	17791	.12
	NW SEDG. CO.	27916	307	97	32.3	37	49.3	5.27	26849	.12
TOTAL		462046							410744	

Sources:

Column 1: Bureau of the Census, <u>1980 Census of Population, Characteristics of the Population of Inhabitants, Kansas</u>, U.S. Department of Commerce, PC80-1-A18, Washington: Government Printing Office, 1981, pp. 18-16 - 18-21; and, Bureau of the Census, <u>1980 Census of Population and Housing, Census Tracts, Wichita, Kans.</u>, U.S. Department of Commerce, PHC-2-371, Washington: Government Printing Office, 1983, pp. P-3 - P-13.

wastes are collected by private operators. Discussions with various officials indicated that there is a very competitive market among the private collectors. An attempt was made to contact the largest hauler of wastes in Wichita, Browning-Ferris Industries (BFI). They did not respond to information requests. No other private collectors were contacted. There are no public collection systems in the study-region.

The Sedgwick report identified a cost of $2.00/ton per mile as representative of the costs of collection in Sedgwick County. This number is assumed to reflect the entire region. Haul-costs per ton minute of operation based on the reported figure were calculated for each county (Appendix A). The haul-cost for Reno County is .10 cents/ton minute. Haul-costs for Harvey and Sedgwick County are .12 cents/ton minute. Previous applications of WRAP reported haul-costs ranging from .09 cents to .13 cents/per ton minute. Haul-costs are shown in Table 4.1.

Transfer station haul costs are not available. Haul-costs for transfer stations will be taken from a previous application of WRAP in the Chicago area. Appendix A contains calculations and assumptions.

Existing and Potential Site Data

WRAP requires data on existing landfill site in terms of the land available in acre-feet, (Appendix B). This is calculated by multiplying the number of available surface acres times the average depth of a cell, and includes the cover soil as part of that depth. The model assumes that the average density of a cubic yard of wastes, when compacted, is 750 lbs./cubic yard. From this and the acre-feet available, the life expectancy of the landfill can be determined.

There are three area type landfills in the region. The Reno County landfill is located southwest of Hutchinson and is operated by the county. It is expected to closeout in early 1987. The new landfill will be located adjacent to the current site. As of the base year of this report, approximately 22 surface acres were remaining. The new site will have 48 acres. The operators of the landfill reported cell depths of 28 feet for the existing landfill and 32 feet for the proposed site.

Harvey County's landfill is also operated by the county and is located southwest of Newton. As of 1982, there were approximately 53 acres of surface acres at the landfill and 20 foot cell depths were reported.

The Brooks Tract serves Sedgwick County and Wichita. It is directed by the city, operated by a private contractor and located in the county, northwest of the city. There were approximately 200 surface acres remaining in 1982. The Landfill Director reported a cell depth of 70 feet.

In addition to the proposed Reno landfill that would be opened in 1987, a fifth new area landfill was selected to be located in north Sedgwick County, north of Wichita and adjacent to I-35. This landfill was added to the data base to give the model more choices. This site was selected based on a comparative analysis of geologic, groundwater, floodplain and other siting criteria. The analysis was conducted by the task force that prepared the Sedgwick report.

Site identification numbers, site names, longitude and latitude coordinates, acre-feet available and other data on the landfills are in Table 4.2.

Process Costs and Site-Process Data

Process information consists of a series of sequential data entries that specify the level of

Table 4.2

Landfill Information

COUNTY	WRAP CODE	LONGITUDE (Deg)	LONGITUDE (Min) (1/10)	LATITUDE (Deg)	LATITUDE (Min) (1/10)	CAPACITY (acre-feet)
RENO	710	98	00.0	38	02.3	616
HARVEY	720	97	23.0	38	00.5	1060
SEDGWICK	730	97	23.1	37	45.4	14000
NEW RENO SITE	740	98	00.0	38	02.3	1536
N SEDG. CO.	750	97	19.3	37	50.3	5000

processing, output density of an A, B or C level process, input and output links of wastes and, most important, the capital and operating costs of the process.

Existing landfills reflect straight line operating costs. The cost to process a ton of wastes in the region is a function of the total receipts divided by the total number of tons that were entered into the landfill for a given year. The cost to process a ton of wastes varied greatly among the three counties. Sedgwick County reported a cost of $2.93 per ton, Harvey County reported $5.30 per ton and Reno County reported a high cost of $11.90 per ton.

A single (average) cost to process a ton of waste could have been entered and assumed to represent a regional processing cost. However, operating costs varied by as much as $9.00 per ton and are assumed to reflect operational efficiency and volume processed. Each landfills operating cost was entered separately to more accurately affect the objective value.

The proposed landfills are assumed to be operated in the same manner, in each respective county, as the existing landfills. No cost information for new landfills is available from the region. Data from a previous application will be used. These costs are represented by two linear segments and are illustrated in Figure 4.2, (Appendix C).

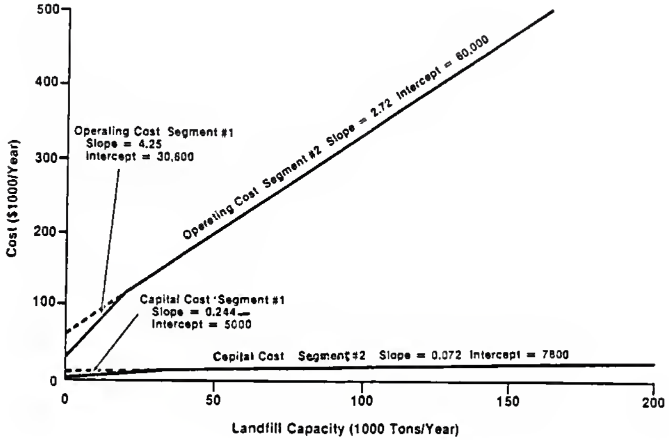

Figure 4.2

Landfill Costs

Source: James F. McAlister, Waste Resources Allocation Program (WRAP): Application in Northeast Illinois, (Durham: Duke University, 1980), p. 14.

Transfer station costs and related data are not available. Consequently, data will again be used from a previous application of WRAP. The two linear segments used to reflect capital and operating costs are illustrated in Figure 4.3, (Appendix D).

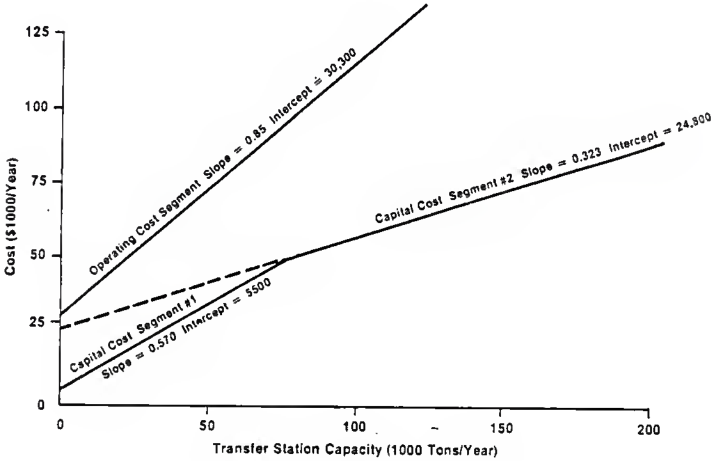

Figure 4.3

Transfer Station Costs

Source: James F. McAlister, <u>Waste Resources Allocation Program (WRAP): Application in Northeast Illinois</u>, (Durham: Duke University, 1980), p. 14.

Modular incinerator process costs and other data were reported in the PEDCo report and the financial analysis addendum to the Sedgwick County report. Sites were identified in each report.

The most likely candidates in Reno County were three salt companies that indicated an interest in the purchase of low pressure steam that would be used in their manufacturing processes. Incinerators would be sited on the salt company properties.

Morton Salt Company expressed the most interest of the three and will be used as a potential site in two model runs. The Carey and Cargill Salt Companies expressed a lesser interest and will be used in only one model run.

"High interest" markets were identified in Wichita as potential purchasers of low pressure steam. Users were not specified by name, but by location, Figure 4.4. Five "high interest" sites were arbitrarily chosen from various geographic locations around the city.

The Sedgwick report stated that 700-900 TPD of processed wastes would be an "economically viable" alternative. Modular incinerators with a capacity to process 200 TPD and operating 260 days per year were chosen as representative process sizes. The facilities

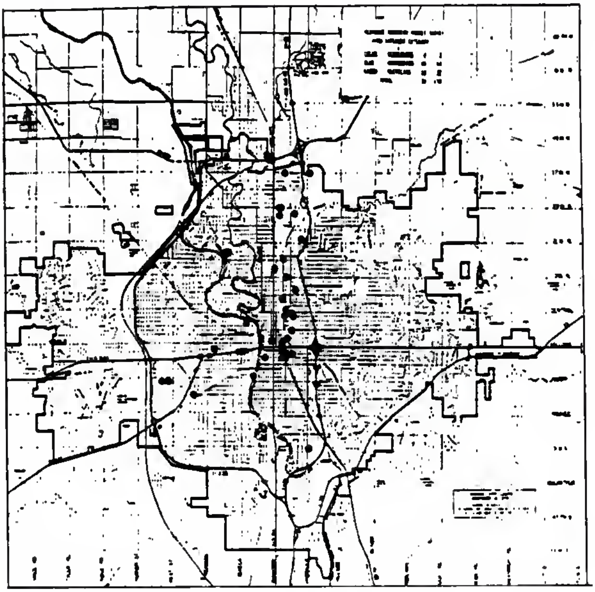

Figure 4.4

High Interest Markets in Wichita

Source: Sedgwick County Department of Environmental Resources, Sedgwick County, Kansas Resource Recovery Feasibility Report, 1982, (Wichita: Department of Environmental Resources, 1982), p. 4-31.

are assumed to operate at capacity and process 52,000 tons per year. Revenues generated from the sale of steam are estimated at $2,457,000 per year, per incinerator. Capital and operating costs differed between the privately and publicly financed facilities.

The cost to process a ton of waste at a privately financed facility is estimated to cost $8.32 per ton. The process cost at a publicly financed facility is estimated at $14.83 per ton, (Appendix E).

Other Data

Transportation related data consists of one-way time and distance values from sources to existing landfills. A road map and an estimated speed of 30 mph for the entire region were used in calculating those values.

CROW-FLY is a subroutine of the program that will create, at the user's option, optimum origin-destination pairs. Option 0 tells the program to expect user generated data and does not effect the solution. Option 1 generates up to ten origin-destination pairs and requires some of the transportation data specified above. Option 2 will generate all origin-destination pairs. Both Option 1 and 2 will generate one-way distance and time values. An estimated speed of 30 mph was used. A maximum radius of the region is also user supplied. The radius of the study region is forty two miles. A larger value of one hundred miles was used to insure that any origin-destination pair exceeding that forty two mile radius value would not be exceeded.

The last data requirement for the CROW-FLY is the length of a longitudinal minute based from the center of the region. The longitudinal center of the region was found to be 37°45'00". This was converted to a decimal equivalent and the cosine of that value equalled .79 which was input as required by the CROW-FLY option.

Dummy Process

WRAP permits the user the option of entering a dummy or non-existent process. The purpose of this process is to differentiate land impact with or without differentiating costs. In terms of cost, the model will split any saleable waste and non-saleable waste and indicate the revenue that could be generated from a site if a revenue generating process were to be collocated at that site.

A dummy transfer station was used in a majority of the runs. The process had an output of one hundred percent. All wastes are assumed to be non-saleable. The purpose of the dummy transfer station was to control land impact at landfills in terms of the amounts of non-saleable waste that each landfill would receive when either CROW-FLY option 1 or 2 were implemented and origin-destination pairs were generated.

Chapter Five

RESULTS AND ANALYSIS OF WRAP OUTPUT

The PEDCo and Sedgwick reports suggested the following solid waste management alternatives:

1. landfilling, as is;
2. landfilling with transfer stations; and,
3. landfilling with modular incineration.

Based on these strategies, a model period of ten years was applied with an assumed starting date of January, 1982 and an ending date of December, 1992. Nine total model runs were performed to evaluate the following eight situations:

1. present landfill situation;
2. two simulated model runs of the present situation;
3. an optimal landfill run;
4. addition of two new landfills in the region;
5. use of a transfer station with existing landfills;
6. a modular incinerator run with four sites using private financing costs;
7. a modular incineration run with four sites using financing; and,

8. a modular incineration run that would process all wastes in the region (eight sites) using private financing.

A map of sources, processes and links is provided with each run. Computer inputs and outputs, data bases and the job control language file (JCL) are contained in Appendix F.

Computer outputs consist of information presented in a readable format. The matrix size of the model and the number of elements in the matrix are presented. The objective value, total tonnage processed in the region and the average system cost to process one ton of wastes are shown. Transportation links between source to various process levels to landfills are a part of the report output. Processing activity levels, in thousands of tons per year, are also presented in the printouts.

In terms of computation time, CPU times varied from 2.39 seconds of execution time for the first simulated present situation run to 3 minutes 46.40 seconds for the eight site modular incineration run.

<u>Present Situation - Existing Landfill</u>

The present situation run applied the ten year model period to the existing landfill conditions.

Wastes were transported from each source to the respective county landfill. No feasible solution was found by the model. The run was aborted before an objective value could be calculated. Table 5.1 helps explain why this happened.

Table 5.1

Landfill Capacities

COUNTY	TTY	TT-10YRS	A-FT	ASSUMED CAPACITY
RENO	41.508	415.080	616	372.680
HARVEY	16.716	167.160	1.060	641.300
SEDGWICK	352.520	3525.200	14.000	8470.000

TTY - thousands of tons per year
TT-10YRS. - total tons processed in model period
A-FT - acre-feet available
ASSUMED CAPACITY - in tons (605tons/acre-feet x a-ft available)

Built into the model is an assumption that the density of solid waste in a landfill is 750 lbs./cubic yard. Based on this assumption, one acre-foot of landfilled solid waste is 605 tons (Appendix B). The run aborted because the amount of waste generated in the model period exceeded the capacity of the Reno County landfill to handle that excess solid waste. To adjust for this a simulation of the existing situation was developed.

Simulation of Present Situation - Existing Landfill

The model period was adjusted from the ten year model period to a one year period which forced the model to handle all the wastes in a simulated ten year model period. This approach is based on a similar one used by McAlister in an application of WRAP in the Chicago area.[41] Table 5.2 is an analysis of the two model runs.

Table 5.2

Simulation of Present Situation Summary

COUNTY	TTY	A-FT USED	TTY	A-FT USED	CAPACITY
(Run1	1/82 - 12/91)		(Run2	1/92 - 12/92)	
RENO	41.40	609	LANDFILL CLOSED		616
HARVEY	16.70	28	16.7	28	1060
SEDG.	352.39	5825	393.8	6509	14000

TTY - thousands of tons per year
A-FT USED - acre-feet used in model run
CAPACITY - ultimate capacity of the landfill

At the end of the approximately nine years the Reno County landfill would be at capacity, (609 acre-feet used out of 616 available). The number of acre-feet used is equal to approximately eighty nine percent of the available capacity. Hence, it is equivalent to

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[41] McAlister, James Frank, Waste Resources Allocation Program (WRAP), Application in Northeast Illinois, (Washington: Government Printing Office, 1980), pp. 61-63.

approximately eight years and eleven months. Table 5.2 indicates that 7 acre-feet would remain at the end of the first model run. This remainder of the landfill capacity would be filled within one month which equals nine years for the first run.

Total system cost to handle the waste was $3.5 million per year. Total waste handled is 410 thousand tons per year, at an average cost of $8.48 per ton.

In the second of the simulation runs, CROW-FLY option 1 was used to allow the model to select origin-destination pairs which would accommodate the waste no longer being directed to the Reno landfill. The Brooks Tract received the additional waste. Sources in Harvey County continued to serve only that landfill.

Total system cost for the second simulation run was $3.05 million per year. Again, 410 thousand tons of waste were handled, at an average system cost of $7.42 per ton. Waste flows for both simulation model runs are illustrated in Figure 5.1.

Based on the two runs a system cost equivalent to the ten year model period was calculated. Table 5.3 shows that a present situation cost of $8.37 is the average cost to process a ton of wastes for the two simulation runs.

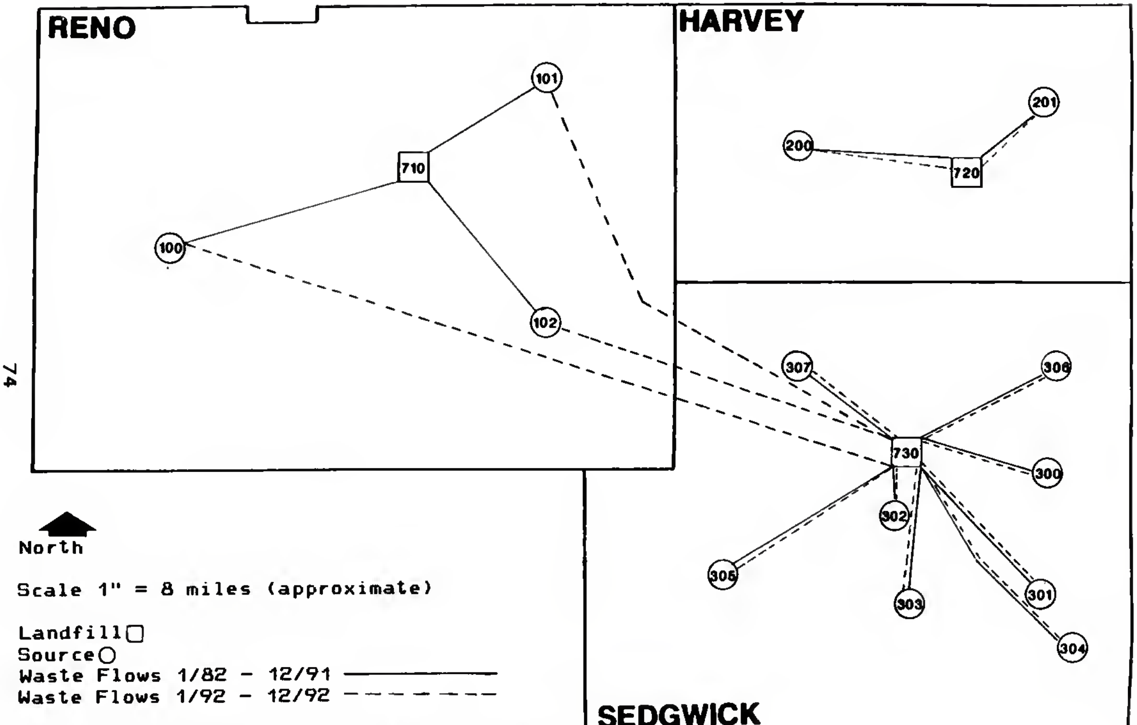


Figure 5.1 Simulation of Present Situation

Table 5.3

Summary of Simulation of Present Situation Costs

MODEL RUN	AVERAGE COST PER TON		PERCENT		COST
Run2	$8.48	x	.90	=	$7.63
Run3	$7.42	x	.10	=	$ .74
PRESENT SITUATION COST					$8.37

The $8.37 cost is assumed to represent the most probable set of circumstances regarding landfilling over the ten year model period. This figure will be used as a basis against which all remaining model runs will be compared.

Optimal Landfilling

In the fourth model run, an optimal landfill situation was considered. The model was forced to look at the entire ten year period; however, CROW-FLY Option 2 was used to allow the model to select all origin-destination pairs. Waste flows are illustrated in Figure 5.2.

As in the simulation runs, 410 thousand tons of waste are handled by the system per year. The flow of wastes in this run indicates that a part of the southeast source in Reno County would be served by the Brooks Tract and the remainder, 31 tons per year, would

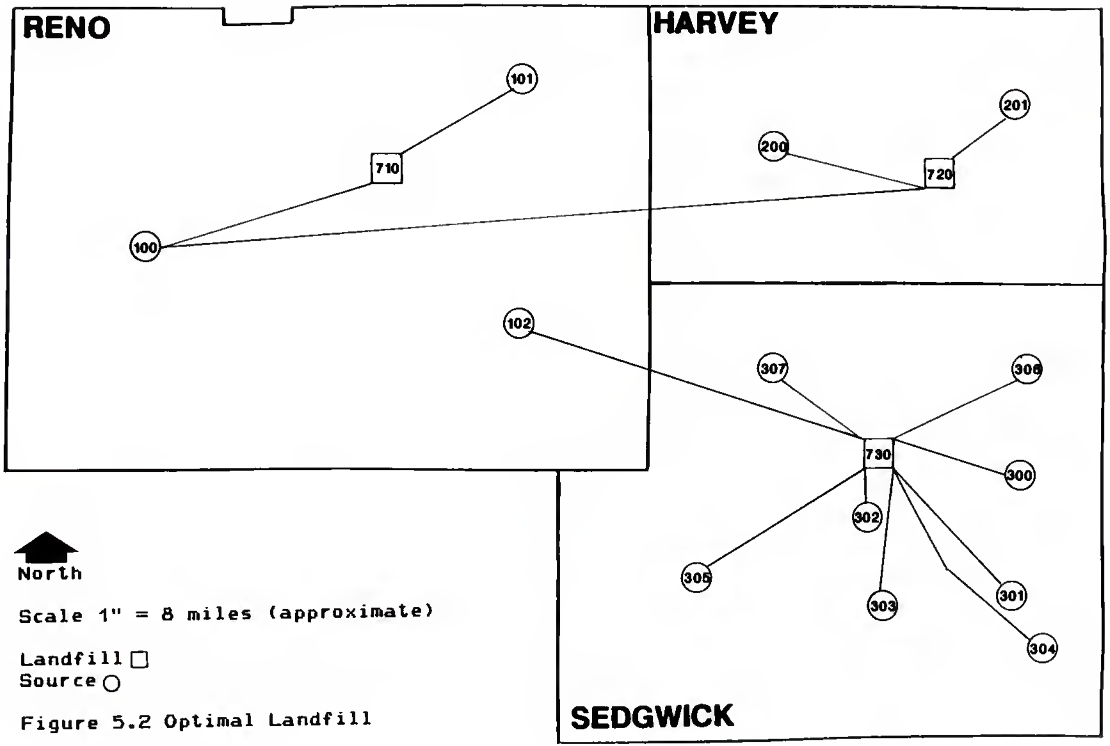


Figure 5.2 Optimal Landfill

go to the Harvey County landfill. The remainder of the sources continued to direct their wastes to their respective landfills.

The total yearly cost is approximately $2.98 million with an average system cost of $7.26 per ton. This is a savings of $1.11 per ton over the Present Situation cost of $8.37. Since 410 thousand tons are processed per year, the $1.11 savings equals a $455,100 total savings over the Present Situation.

New Landfill

Reno County officials indicated a new landfill would be opened in early 1987 at a site adjacent to the existing landfill. This landfill and a second landfill located in north Sedgwick County were proposed. The latter landfill was added to give the model more choices between existing and proposed sites. The model selected the collocated Reno site, but did not choose to send any wastes to the other site. Waste flows are shown in Figure 5.3.

Again, 410 thousand tons per year of waste were handled at a total yearly cost of $2.70 million. The average system cost was $6.56 per ton. This is a substantial savings over the Optimal Situation and the

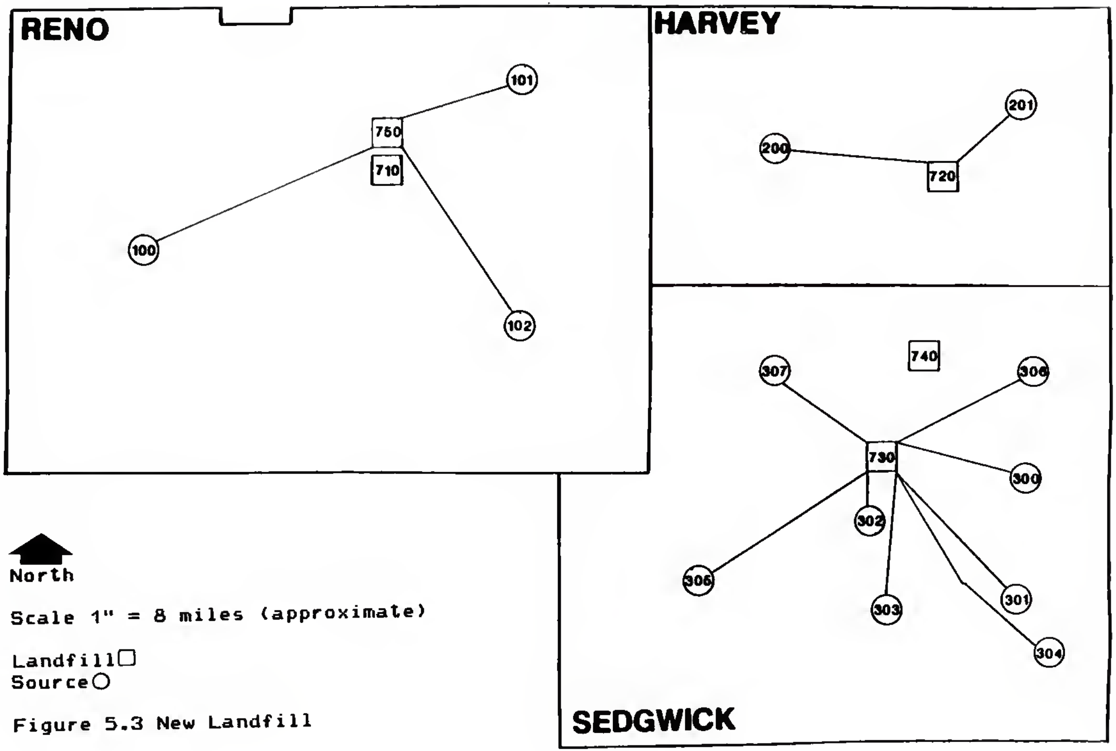


Figure 5.3 New Landfill

Present Situation. A savings of $1.81 over the Present Situation is equal to a yearly savings of $742,100. Cost savings are most likely due to the economies of scale the collocated site offered over the existing landfill.

Transfer Station

A potential site for a transfer station was chosen for southeast Reno County. The site was located in Haven and is along a major trafficway, US 96, between Hutchinson and Wichita. The economies of scale this site offered must account in large part for the solution the model recommended. The Reno County landfill was recommended to be closed and all Reno County sources would transfer their wastes to the Brooks Tract. The waste flows are illustrated in Figure 5.4. The transfer station would handle 41.4 thousand tons of waste per year.

Yearly costs for this run were $2.94 million and average system costs were $7.16 per ton. This is equivalent to a $496,000 savings over the Present Situation runs. More transfer stations sites in the region might have allowed the model to seek a lower cost solution.

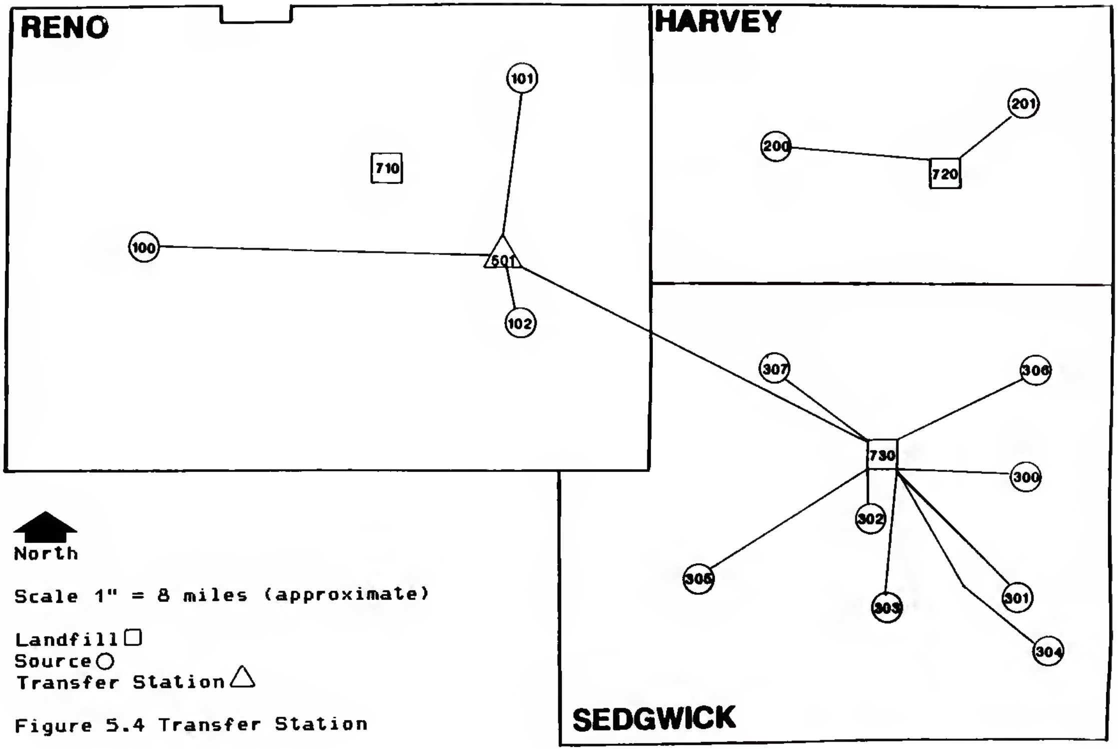


Figure 5.4 Transfer Station

Modular Incinerators

Three modular incinerator runs were conducted. In two of the runs, four sites were selected with three in north, southeast and central Wichita, and one site in Hutchinson. The cost to process a ton of waste based on either private or public funding schemes differentiated the first two runs. The last run used private financing costs to evaluate an approach that sited eight modular incinerators throughout the region. Three sites, all salt companies, were located in Hutchinson and the remaining five were in various parts of Wichita based on those indicated on the "high interest" map previously discussed.

Unlike the previous runs in which two linear segments were used to allow the model to seek a least cost solution for a given tonnage, only one segment was used in these three runs.

The private financing run had an input cost per ton to process of $8.32. None of the Wichita sites were selected and all wastes in Wichita and Harvey County were landfilled. The model did select the modular incinerator in Hutchinson. Waste flows are illustrated in Figure 5.5.

The yearly cost of this run was $2.94 million

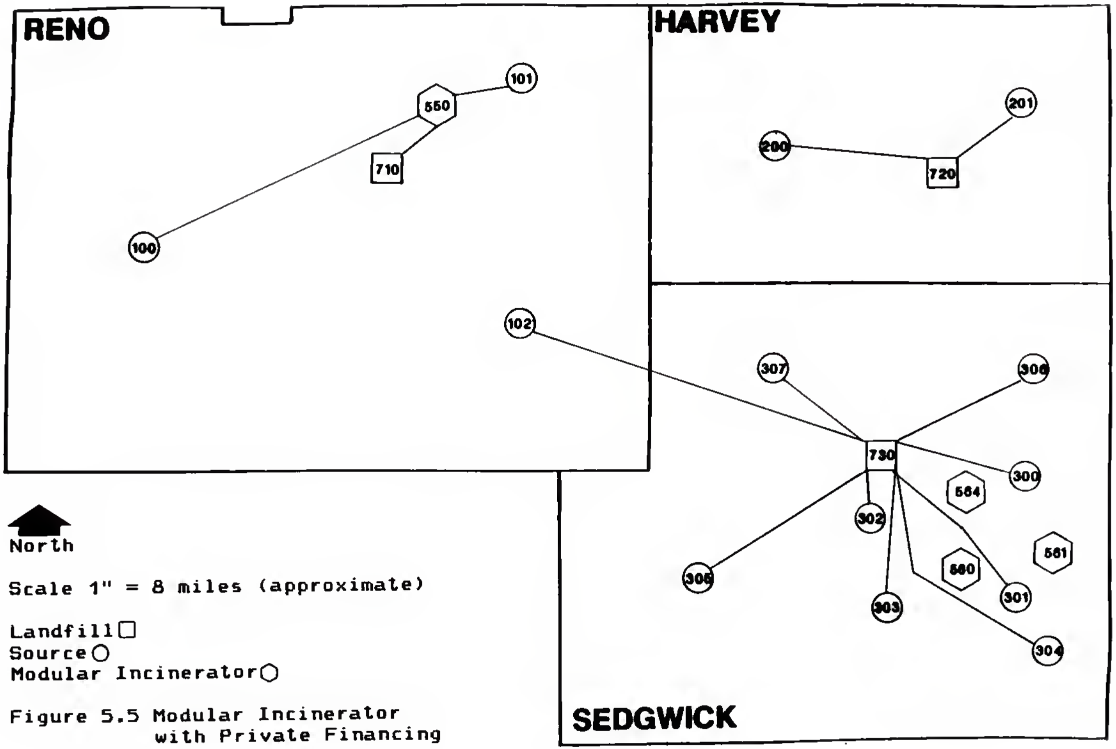
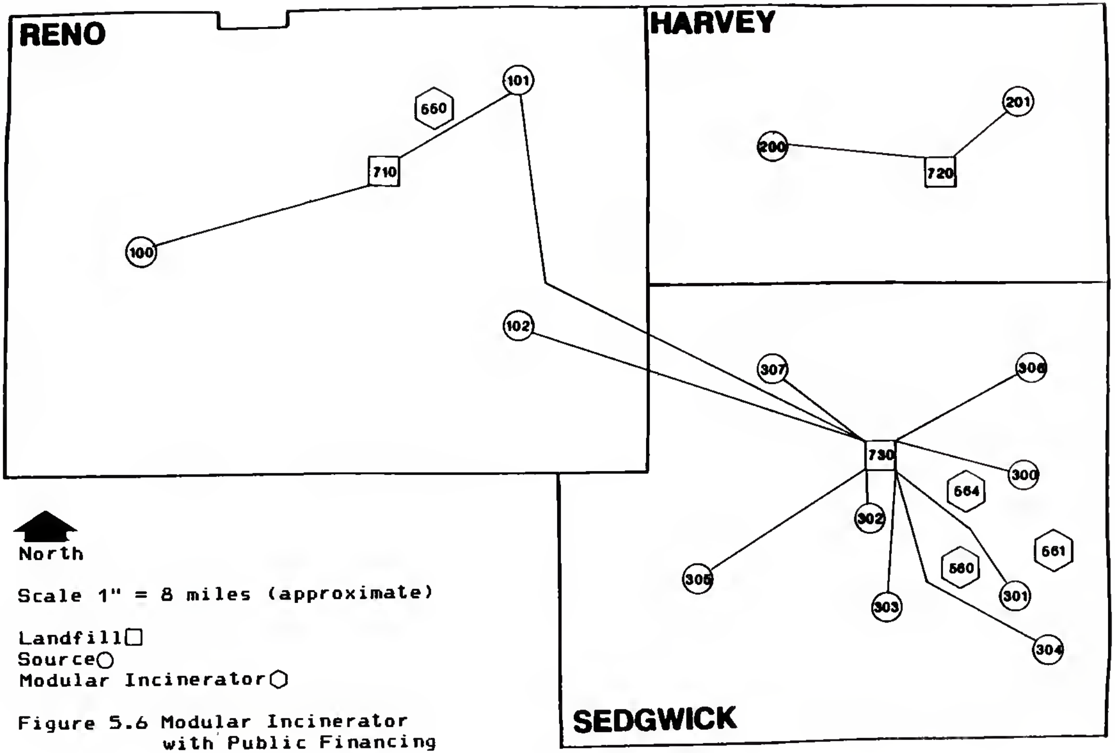


Figure 5.5 Modular Incinerator
with Private Financing

and the average system cost was $7.15 per ton. This is a savings of $500,200 over the Present Situation. The solution to this run could have been anticipated since the cost to process a ton of waste in the incinerator was $8.32 versus a landfill cost of $11.90 per ton. This same idea is applicable as to why the model did not choose a site in Wichita. The Brooks Tract processes waste at $2.93 per ton. This is significantly lower than the incinerator costs. The model selected the lowest cost solution by only having to balance lesser or greater costs.

The modular incinerator processed all of the Hutchinson City source wastes, 31.9 thousand tons per year. The remaining Reno wastes were landfilled. Of the 31.9 thousand tons processed, that which was reduced to ash, 10.53 thousand tons was landfilled at the Reno landfill. The cumulative effect would be the extension of the landfills life expectancy, in addition to the cost savings already mentioned.

The public financing run used a cost of $14.83 to process a ton of waste. No modular incinerators were recommended by the model. Waste flows are illustrated in Figure 5.6. Two of the Reno County sources were, however, directed to the Brooks Tract.



North

Scale 1" = 8 miles (approximate)

Landfill □
Source ○
Modular Incinerator ⬡

Figure 5.6 Modular Incinerator with Public Financing

Overall costs were higher than in the private financing case. This alternative would cost $2.99 million per year and average $7.25 per ton. It is a savings over the Present Situation of $459,200, but does not reflect the alternative posed.

In the final run, the model was forced to route all source wastes to eight modular incinerators. Waste flows are illustrated in Figure 5.7.

Sources in Wichita split their wastes between the five incinerators. The only source outside the city to route its waste to an incinerator was the Derby City source. All other sources outside Wichita sent their wastes to Hutchinson for processing.

The wastes produced by the five sites were sent to the Brooks Tract. In previous runs the Brooks Tract had handled 352 thousand tons per year of unprocessed wastes. This amount was reduced to 42.9 tons per year after processing.

The Harvey County sources routed all wastes to Hutchinson. The model recommended the Harvey landfill be closed.

The three Hutchinson sites processed 150 thousand tons of waste per year, of which 24.8 thousand were ultimately landfilled after processing.

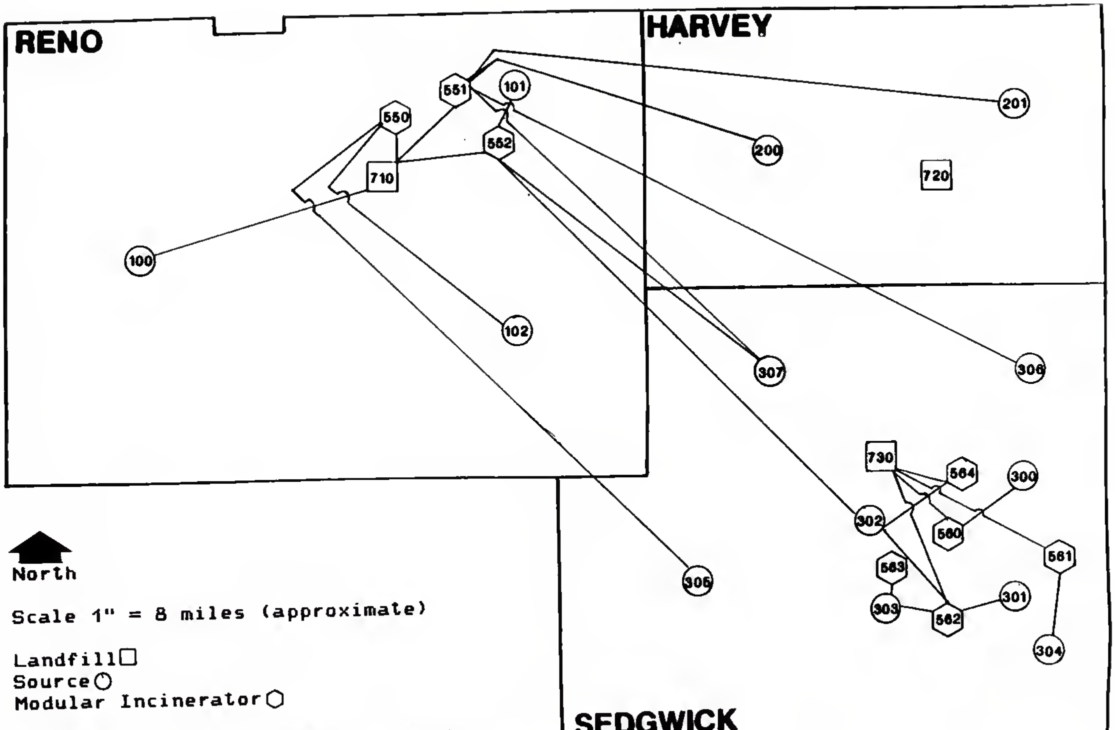


Figure 5.7 Eight Modular Incinerators

The total system cost was $6.4 million per year and the average cost jumped to $15.57 per ton. This is a $7.20 per ton increase over the Present Situation.

In this instance, the total annual revenues from the sale of steam would be $19.7 million per year.

Only by forcing the model to process all the wastes could a site in Wichita be selected. Again, it is the extremely low cost of landfilling that causes this.

Summary of Model Runs

The seven alternatives presented in the previous model runs are summarized in Figure 5.8. They are ranked in increasing cost form left to right. The least cost solution is represented by the new landfill alternative in which a collocated landfill for Reno County was suggested. The private financing modular incineration alternative and the existing landfills supported by a transfer station were almost identical in terms of costs. The public financing modular incineration alternative is actually a landfill solution and is equivalent in cost to the optimum landfill alternative.

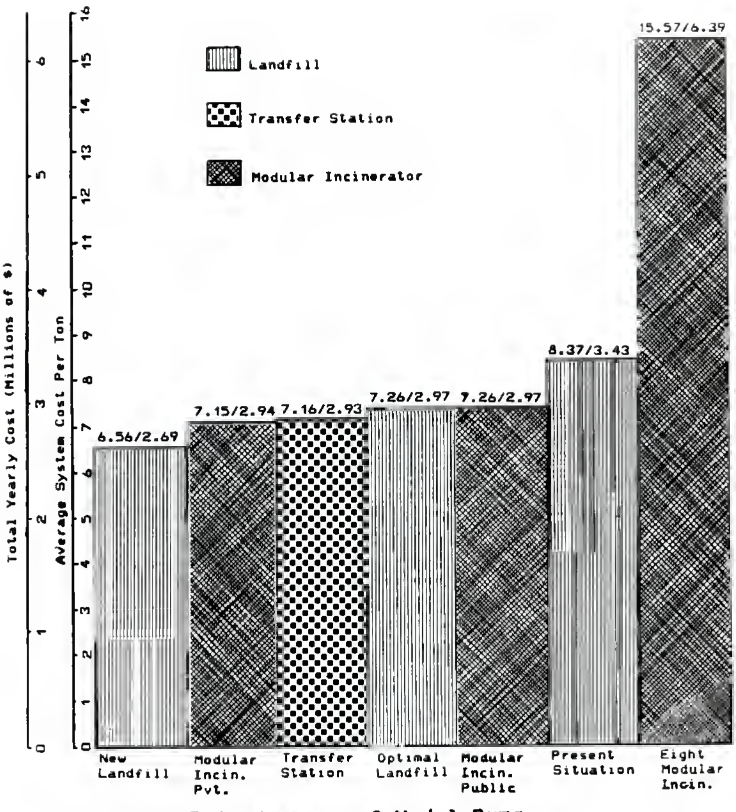


Figure 5.8 Summary of Model Runs

The addition of a new landfill should save the region $750,000 a year, if it were implemented. Rerouting vehicles in the optimum landfill alternative would save the region $460,000 per year.

The private financing of a modular incinerator would have a total debt service of $29,465,650 over a twenty year period. Initial installation costs would be $6,811,000, and yet cost the region $500,000 less in processing costs than the Present Situation.

The siting of eight incinerators would process all of the region's waste, but is not a realistic solution. The installation costs, excluding any land or site preparation, would be $54.5 million. Additionally, the model was forced to choose this alternative and would not have selected this solution if less than eight sites had been selected.

Chapter Six

SUMMARY AND CONCLUSIONS

Summary

The Waste Resources Allocation Program (WRAP) is a powerful tool for determining alternative resource recovery plans for a region. The program was written to achieve economies of scale through the centralization of processing at a location balanced against the increasing costs of transportation to that process.

The purpose of the report was to evaluate and implement the WRAP model as a city planner's tool and prepare a set of regional alternative resource recovery plans that addressed political and technical issues for the municipal solid waste branch of the total solid waste management system. A region was chosen based on the findings in two reports: the Sedgwick County, Kansas Resource Recovery Feasibility Study, 1982 and the PEDCo Environmental report Technical Assistance to Reno County, Kansas. Both of these reports considered resource recovery as an alternative to landfilling.

The model was used to analyze the existing landfill conditions and a series of alternatives that would be increasingly more complex in terms of both political and technical issues. The model results of each alternative were discussed and illustrated with a map that showed waste flows recommended by the model. A final comparison of the alternatives was discussed that would be a starting basis from which political decision makers could make more informed choices.

Conclusions

1. The WRAP model recommended that a collocated landfill in Reno County, adjacent to the existing landfill, would be the least cost approach to handling solid waste in the region.
2. The addition of a transfer station in Reno County would close that county's landfill and reduce the region's overall cost to process solid waste.
3. A 200 TPD modular incinerator could be sited in Reno County in Hutchinson and revenue would be derived from the sale of low pressure steam to a salt company.
4. The scope of the report implied that solid waste data needed to implement the program is derived from very specific records on existing conditions. In reality, much of the data needed to effectively use the

WRAP model in determining an alternative plan, based on centralization of processing, is derived from data prepared in previous applications of the model.

5. The calculation of piecewise linear approximations of a total cost curve allows the user to input two or more linear segments. Two or more segments gives the model the necessary information to recommend a site based on economies of scale. Calculation of the linear segments requires an expert.

6. Sensitivity analysis can be conducted with the WRAP model. For example, if the expected costs of fuel were forecasted to double within four years of the initial date of the planning model period, that rise in cost could be calculated for a new haul cost per ton minute of operation. For the given model period or periods, depending on which mode is used, the change in the total system cost and average cost to process a ton of waste should reflect the change of the new haul cost. If the user is in the static mode, the increased haul cost will be assumed to be a constant over the entire model period. However, in the dynamic mode, haul costs can be entered for a portion of the entire model period, for up to four periods of the total model period. The forecasted increase in haul costs could be handled more effectively in the dynamic mode than in

the static mode. In terms of sensitivity analysis, the dynamic mode offers more opportunity to test for changes in all aspects of the data set.

7. The model is a powerful planning tool. Use of the program is currently dependent on access to a mainframe computer. City Planners may, however, be able to apply the model in a microcomputer environment.

As configured, the model requires 270K bytes of storage space to accommodate a 90 x 360 matrix. Overlay structures are available which will reduce the amount of storage requirements. If the overlays are not used, the storage requirements increase by 100K bytes.

In the program runs for this report, 1024K bytes of memory storage was set aside; however, in one of the longer model runs only 398K bytes of memory was used. CPU execution time for that run was 4 min. 53.63 sec.. A microcomputer with 1M byte or more of RAM may be a feasible approach for handling the WRAP model.

A microcomputer user would also have to have access to a FORTRAN IV compiler or be able to rewrite program lines for another FORTRAN compiler. This may be a formidable task since there are 7000 source code lines in the program. For further information, the reader should consult the WRAP Programmer's Guide.

8. The WRAP model has been applied primarily in an urban environment and only on a limited basis. EPA demonstration projects in St. Louis, Massachusetts and an application run in Chicago are accounted for through government document sources. A source separation scenario for the model was developed in a thesis. One other application was reported in an engineering journal. No other indication of the use of the model was found by the writer.

The model apppears to have been conceived for a densely populated urban setting faced with the impending closure of its landfill or landfills. The price of land would be expected to be costly with the only available and affordable land some distance from the urban area. This leads to expected high transportation costs and higher collection fees to cover those costs. The model is useful for a political decision making body seeking to achieve economies of scale, through implementation of a centralized regional resource recovery facility, which might be offset by increasing transportation costs to that facility. There is no assumption that there is a solid waste authority to implement the alternative, which a regional application may imply.

Based on the above idea, a limitation of the model seems to be its express orientation towards a publicly owned collection system. Since each model run recommends a set of source to process transportation links and activity levels of wastes that should be hauled to meet the objective value, any system other than a publicly owned one would be very difficult to manage and coordinate. This could be further complicated if ownership of the wastes is vested, in any way, to a private collector who could disrupt the required flow of wastes to a recovery process. Such is the case in Kansas and would probably hinder the implementation of any regional alternative.

A limitation on the implementation of an alternative recommended by the model is that an authority to manage the waste system, backed by state enabling legislation to direct the system, irregardless of jurisdictional boundaries, is necessary to successfully implement an alternative recommended by the model. Kansas law permits cities and counties, or combinations of either, to collectively landfill solid wastes. However, one of the criteria for acceptance of a multiple jurisdiction approach, is based on an assessment of geographic and demographic differences. The three counties in this report are distinctly different enough that a regional approach would probably not be accepted based on demographics alone.

Also, in Wichita, there is a strong correlation between the acknowledgement of landfilling as an acceptable alternative for handling solid wastes, as long as those landfills are far enough away from those acknowledging landfills as acceptable. This same relationship could be applied to a resource recovery plant and the nuisances it would create, and the distance it should be located from those that agree in principle to its use. Consequently, it is unlikely that solid wastes from another county or city would be accepted in another jurisdiction, unless there was a regional authority to require the shipment of the wastes, or with some the explicit appproval of the voters.

A further limitation on the implementation of the model is the unstated assumption that there is an adequate population, hence waste generation, base. Although no reported application of the model has been reported using a dispersed rural population as a basis for model runs, it is unlikely that the model could be effectively applied in that situation. The increasing costs of transportation for small quantities of wastes would outweigh any economies of scale that might be achieved from a centralized plant serving a dispersed population. Only through application of the model could this assumption be tested.

9. The model demands an accurate data set. The output of the model is no stronger than the assumptions of that data set.

To accurately calculate the per capita wastes generated in a region, the total amount of wastes hauled to a landfill must be known. Using national averages disregards the uniqueness of the consumer's behavior in that region. The only way to determine the amounts entering a landfill is to set up a weigh station and take daily measurements. This process would have to continue for at least one year, since seasonal fluctuations would also need to be known. Daily waste requirements of a resource recovery plant could not be expected to compensate for unanticipated seasonal fluctuations in the waste stream.

Other demands of the data set that need to be known are the operating and capital costs of existing or proposed facilities, and haul costs of public and/or private haulers. Public and private entities may use a variety of accounting procedures. For an accurate solution to the objective value, a standardized accounting procedure would have to be set up to correlate the various approaches to measuring costs. In addition, private entities may be very reluctant to disclose cost information if there is a competitive market in the target area. These same entities may also not have established cost accounting procedures which would further complicate obtaining an accurate data set.

In terms of using generalized data from previous applications of the model, the original compilation of that data was based in part or whole on EPA grants which were a result of objectives set out in the 1976 Resource Conservation and Recovery Act. Policy changes have shifted solid waste objectives to hazardous wastes and more recently to Superfund activity. Funding for the collection of data on processes and waste generation activity around the country appears to have ended in the late 1970's. Consequently, sources for current information on solid waste activities are limited, if at all available, from government sources that collected that type of information when funds were available. In conclusion, a city planner can expect to spend a considerable amount of time and money developing a data set for the WRAP model.

Appendix A

Haul Cost Calculations

Collection Vehicles

Assumptions: $2.00/Mile
20 cubic yard capacity
Average load 5 tons
Average speed over entire region 30mph

Average distance to landfill in Reno Co.	12 miles
Average distance to landfill in Harvey Co.	13 miles
Average distance to landfill in Sedgwick Co.	13 miles

Roundtrip time to Reno Co. landfill	24 min.
Roundtrip time to Harvey Co. landfill	30 min.
Roundtrip tiime to Sedgwick Co. landfill	30 min.

$2.00/mile x .30 min/hr. = .60 cents/ton-minute / 5 tons = .12/ton-minute

$2.00/mile x .24 min/hr. = .48 cents/ton-minute / 5 tons = .10/ton-minute

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Transfer vehicles

Assumptions: 70 cubic yard capacity
19 ton load
Haul cost $1.77/ton/hour
.03/ton/minute

Source: James McAlister, <u>Waste Resources Allocation Program (WRAP): Application in Northeast Illinois</u>, (Durham: Duke University, 1980), p.57.

Appendix B

Landfill Cost Calculations

Abbreviations: cy = cubic yards
sf = square feet
cf = cubic feet
lb = pound
a = acre

Assumptions: Landfill density = 750lbs/cy

Volume: 1 acre-foot of landfill =

(1 foot deep) x (43560sf/acre) x (1cy/27cf) = 1613 cy

Weight: 1 acre-foot of landfill =

750lbs/cy x 1613cy/acre-foot x 1 ton/2000lbs = 605 tons

Source: James McAlister, Waste Resources Allocation Program (WRAP): Application in Northeast Illinois, (Durham: Duke University, 1980), p.61.

Reno Co. landfill	22 a. x 28ft = 616 acre-feet
Harvey Co. landfill	48 a. x 32ft = 1060 acre-feet
Sedgwick Co. landfill	200 a. x 70ft = 1400 acre-feet

Appendix C

Landfill Process Costs

New Landfill Cost

Assumptions: 10 year facility life
land costs not included
8% amortization

Table C.1

Landfill Costs for Five Facility Sizes
(In 1977 dollars per year)

Capacity (tons/year)	Capital Costs	Operating Costs
3,250	3,360	30,650
6,500	4,780	40,180
19,500	7,720	118,780
65,000	13,000	216,300
260,000	27,090	768,130

First Linear Approximation:
Capital slope = \$0.244/ton
Capital intercept = \$5000/year
Operating slope = \$4.25/ton
Operating intercept = \$30,625/year

Second Linear Approximation
Capital slope = \$0.0723/ton
Capital intercept = \$7800/year
Operating slope = \$2.72/ton
Operating intercept = \$60,000/year

Source: James McAlister, Waste Resources Allocation Program (WRAP): Application in Northeast Illinois, (Durham: Duke University, 1980), p.52.

Appendix D

Transfer Station Process Costs

Transfer Station Cost

Assumptions: 15 year building life
10 year equipment life
8 % amortization
Operate 260 days/year, 8 hours/day

Table D.1

Transfer Station Costs for Six Facility Sizes
(In 1977 dollars per year)

Capacity (tons/year)	Capital Costs	Operating Costs
13,000	5,510	52,400
26,000	14,676	52,400
52,000	26,500	74,000
78,000	50,000	96,600
104,000	56,672	119,200
130,000	66,777	140,800

First Linear Approximation:
Capital slope = $0.57/ton
Capital intercept = $5,500/year
Operating slope = $0.85/ton
Operating intercept = $30,300/year

Second Linear Approximation:
Capital slope = $0.323/ton
Capital intercept = $24,800/year
Operating slope = $0.85/ton
Operating intercept = $30,300/year

Source: James McAlister, Waste Resources Allocation Program (WRAP): Application in Northeast Illinois, (Durham: Duke University, 1980), p.52.

Appendix E

Modular Incineration Process Costs

Assumptions: 200 TPD Capacity
52,000 Tons/Year
Operate 5 days/week 52 weeks/year
20 year bonds
13% interest
$6,811,000 installation cost
$29,465,650 total debt service
Private funding: irb, leverage leasing

Average annual revenue	=	$2,457,000
Average annual operating cost	=	$ 615,302
Average annual capital cost	=	$1,408,975
Average annual net revenue	=	$ 432,723
$432,723/52000 tons/year	=	$8.32/ton

Assumptions: Same As Above Except:
15 Year bonds
10% interest
$16,055,500 total debt service
G.O. Bond Debt

Average annual revenue	=	$2,457,000
Average annual operating cost	=	$ 615,302
Average annual capital cost	=	$1,070,367
Average annual net revenue	=	$ 771,331
$771,331/52000 tons/year	=	$14.83/ton

Source: Sedgwick County Detailed Financial Analyses

Appendix F

Computer Runs

Figure F.1

Job Control Language

```
//WRAP     JOB (246880795,CAA7CYL2,,8,,1602),'ZILKIE STEVE',
//         TIME=(8,0)
/*SERVICE        STANOARD
/*REGION         1024K
//THEN    EXEC PGM=WRAP,REGION=1024K
//STEPLIB DD OSN=CSK48.LOAOLI82,DISP=SHR
//FT05F001 DD *
************************ INSERT DATA HERE ************************
//FTC6F001 OC SYSCUT=A
//FTC7F001 OC SYSOUT=B
//FT21F001 OO UNIT=SYSOA,SPACE=(80,(3)),OCB=(RECFM=FB,LRECL=80,
// BLKSIZE=80)
//FT22F001 CO UNIT=SYSOA,SPACE=(105,(100)),OCB=(RECFM=FB,LRECL=105,
// BLKSIZE=210C,BUFNC=1)
//FT23FOC1 OO UNIT=SYSDA,SPACE=(70,(50)),OCB=(RECFM=FE,LRECL=70,
// BLKSIZE=140C,BUFNO=1)
//FT24F001 OO UNIT=SYSOA,SPACE=(950,(2C)),CCB=(RECFM=FB,LRECL=950,
// BLKSIZE=9500,BUFNO=1)
//FT25F001 OO UNIT=SYSOA,SPACE=(50,(450)),DCB=(RECFM=FB,LRECL=50,
// BLKSIZE=1C0C,BUFNG=1)
//FT26F001 OD UNIT=SYSOA,SPACE=(50,(25)),OCB=(RECFM=FB,LRECL=50,
// BLKSIZE=1000,BUFNO=1)
//FT27F001 OO UNIT=SYSOA,SPACE=(80,(125)),OCB=(RECFM=FB,LRECL=80,
// BLKSIZE=1600,BUFNO=1)
//FT29F001 CO UNIT=SYSOA,SPACE=(L4C,(36C)),DCB=(RECFM=FB,LRECL=140,
// BLKSIZE=2800,BUFNO=1)
/*
```

Figure F.2

Source Data Input

CODE	NAME	LONGITUDE DEG	LONGITUDE MIN	LATITUDE DEG	LATITUDE MIN	THOS TONS/YEAR/PERIOD 1	2	3	4	HAUL COST $/TON-MIN/PERIOD 1	2	3	4
100	WEST RENO CO.	98	15.0	37	58.1	5.4	0.0	0.0	0.0	0.10000	0.0	0.0	0.0
101	HUTCHINSON CITY	97	55.0	38	2.3	31.9	0.0	0.0	0.0	0.10000	0.0	0.0	0.0
102	SE RENO CO.	97	46.5	37	54.1	4.1	0.0	0.0	0.0	0.10000	0.0	0.0	0.0
200	WEST HARVEY CO.	97	30.0	38	0.0	5.8	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
201	NEWTON/E. HARVEY	97	15.0	38	2.3	10.9	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
300	NE WICHITA CITY	97	17.3	37	42.3	58.7	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
301	SE WICHITA CITY	97	17.3	37	40.0	43.2	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
302	NW WICHITA CITY	97	22.3	37	42.3	64.6	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
303	SW WICHITA CITY	97	22.3	37	40.0	54.9	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
304	DERBY CITY	97	16.1	37	32.3	44.2	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
305	GODDARD CITY	97	34.3	37	40.0	42.2	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
306	NE SEDGWICK CO.	97	15.0	37	52.1	17.8	0.0	0.0	0.0	0.12000	0.0	0.0	0.0
307	NW SEDGWICK CO.	97	32.3	37	49.3	26.8	0.0	0.0	0.0	0.12000	0.0	0.0	0.0

Figure F.3

Process Data Input

```
                                         OUTPUT             HAUL COST $/TON-MIN/PERIOD        LEAD PERIODS       PROCESS  NO.
CODE            NAME          LEVEL EXIST % WGT  DENSITY      1          2          3        4  TIME AVAILABLE     LIFE     SEGS

 810 LANDFILL                     0     0   0.0           0  0.0       0.0       0.0       0.0       0 1 0 0 0       1 0 0 0     1
      INPUT LINKS POSSIBLE           2 890
COSTS: PERIOD/                    CAPITAL                                 OPERATING
          SEGMENT             SLOPE          INTERCEPT          SLOPE           INTERCEPT

          11                  0.0             0.0              11.900000          0.0
                                         OUTPUT             HAUL COST $/TON-MIN/PERIOD        LEAD PERIODS       PROCESS  NO.
CODE            NAME          LEVEL EXIST % WGT  DENSITY      1          2          3        4  TIME AVAILABLE     LIFE     SEGS

 820 LANDFILL                     0     0   0.0           0  0.0       0.0       0.0       0.0       0 1 0 0 0       1 0 0 0     1
      INPUT LINKS POSSIBLE           2 890
COSTS: PERIOD/                    CAPITAL                                 OPERATING
          SEGMENT             SLOPE          INTERCEPT          SLOPE           INTERCEPT

          11                  0.0             0.0              5.299998           0.0
                                         OUTPUT             HAUL COST $/TON-MIN/PERIOD        LEAD PERIODS       PROCESS  NO.
CODE            NAME          LEVEL EXIST % WGT  DENSITY      1          2          3        4  TIME AVAILABLE     LIFE     SEGS

 830 LANDFILL                     0     0   0.0           0  0.0       0.0       0.0       0.0       0 1 0 0 0       1 0 0 0     1
      INPUT LINKS POSSIBLE           2 890
COSTS: PERIOD/                    CAPITAL                                 OPERATING
          SEGMENT             SLOPE          INTERCEPT          SLOPE           INTERCEPT

          11                  0.0             0.0              2.929998           0.0
                                         OUTPUT             HAUL COST $/TON-MIN/PERIOD        LEAD PERIODS       PROCESS  NO.
CODE            NAME          LEVEL EXIST % WGT  DENSITY      1          2          3        4  TIME AVAILABLE     LIFE     SEGS

 840 N. SEDGWICK                  0     1   0.0           0  0.0       0.0       0.0       0.0       0 1 0 0 0       1 0 0 0     2
      INPUT LINKS POSSIBLE           2 890
COSTS: PERIOD/                    CAPITAL                                 OPERATING
          SEGMENT             SLOPE          INTERCEPT          SLOPE           INTERCEPT

          11                  0.244000        5.000000          4.250000         30.625000
          12                  0.123000        1.199999          2.719998         60.000000
```

F.3 continued

```
                                        OUTPUT              HAUL COST $/TON-MIN/PERIOD       LEAD PERIODS       PROCESS  NO.
CODE           NAME          LEVEL EXIST % WGT   DENSITY      1        2        3      4     TIME AVAILABLE     LIFE     SEGS

 840 N. SEDGWICK               0     1    0.0         0   0.0      0.0      0.0      0.0        0  1 0 0 0      1 0 0 0     2
      INPUT LINKS POSSIBLE        2 890
COSTS: PERIOD/                 CAPITAL                                 OPERATING
       SEGMENT               SLOPE         INTERCEPT          SLOPE          INTERCEPT

         11                0.244000        5.000000         4.250000        30.625000
         12                0.012000        7.199999         2.119998        60.000000
                                        OUTPUT              HAUL COST $/TON-MIN/PERIOD       LEAD PERIODS       PROCESS  NO.
CODE           NAME          LEVEL EXIST % WGT   DENSITY      1        2        3      4     TIME AVAILABLE     LIFE     SEGS

 050 COLLOCATED RENO           0     1    0.0         0   0.0      0.0      0.0      0.0        0  1 0 0 0      1 0 0 0     2
      INPUT LINKS POSSIBLE        2 890
COSTS: PERIOD/                 CAPITAL                                 OPERATING
       SEGMENT               SLOPE         INTERCEPT          SLOPE          INTERCEPT

         11                0.244000        5.000000         4.250000        30.625000
         12                0.012000        7.199999         2.719998        60.000000
                                        OUTPUT              HAUL COST $/TON-MIN/PERIOD       LEAD PERIODS       PROCESS  NO.
CODE           NAME          LEVEL EXIST % WGT   DENSITY      1        2        3      4     TIME AVAILABLE     LIFE     SEGS

 R90 HAVEN TRANSFER STA.       A     1  100.000     750   0.03000 0.0      0.0      0.0        0  1 0 0 0      1 0 0 0     2
      INPUT LINKS POSSIBLE        2
      OUTPUT LINKS POSSIBLE    810 820 830
COSTS: PERIOD/                 CAPITAL                                 OPERATING
       SEGMENT               SLOPE         INTERCEPT          SLOPE          INTERCEPT

         11                0.510000        5.500000         0.850000        30.299938
         12                0.323000       24.799988         0.850000        30.299968

                                        OUTPUT              HAUL COST $/TON-MIN/PERIOD       LEAD PERIODS       PROCESS  NO.
CODE           NAME          LEVEL EXIST % WGT   DENSITY      1        2        3      4     TIME AVAILABLE     LIFE     SEGS

 900 MODULAR INC. 200TPD       8     1   33.000    1500   0.12000 0.0      0.0      0.0        0  1 0 0 0      1 0 0 0     1
      INPUT LINKS POSSIBLE        2 890
      OUTPUT LINKS POSSIBLE    010 820 830
COSTS: PERIOD/                 CAPITAL                                 OPERATING
       SEGMENT               SLOPE         INTERCEPT          SLOPE          INTERCEPT

         11                0.0             0.0              8.320000         0.0
```

F.3 continued

```
                                         OUTPUT            HAUL CCST $/TON-MIN/PERIOD
CODE          NAME      LEVEL EXIST % WGT  DENSITY     1       2       3       4     TIME              LIFE

 900 MODULAR INC. 200TPO    8    1  33.000  1500  0.12000 0.0    0.0     0.0        0  1 0 0 0    1 0 0 0    1
     INPUT LINKS POSSIBLE       2 890
     OUTPUT LINKS POSSIBLE   810 820 830
COSTS: PERIOD/               CAPITAL                                OPERATING
       SEGMENT            SLOPE          INTERCEPT          SLOPE          INTERCEPT

        11                0.0              0.0            14.830000          0.0
```

Figure F.4

Transportation Data Base

	COOE	CRIGIN	PROCESS	SITE CEST.	TIME	CISTANCE	SPEEC
TRANS	1	100	100	710	34.40	17.20	30.0
TRANS	1	101	101	71C	18.00	9.50	3C.0
TRANS	1	1C2	102	710	36.80	18.40	30.0
TRANS	1	2CC	200	720	12.40	6.20	3C.0
TRANS	1	2C1	201	720	19.80	9.90	3C.0
TRANS	1	3CC	300	730	17.60	8.80	3C.0
TRANS	1	301	301	730	15.20	12.60	30.0
TRANS	1	3C2	302	73C	8.20	4.10	3C.0
TRANS	1	303	303	730	12.00	6.00	3C.0
TRANS	1	304	304	730	27.40	18.70	3C.0
TRANS	1	3C5	3C5	73C	35.40	17.20	30.0
TRANS	1	306	3C6	730	36.40	18.20	3C.C
TRANS	1	307	307	730	19.00	9.50	30.0
TRANS	1	100	100	730	85.80	42.90	30.0
TRANS	1	101	101	730	60.70	30.30	3C.C
TRANS	1	1C2	102	730	40.90	2C.40	30.0
TRANS	1	2C0	2C0	720	11.10	5.60	3C.0
TRANS	1	2C1	201	720	13.10	6.60	30.0
7RANS	1	3CC	300	730	11.10	5.50	3C.C
7RANS	1	301	301	730	14.20	7.10	30.0
7RANS	1	3C2	302	730	6.30	3.20	30.0
7RANS	1	303	303	730	10.90	5.40	30.C
TRANS	1	304	304	730	28.40	14.20	3C.C
TRANS	1	3C5	305	730	20.70	10.40	3C.C
7RANS	1	306	306	730	18.50	9.30	3C.0
TRANS	1	3C7	307	730	16.50	8.20	3C.0
TRANS	1	100	100	710	25.10	12.60	30.0
TRANS	1	100	100	720	82.30	41.20	30.0
TRANS	1	100	100	730	85.80	42.90	30.0
TRANS	1	101	101	710	7.90	3.90	30.0
7RANS	1	101	101	720	50.70	25.30	30.0
TRANS	1	101	101	730	60.70	30.30	30.0
7RANS	1	102	102	710	26.90	13.50	30.0
TRANS	1	102	102	720	39.30	19.60	30.0
7RANS	1	102	102	730	40.90	20.40	30.0
TRANS	1	200	200	710	47.60	23.80	30.0
TRANS	1	200	200	720	11.10	5.60	30.0
7RANS	1	200	200	730	31.20	15.60	30.0
TRANS	1	201	201	710	71.10	35.50	30.0
TRANS	1	201	201	720	13.10	6.60	30.0
TRANS	1	201	201	730	36.10	18.10	30.0
TRANS	1	300	300	710	78.40	39.20	30.0
TRANS	1	300	300	720	37.50	18.70	30.0
TRANS	1	300	300	730	11.10	5.50	30.0
7RANS	1	301	301	710	80.90	40.40	30.0
7RANS	1	301	301	720	42.00	21.00	30.0
TRANS	1	301	301	730	14.20	7.10	3C.0
TRANS	1	302	302	710	71.80	35.90	30.0
TRANS	1	302	302	720	36.40	18.20	30.0
7RANS	1	302	302	730	6.30	3.20	30.0
TRANS	1	303	303	710	74.40	37.20	30.0
TRANS	1	303	303	720	41.00	20.50	30.0
TRANS	1	303	303	730	10.90	5.40	30.0
TRANS	1	304	304	710	91.70	45.90	30.C
7RANS	1	304	304	720	57.40	28.70	30.0
TRANS	1	304	304	730	28.40	14.20	30.0
TRANS	1	305	305	710	60.30	30.20	30.0
TRANS	1	305	305	720	44.70	22.40	30.0
7RANS	1	305	305	730	20.70	10.40	30.0
7RANS	1	306	306	710	74.00	37.00	3C.0
TRANS	1	306	306	720	21.00	10.50	30.0
TRANS	1	306	306	730	18.50	9.30	30.0

F.4 continued

TRANS	1	307	307	710	50.90	25.50	30.0
TRANS	1	307	307	720	26.80	13.40	30.0
TRANS	1	307	307	730	16.50	8.20	30.0
TRANS	2	100	100	510	*****	64.40	30.0
TRANS	2	101	101	510	*****	55.00	30.0
TRANS	2	102	102	510	88.80	44.40	30.0
TRANS	2	200	200	510	83.50	41.70	30.0
TRANS	2	201	201	510	80.90	40.50	30.0
TRANS	2	300	300	510	43.00	21.50	30.0
TRANS	2	301	301	510	38.80	19.40	30.0
TRANS	2	302	302	510	46.50	23.20	30.0
TRANS	2	303	303	510	42.60	21.30	30.0
TRANS	2	304	304	510	24.40	12.20	30.0
TRANS	2	305	305	510	55.40	27.70	30.0
TRANS	2	306	306	510	60.80	30.40	30.0
TRANS	2	307	307	510	66.90	33.50	30.0
TRANS	4	510	890	710	*****	57.70	30.0
TRANS	4	510	890	720	80.30	40.20	30.0
TRANS	4	510	890	730	52.50	26.30	30.0
TRANS	1	100	100	710	25.10	12.60	30.0
TRANS	1	100	100	720	82.30	41.20	30.0
TRANS	1	100	100	730	85.80	42.90	30.0
TRANS	1	101	101	710	7.90	3.90	30.0
TRANS	1	101	101	720	50.70	25.30	30.0
TRANS	1	101	101	730	60.70	30.30	30.0
TRANS	1	102	102	710	26.90	13.50	30.0
TRANS	1	102	102	720	39.30	19.60	30.0
TRANS	1	102	102	730	40.90	20.40	30.0
TRANS	1	200	200	710	47.60	23.80	30.0
TRANS	1	200	200	720	11.10	5.60	30.0
TRANS	1	200	200	730	31.20	15.60	30.0
TRANS	1	201	201	710	71.10	35.50	30.0
TRANS	1	201	201	720	13.10	6.60	30.0
TRANS	1	201	201	730	36.10	18.10	30.0
TRANS	1	300	300	710	78.40	39.20	30.0
TRANS	1	300	300	720	37.50	18.70	30.0
TRANS	1	300	300	730	11.10	5.50	30.0
TRANS	1	301	301	710	80.90	40.40	30.0
TRANS	1	301	301	720	42.00	21.00	30.0
TRANS	1	301	301	730	14.20	7.10	30.0
TRANS	1	302	302	710	71.80	35.90	30.0
TRANS	1	302	302	720	36.40	18.20	30.0
TRANS	1	302	302	730	6.30	3.20	30.0
TRANS	1	303	303	710	74.40	37.20	30.0
TRANS	1	303	303	720	41.00	20.50	30.0
TRANS	1	303	303	730	10.90	5.40	30.0
TRANS	1	304	304	710	91.70	45.90	30.0
TRANS	1	304	304	720	57.40	28.70	30.0
TRANS	1	304	304	730	28.40	14.20	30.0
TRANS	1	305	305	710	60.30	30.20	30.0
TRANS	1	305	305	720	44.70	22.40	30.0
TRANS	1	305	305	730	20.70	10.40	30.0
TRANS	1	306	306	710	74.00	37.00	30.0
TRANS	1	306	306	720	21.00	10.50	30.0
TRANS	1	306	306	730	18.50	9.30	30.0
TRANS	1	307	307	710	50.90	25.50	30.0
TRANS	1	307	307	720	26.80	13.40	30.0
TRANS	1	307	307	730	16.50	8.20	30.0
TRANS	2	100	100	501	45.70	22.90	30.0
TRANS	2	101	101	501	21.20	10.60	30.0
TRANS	2	102	102	501	0.0	0.0	30.0
TRANS	2	200	200	501	28.60	14.30	30.0
TRANS	2	201	201	501	52.40	26.20	30.0
TRANS	2	300	300	501	51.80	25.90	30.0
TRANS	2	301	301	501	54.10	27.00	30.0
TRANS	2	302	302	501	44.90	22.50	30.0
TRANS	2	303	303	501	47.50	23.80	30.0
TRANS	2	304	304	501	64.90	32.40	30.0
TRANS	2	305	305	501	34.20	17.10	30.0
TRANS	2	306	306	501	49.90	25.00	30.0
TRANS	2	307	307	501	24.40	12.20	30.0
TRANS	4	501	890	710	26.90	13.50	30.0
TRANS	4	501	890	720	39.30	19.60	30.0
TRANS	4	501	890	730	40.90	20.40	30.0

F.4 continued

TRANS	1	305	3C5	710	60.30	3C.2C	3C.C
TRANS	1	3C5	3C5	720	44.70	22.4C	3C.C
TRANS	1	3C5	3C5	T30	20.70	1C.4C	3C.C
TRANS	1	3C5	3C5	740	31.40	15.7C	3C.C
TRANS	1	3C5	3C5	750	60.30	30.2C	3C.C
TRANS	1	3C6	3C6	71C	74.00	37.C0	3C.C
TRANS	1	3C6	3C6	720	21.00	10.5C	3C.C
TRANS	1	3C6	3C6	T3C	18.50	9.3C	3C.C
TRANS	1	306	3C6	74C	7.T0	3.8C	3C.C
TRANS	1	3C6	3C6	750	74.00	37.00	3C.C
TRANS	1	307	3C7	71C	5C.9C	25.5C	3C.C
TRANS	1	3C7	3C7	720	26.80	13.4C	3C.0
7RANS	1	3C7	3C7	T30	16.50	8.2C	3C.C
TRANS	1	3C7	3C7	74C	20.60	10.3C	3C.C
7RANS	1	3C7	3C7	75C	50.90	25.5C	3C.C
TRANS	2	1C0	100	510	*****	64.4C	3C.C
TRANS	2	1C1	1C1	510	*****	55.0C	3C.C
TRANS	2	102	102	510	88.80	44.4C	3C.C
TRANS	2	2CC	2C0	510	83.50	41.70	3C.C
TRANS	2	201	2C1	510	80.90	40.5C	3C.C
TRANS	2	300	3C0	51C	43.00	21.5C	3C.C
TRANS	2	3C1	301	51C	38.80	19.40	3C.C
TRANS	2	3C2	3C2	51C	46.50	23.2C	3C.0
TRANS	2	3C3	3C3	51C	42.60	21.3C	3C.C
7RANS	2	3C4	304	51C	24.40	12.2C	3C.0
TRANS	2	3C5	3C5	510	55.40	27.7C	3C.0
TRANS	2	306	3C6	510	60.80	30.40	3C.0
TRANS	2	307	307	510	66.90	33.50	3C.0
TRANS	4	510	890	71C	*****	57.TC	3C.0
TRANS	4	51C	890	720	80.30	40.20	3C.0
TRANS	4	510	850	730	52.50	26.30	3C.0
TRANS	4	510	850	740	59.10	29.6C	3C.C
TRANS	4	510	890	75C	*****	57.7C	3C.0
7RANS	2	102	102	550	23.70	11.80	30.0
TRANS	2	102	102	560	50.20	25.10	3C.C
TRANS	2	1C2	102	561	69.30	34.60	3C.C
TRANS	2	102	102	564	46.30	23.20	3C.C
7RANS	2	200	200	510	83.50	41.70	3C.0
TRANS	2	200	200	550	43.40	21.T0	3C.0
TRANS	2	20C	200	560	41.50	20.80	3C.C
TRANS	2	200	200	561	64.50	32.30	3C.C
TRANS	2	2CC	200	564	34.10	17.1C	30.C
TRANS	2	2C1	2C1	510	80.90	40.50	3C.0
TRANS	2	2C1	2C1	55C	66.80	33.40	3C.C
TRANS	2	2C1	201	56C	43.20	21.60	3C.0
TRANS	2	2C1	201	561	64.60	32.30	30.C
TRANS	2	2C1	201	564	35.10	17.6C	3C.0
7RANS	2	3CC	300	51C	43.0C	21.50	3C.0
TRANS	2	3C0	300	550	74.80	37.40	3C.0
TRANS	2	3CC	300	56C	4.20	2.10	3C.0
7RANS	2	3CC	300	561	24.90	12.4C	3C.0
TRANS	2	300	300	564	6.60	3.30	3C.C
TRANS	2	3C1	3C1	510	38.80	19.4C	3C.0
TRANS	2	3C1	301	550	77.40	38.TC	3C.C
TRANS	2	3C1	3C1	560	3.90	1.90	3C.0
TRANS	2	3C1	301	561	20.30	10.20	3C.0
TRANS	2	3C1	301	564	10.80	5.40	3C.0
TRANS	2	3C2	3C2	51C	46.50	23.20	3C.C
TRANS	2	3C2	3C2	550	68.30	34.10	3C.C
TRANS	2	3C2	3C2	56C	5.30	2.60	3C.C
TRANS	2	3C2	3C2	561	27.20	13.60	3C.C

F.4 continued

TRANS	2	302	302	564	7.10	3.60	30.0
TRANS	2	303	303	510	42.60	21.30	30.0
TRANS	2	303	303	550	71.00	35.50	30.0
TRANS	2	303	303	560	5.00	2.50	30.0
TRANS	2	303	303	561	23.10	11.50	30.0
TRANS	2	303	303	564	11.10	5.60	30.0
TRANS	2	304	304	510	24.40	12.20	30.0
TRANS	2	304	304	550	88.50	44.30	30.0
TRANS	2	304	304	560	18.20	9.10	30.0
TRANS	2	304	304	561	4.90	2.50	30.0
TRANS	2	304	304	564	26.20	13.10	30.0
TRANS	2	305	305	510	55.40	27.70	30.0
TRANS	2	305	305	550	57.50	28.80	30.0
TRANS	2	305	305	560	23.60	11.80	30.0
TRANS	2	305	305	561	36.50	18.20	30.0
TRANS	2	305	305	564	25.50	12.80	30.0
TRANS	2	306	306	510	60.80	30.40	30.0
TRANS	2	306	306	550	69.90	34.90	30.0
TRANS	2	306	306	560	23.30	11.60	30.0
TRANS	2	306	306	561	44.20	22.10	30.0
TRANS	2	306	306	564	15.70	7.90	30.0
TRANS	2	307	307	510	66.90	33.50	30.0
TRANS	2	307	307	550	47.30	23.60	30.0
TRANS	2	307	307	560	26.30	13.10	30.0
TRANS	2	307	307	561	47.30	23.60	30.0
TRANS	2	307	307	564	21.90	10.90	30.0
TRANS	3	510	890	550	*****	56.20	30.0
TRANS	3	510	890	560	42.00	21.00	30.0
TRANS	3	510	890	561	19.60	9.80	30.0
TRANS	3	510	890	564	49.50	24.80	30.0
TRANS	4	510	890	710	*****	57.70	30.0
TRANS	4	510	890	720	80.30	40.20	30.0
TRANS	4	510	890	730	52.50	26.30	30.0
TRANS	4	550	900	710	4.30	2.10	30.0
TRANS	4	550	900	720	54.30	27.20	30.0
TRANS	4	550	900	730	63.70	31.90	30.0
TRANS	4	560	900	710	77.00	38.50	30.0
TRANS	4	560	900	720	39.40	19.70	30.0
TRANS	4	560	900	730	10.60	5.30	30.0
TRANS	4	561	900	710	96.10	48.00	30.0
TRANS	4	561	900	720	62.30	31.10	30.0
TRANS	4	561	900	730	33.40	16.70	30.0
TRANS	4	564	900	710	72.70	36.30	30.0
TRANS	4	564	900	720	31.30	15.60	30.0
TRANS	4	564	900	730	5.70	2.90	30.0
TRANS	1	100	100	710	25.10	12.60	30.0
TRANS	1	100	100	720	82.30	41.20	30.0
TRANS	1	100	100	730	85.80	42.90	30.0
TRANS	1	101	101	710	7.90	3.90	30.0
TRANS	1	101	101	720	50.70	25.30	30.0
TRANS	1	101	101	730	60.70	30.30	30.0
TRANS	1	102	102	710	26.90	13.50	30.0
TRANS	1	102	102	720	39.30	19.60	30.0
TRANS	1	102	102	730	40.90	20.40	30.0
TRANS	1	200	200	710	47.60	23.80	30.0
TRANS	1	200	200	720	11.10	5.60	30.0
TRANS	1	200	200	730	31.20	15.60	30.0
TRANS	1	201	201	710	71.10	35.50	30.0
TRANS	1	201	201	720	13.10	6.60	30.0
TRANS	1	201	201	730	36.10	18.10	30.0
TRANS	1	300	300	710	78.40	39.20	30.0
TRANS	1	300	300	720	37.50	18.70	30.0
TRANS	1	300	300	730	11.10	5.50	30.0
TRANS	1	301	301	710	80.90	40.40	30.0
TRANS	1	301	301	720	42.00	21.00	30.0
TRANS	1	301	301	730	14.20	7.10	30.0
TRANS	1	302	302	710	71.80	35.90	30.0
TRANS	1	302	302	720	36.40	18.20	30.0
TRANS	1	302	302	730	6.30	3.20	30.0

F.4 continued

TRANS	1	3C3	303	T10	74.40	37.20	3C.C
TRANS	1	3C3	3C3	72C	41.00	20.50	3C.C
TRANS—	1	3C3	3C3	730	10.90	5.40	30.0
TRANS	1	3C4	3C4	710	91.70	45.9C	3C.C
TRANS	1	3C4	304	72C	57.40	28.7C	3C.0
TRANS	1	3C4	304	73C	28.40	14.2C	3C.C
TRANS	1	3C5	305	710	6C.30	30.2C	3C.C
TRANS	1	3C5	3C5	72C	44.7C	22.40	3C.C
TRANS	1	3C5	305	730	20.70	10.40	3C.C
TRANS	1	3C6	3C6	71C	74.CC	37.00	30.0
TRANS	1	3C6	306	720	21.00	10.5C	30.0
TRANS	1	306	3C6	730	18.50	9.3C	3C.C
TRANS	1	3C7	3C7	710	5C.90	25.5C	3C.C
TRANS	1	3C7	307	720	26.80	13.40	3C.C
TRANS	1	3C7	3C7	730	16.50	8.20	3C.C
TRANS	2	1CC	1C0	51C	*****	64.4C	3C.C
TRANS	2	1CC	1C0	55C	29.20	14.6C	30.C
TRANS	2	1C0	100	560	94.30	47.1C	3C.0
TRANS	2	1CC	1C0	561	*****	55.1C	30.C
TRANS	2	1CC	100	564	91.50	45.7C	3C.C
TRANS	2	101	1C1	51C	*****	55.00	3C.C
TRANS	2	1C1	101	550	3.60	1.80	3C.C
TRANS	2	1C1	101	560	70.60	35.3C	3C.0
TRANS	2	1C1	1C1	561	90.40	45.20	3C.C
TRANS	2	101	101	564	65.80	32.9C	3C.0
TRANS	2	102	1C2	510	88.80	44.40	3C.0
TRANS	1	100	100	710	25.10	12.6C	3C.0
TRANS	1	1C0	100	72C	82.30	41.20	3C.0
TRANS	1	100	1C0	730	65.80	42.9C	3C.C
TRANS	1	101	1C1	710	7.90	3.90	3C.C
TRANS	1	1C1	1C1	720	50.70	25.3C	3C.C
TRANS	1	1C1	1C1	73C	60.70	30.30	30.C
TRANS	1	1C2	1C2	710	26.90	13.5C	3C.C
TRANS	1	102	1C2	720	39.30	19.60	30.0
TRANS	1	1C2	1C2	73C	40.90	20.4C	3C.C
TRANS	1	2C0	200	71C	47.60	23.8C	3C.C
TRANS	1	2CC	2C0	720	11.10	5.60	3C.C
TRANS	1	200	200	730	31.20	15.6C	3C.C
TRANS	1	2C1	2C1	710	71.10	35.50	3C.C
TRANS	1	2C1	201	720	13.10	6.60	3C.C
TRANS	1	2C1	2C1	730	36.1C	18.1C	3C.C
TRANS	1	3C0	3C0	71C	78.40	39.20	3C.C
TRANS	1	3CC	3CC	720	37.50	18.7C	3C.C
TRANS	1	3C0	3C0	730	11.1C	5.50	3C.C
TRANS	1	3C1	3C1	710	80.90	40.4C	3C.C
TRANS	1	3C1	3C1	720	42.00	21.00	3C.C
TRANS	1	3C1	301	730	14.20	7.1C	3C.C
TRANS	1	3C2	3C2	710	71.80	35.9C	3C.C
TRANS	1	3C2	3C2	720	36.40	16.20	3C.C
TRANS	1	3C2	3C2	73C	6.3C	3.2C	3C.C
TRANS	1	3C3	3C3	71C	74.40	37.2C	3C.C
TRANS	1	3C3	3C3	72C	41.0C	20.5C	3C.C
TRANS	1	3C3	3C3	73C	1C.9C	5.40	3C.C
TRANS	1	3C4	304	710	91.70	45.9C	3C.C
TRANS	1	3C4	3C4	720	57.40	28.7C	3C.C
TRANS	1	3C4	3C4	73C	28.40	14.20	3C.C
TRANS	1	3C5	305	T10	60.30	3C.2C	3C.C
TRANS	1	3C5	3C5	72C	44.T0	22.4C	3C.C
TRANS	1	3C5	3C5	730	2C.70	10.4C	3C.0
TRANS	1	3C6	306	71C	74.00	37.0C	3C.C
TRANS	1	306	3C6	72C	21.00	10.50	3C.C
TRANS	1	3C6	306	730	18.50	9.3C	3C.C
TRANS	1	3C7	3C7	710	50.90	25.5C	3C.0
TRANS	1	3C7	3C7	72C	26.80	13.40	3C.C
TRANS	1	3C7	3C7	73C	16.5C	8.2C	3C.C
TRANS	2	1CC	1C0	510	*****	64.40	30.0
TRANS	2	1CC	100	55C	29.20	14.6C	3C.C
TRANS	2	1C0	100	560	94.3C	47.1C	3C.C
TRANS	2	1CC	1C0	561	*****	55.1C	3C.C
TRANS	2	1CC	1C0	564	91.50	45.7C	3C.C
TRANS	2	1C1	1C1	51C	*****	55.00	3C.0
TRANS	2	1C1	101	550	3.60	1.80	3C.C
TRANS	2	1C1	101	560	70.60	35.30	3C.C
TRANS	2	1C1	1C1	561	90.40	45.20	3C.C
TRANS	2	1C1	1C1	564	65.80	32.9C	3C.C
TRANS	2	1C2	102	510	88.80	44.40	3C.C

F.4 continued

TRANS	2	102	102	550	23.70	11.80	30.0
TRANS	2	102	102	560	50.20	25.10	30.0
TRANS	2	102	102	561	69.30	34.60	30.0
TRANS	2	102	102	564	46.30	23.20	30.0
TRANS	2	200	200	510	83.50	41.70	30.0
TRANS	2	200	200	550	43.40	21.70	30.0
TRANS	2	200	200	560	41.50	20.80	30.0
TRANS	2	200	200	561	64.50	32.30	30.0
TRANS	2	200	200	564	34.10	17.10	30.0
TRANS	2	201	201	510	80.90	40.50	30.0
TRANS	2	201	201	550	66.80	33.40	30.0
TRANS	2	201	201	560	43.20	21.60	30.0
TRANS	2	201	201	561	64.60	32.30	30.0
TRANS	2	201	201	564	35.10	17.60	30.0
TRANS	2	300	300	510	43.00	21.50	30.0
TRANS	2	300	300	550	74.80	37.40	30.0
TRANS	2	300	300	560	4.20	2.10	30.0
TRANS	2	300	300	561	24.90	12.40	30.0
TRANS	2	300	300	564	6.60	3.30	30.0
TRANS	2	301	301	510	38.80	19.40	30.0
TRANS	2	301	301	550	77.40	38.70	30.0
TRANS	2	301	301	560	3.90	1.90	30.0
TRANS	2	301	301	561	20.30	10.20	30.0
TRANS	2	301	301	564	10.80	5.40	30.0
TRANS	2	302	302	510	46.50	23.20	30.0
TRANS	2	302	302	550	68.30	34.10	30.0
TRANS	2	302	302	560	5.30	2.60	30.0
TRANS	2	302	302	561	27.20	13.60	30.0
TRANS	2	302	302	564	7.10	3.60	30.0
TRANS	2	303	303	510	42.60	21.30	30.0
TRANS	2	303	303	550	71.00	35.50	30.0
TRANS	2	303	303	560	5.00	2.50	30.0
TRANS	2	303	303	561	23.10	11.50	30.0
TRANS	2	303	303	564	11.10	5.60	30.0
TRANS	2	304	304	510	24.40	12.20	30.0
TRANS	2	304	304	550	88.50	44.30	30.0
TRANS	2	304	304	560	18.20	9.10	30.0
TRANS	2	304	304	561	4.90	2.50	30.0
TRANS	2	304	304	564	26.20	13.10	30.0
TRANS	2	305	305	510	55.40	27.70	30.0
TRANS	2	305	305	550	57.50	28.80	30.0
TRANS	2	305	305	560	23.60	11.80	30.0
TRANS	2	305	305	561	36.50	18.20	30.0
TRANS	2	305	305	564	25.50	12.80	30.0
TRANS	2	306	306	510	60.80	30.40	30.0
TRANS	2	306	306	550	69.90	34.90	30.0
TRANS	2	306	306	560	23.30	11.60	30.0
TRANS	2	306	306	561	44.20	22.10	30.0
TRANS	2	306	306	564	15.70	7.90	30.0
TRANS	2	307	307	510	66.90	33.50	30.0
TRANS	2	307	307	550	47.30	23.60	30.0
TRANS	2	307	307	560	26.30	13.10	30.0
TRANS	2	307	307	561	47.30	23.60	30.0
TRANS	2	307	307	564	21.90	10.90	30.0
TRANS	3	510	690	550	*****	56.20	30.0
TRANS	3	510	690	560	42.00	21.00	30.0
TRANS	3	510	690	561	19.60	9.80	30.0
TRANS	3	510	690	564	49.50	24.80	30.0
TRANS	4	510	690	710	*****	57.70	30.0
TRANS	4	510	690	720	80.30	40.20	30.0
TRANS	4	510	690	730	52.50	26.30	30.0
TRANS	4	550	900	710	4.30	2.10	30.0
TRANS	4	550	900	720	54.30	27.20	30.0
TRANS	4	550	900	730	63.70	31.90	30.0
TRANS	4	560	900	710	77.00	38.50	30.0
TRANS	4	560	900	720	39.40	19.70	30.0
TRANS	4	560	900	730	10.60	5.30	30.0
TRANS	4	561	900	710	96.10	48.00	30.0
TRANS	4	561	900	720	62.30	31.10	30.0
TRANS	4	561	900	730	33.40	16.70	30.0
TRANS	4	564	900	710	72.70	36.30	30.0
TRANS	4	564	900	720	31.30	15.60	30.0
TRANS	4	564	900	730	5.70	2.90	30.0

F.4 continued

TRANS	2	100	100	510	*****	64.40	30.0
TRANS	2	100	100	550	29.20	14.60	30.0
TRANS	2	100	100	551	35.40	17.70	30.0
TRANS	2	100	100	552	32.50	16.30	30.0
TRANS	2	100	100	560	94.30	47.10	30.0
TRANS	2	100	100	561	*****	55.10	30.0
TRANS	2	100	100	562	97.10	48.60	30.0
TRANS	2	100	100	563	91.20	45.60	30.0
TRANS	2	100	100	564	91.50	45.70	30.0
TRANS	2	101	101	510	*****	55.00	30.0
TRANS	2	101	101	550	3.60	1.80	30.0
TRANS	2	101	101	551	2.80	1.40	30.0
TRANS	2	101	101	552	0.20	0.10	30.0
TRANS	2	101	101	560	70.60	35.30	30.0
TRANS	2	101	101	561	90.40	45.20	30.0
TRANS	2	101	101	562	74.70	37.30	30.0
TRANS	2	101	101	563	69.20	34.60	30.0
TRANS	2	101	101	564	65.80	32.90	30.0
TRANS	2	102	102	510	88.80	44.40	30.0
TRANS	2	102	102	550	23.70	11.80	30.0
TRANS	2	102	102	551	21.00	10.50	30.0
TRANS	2	102	102	552	21.30	10.60	30.0
TRANS	2	102	102	560	50.20	25.10	30.0
TRANS	2	102	102	561	69.30	34.60	30.0
TRANS	2	102	102	562	54.00	27.00	30.0
TRANS	2	102	102	563	48.40	24.20	30.0
TRANS	2	102	102	564	46.30	23.20	30.0
TRANS	2	200	200	510	83.50	41.70	30.0
TRANS	2	200	200	550	43.40	21.70	30.0
TRANS	2	200	200	551	37.60	18.80	30.0
TRANS	2	200	200	552	39.90	20.00	30.0
TRANS	2	200	200	560	41.50	20.80	30.0
TRANS	2	200	200	561	64.50	32.30	30.0
TRANS	2	200	200	562	47.10	23.60	30.0
TRANS	2	200	200	563	43.40	21.70	30.0
TRANS	2	200	200	564	34.10	17.10	30.0
TRANS	2	201	201	510	80.90	40.50	30.0
TRANS	2	201	201	550	66.80	33.40	30.0
TRANS	2	201	201	551	60.80	30.40	30.0
TRANS	2	201	201	552	63.40	31.70	30.0
TRANS	2	201	201	560	43.20	21.60	30.0
TRANS	2	201	201	561	64.60	32.30	30.0
TRANS	2	201	201	562	48.80	24.40	30.0
TRANS	2	201	201	563	47.90	23.90	30.0
TRANS	2	201	201	564	35.10	17.60	30.0
TRANS	2	300	300	510	43.00	21.50	30.0
TRANS	2	300	300	550	74.80	37.40	30.0
TRANS	2	300	300	551	70.60	35.30	30.0
TRANS	2	300	300	552	71.90	35.90	30.0
TRANS	2	300	300	560	4.20	2.10	30.0
TRANS	2	300	300	561	24.90	12.40	30.0
TRANS	2	300	300	562	8.80	4.40	30.0
TRANS	2	300	300	563	10.40	5.20	30.0
TRANS	2	300	300	564	6.60	3.30	30.0
TRANS	2	301	301	510	38.80	19.40	30.0
TRANS	2	301	301	550	77.40	38.70	30.0
TRANS	2	301	301	551	73.40	36.70	30.0
TRANS	2	301	301	552	74.50	37.30	30.0
TRANS	2	301	301	560	3.90	1.90	30.0
TRANS	2	301	301	561	20.30	10.20	30.0
TRANS	2	301	301	562	4.70	2.30	30.0
TRANS	2	301	301	563	8.40	4.20	30.0
TRANS	2	301	301	564	10.80	5.40	30.0
TRANS	2	302	302	510	46.50	23.20	30.0
TRANS	2	302	302	550	68.30	34.10	30.0
TRANS	2	302	302	551	64.40	32.20	30.0
TRANS	2	302	302	552	65.50	32.70	30.0
TRANS	2	302	302	560	5.30	2.60	30.0
TRANS	2	302	302	561	27.20	13.60	30.0
TRANS	2	302	302	562	9.90	4.90	30.0
TRANS	2	302	302	563	6.40	3.20	30.0
TRANS	2	302	302	564	7.10	3.60	30.0
TRANS	2	303	303	510	42.60	21.30	30.0
TRANS	2	303	303	550	71.00	35.50	30.0
TRANS	2	303	303	551	67.40	33.70	30.0

F.4 continued

TRANS	2	303	303	552	68.40	34.20	30.0
TRANS	2	303	303	560	5.00	2.50	30.0
TRANS	2	303	303	561	23.10	11.50	30.0
TRANS	2	303	303	562	6.40	3.20	30.0
TRANS	2	303	303	563	1.80	0.90	30.0
TRANS	2	303	303	564	11.10	5.60	30.0
TRANS	2	304	304	510	24.40	12.20	30.0
TRANS	2	304	304	550	88.50	44.30	30.0
TRANS	2	304	304	551	85.20	42.60	30.0
TRANS	2	304	304	552	86.00	43.00	30.0
TRANS	2	304	304	560	18.20	9.10	30.0
TRANS	2	304	304	561	4.90	2.50	30.0
TRANS	2	304	304	562	12.50	6.20	30.0
TRANS	2	304	304	563	16.90	8.50	30.0
TRANS	2	304	304	564	26.20	13.10	30.0
TRANS	2	305	305	510	55.40	27.70	30.0
TRANS	2	305	305	550	57.50	28.80	30.0
TRANS	2	305	305	551	55.10	27.60	30.0
TRANS	2	305	305	552	55.40	27.70	30.0
TRANS	2	305	305	560	23.60	11.80	30.0
TRANS	2	305	305	561	36.50	18.20	30.0
TRANS	2	305	305	562	24.50	12.20	30.0
TRANS	2	305	305	563	18.70	9.40	30.0
TRANS	2	305	305	564	25.50	12.80	30.0
TRANS	2	306	306	510	60.80	30.40	30.0
TRANS	2	306	306	550	69.90	34.90	30.0
TRANS	2	306	306	551	64.60	32.30	30.0
TRANS	2	306	306	552	66.60	33.30	30.0
TRANS	2	306	306	560	23.30	11.60	30.0
TRANS	2	306	306	561	44.20	22.10	30.0
TRANS	2	306	306	562	28.70	14.40	30.0
TRANS	2	306	306	563	28.60	14.30	30.0
TRANS	2	306	306	564	15.70	7.90	30.0
TRANS	2	307	307	510	66.90	33.50	30.0
TRANS	2	307	307	550	47.30	23.60	30.0
TRANS	2	307	307	551	43.30	21.60	30.0
TRANS	2	307	307	552	44.40	22.20	30.0
TRANS	2	307	307	560	26.30	13.10	30.0
TRANS	2	307	307	561	47.30	23.60	30.0
TRANS	2	307	307	562	30.70	15.40	30.0
TRANS	2	307	307	563	25.60	12.80	30.0
TRANS	2	307	307	564	21.90	10.90	30.0
TRANS	3	510	890	550	*****	56.20	30.0
TRANS	3	510	890	551	*****	54.70	30.0
TRANS	3	510	890	552	*****	55.00	30.0
TRANS	3	510	890	560	42.00	21.00	30.0
TRANS	3	510	890	561	19.60	9.60	30.0
TRANS	3	510	890	562	36.60	18.30	30.0
TRANS	3	510	890	563	41.30	20.70	30.0
TRANS	3	510	890	564	49.50	24.60	30.0
TRANS	4	550	900	710	4.30	2.10	30.0
TRANS	4	550	900	720	54.30	27.20	30.0
TRANS	4	550	900	730	63.70	31.90	30.0
TRANS	4	551	900	710	10.40	5.20	30.0
TRANS	4	551	900	720	48.40	24.20	30.0
TRANS	4	551	900	730	59.60	29.80	30.0
TRANS	4	552	900	710	7.70	3.90	30.0
TRANS	4	552	900	720	50.80	25.40	30.0
TRANS	4	552	900	730	60.80	30.40	30.0
TRANS	4	560	900	710	77.00	38.50	30.0
TRANS	4	560	900	720	39.40	19.70	30.0
TRANS	4	560	900	730	10.60	5.30	30.0
TRANS	4	561	900	710	96.10	48.00	30.0
TRANS	4	561	900	720	62.30	31.10	30.0
TRANS	4	561	900	730	33.40	16.70	30.0
TRANS	4	562	900	710	80.90	40.40	30.0
TRANS	4	562	900	720	45.20	22.60	30.0
TRANS	4	562	900	730	16.00	8.00	30.0
TRANS	4	563	900	710	75.30	37.60	30.0
TRANS	4	563	900	720	42.80	21.40	30.0
TRANS	4	563	900	730	12.60	6.30	30.0
TRANS	4	564	900	710	72.70	36.30	30.0
TRANS	4	564	900	720	31.30	15.60	30.0
TRANS	4	564	900	730	5.70	2.90	30.0

Figure F.5

Present Situation -- Run 1

```
CONTRL  1 4 1 2 2 1 1 0 0 0 1 1  13   3 3   3  13  0    20 10 10              5 19
TITLE PRESENT SITUATION SEDGWICK-HARVEY-RENO CO. REGION     ***RUN 1***
SOURCE100 WEST RENO CO.        9815037581   54                100
SOURCE101 HUTCHINSON CITY      9755038023  319                100
SOURCE102 SE RENO CO.          9746537541   41                100
SOURCE200 WEST HARVEY CO.      9730038000   58                120
SOURCE201 NEWTON/E. HARVEY     9715038023  109                120
SOURCE300 NE WICHITA CITY      9717337423  587                120
SOURCE301 SE WICHITA CITY      9717337400  432                120
SOURCE302 NW WICHITA CITY      9722337423  646                120
SOURCE303 SW WICHITA CITY      9722337400  549                120
SOURCE304 DERBY CITY           9716137323  442                120
SOURCE305 GODDARD CITY         9734337400  422                120
SOURCE306 NE SEDGWICK CO.      9715037521  178                120
SOURCE307 NW SEDGWICK CO.      9732337493  268                120
SITE 710 RENO CO. LANDFILL      1 96000 38023 1             616
SITE 720 HARVEY CO. L'FILL      1 97230 38005 1            1060
SITE 730 BROOKS TRACT           1 97231 37454 1           14000
PRC1     810 LANDFILL                0 1
PRC2  2        1                1                                                810
LNK1     2                                                                       810
PRCOST 11                      1190          0                                   810
PRC1     820 LANDFILL                0 1
PRC2  2        1                1                                                820
LNK1     2                                                                       820
PRCOST 11                        530          0                                  820
PRC1     830 LANDFILL                0 1
PRC2  2        1                1                                                830
LNK1     2                                                                       830
PRCOST 11                        293          0                                  830
SIPROC 710 810    01                                  0
SIPROC 720 820    01                                  0
SIPROC 730 830    01                                  0
TRANS 1 100 100 710       34.4  172 300
TRANS 1 101 101 710       18.0   95 300
TRANS 1 102 102 710       36.8  184 300
TRANS 1 200 200 720       12.4   62 300
TRANS 1 201 201 720       19.8   99 300
TRANS 1 300 300 730       17.6   88 300
TRANS 1 301 301 730       15.2  126 300
TRANS 1 302 302 730        8.2   41 300
TRANS 1 303 303 730       12.0   60 300
TRANS 1 304 304 730       27.4  167 300
TRANS 1 305 305 730       35.4  172 300
TRANS 1 306 306 730       36.4  182 300
TRANS 1 307 307 730       19.0   95 300
/*

          S U M M A R Y   O F   M R A P   O P T I M I Z A T I O N
          *****************************************************

                         M A T R I X   S I Z E
                         *********************


                     NUMBER OF ROWS      =  19
                     NUMBER OF COLUMNS   =  36
          NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX =    38
          THE ACTUAL SIZE OF THE (A) MATRIX IS    76 ELEMENTS

               ERROR 11.1.11 NO FEASIBLE SOLUTION


               ERROR 11.1.11A Z COL IN BASIS. PROGRAM HALTS.
```

Figure F.6

Simulation of Present Situation -- Run 2

```
CONTRL  1 4 1 2 2 1 1 0 0 0 1 1  13    3 3    3  13  0     20  1  1            5 19
TITLE PRESENT SITUATION SEDGWICK-HARVEY-RENO CO. REGION   ***RUN2 ***
SOURCE100 WEST RENO CO.         9815037581    54               100
SOURCE101 HUTCHINSON CITY       9755038023   319               100
SOURCE102 SE RENO CO.           9746537541    41               100
SOURCE200 WEST HARVEY CO.       9730038000    58               120
SOURCE201 NEWTON/E. HARVEY      9715038023   109               120
SOURCE300 NE WICHITA CITY       9717337423   587               120
SOURCE301 SE WICHITA CITY       9717337400   432               120
SOURCE302 NW WICHITA CITY       9722337423   646               120
SOURCE303 SW WICHITA CITY       9722337400   549               120
SOURCE304 DERBY CITY            9716137323   442               120
SOURCE305 GODDARD CITY          9734337400   422               120
SOURCE306 NE SEDGWICK CO.       9715037521   178               120
SOURCE307 NW SEDGWICK CO.       9732337493   268               120
SITE 710 RENO CO. LANDFILL       1 98000 38C23 1            616
SITE 720 HARVEY CO. L'FILL       1 97230 38C05 1           1060
SITE 730 BROOKS TRACT            1 97231 37454 1          14000
PRC1     810 LANDFILL                 0 1
PRC2  2       1                1                                                 810
LNK1     2                                                                       810
PRCOST 11                       1190                                             810
PRC1     820 LANDFILL                 0 1
PRC2  2       1                1                                                 820
LNK1     2                                                                       820
PRCOST 11                         530                                            820
PRC1     830 LANDFILL                 0 1
PRC2  2       1                1                                                 830
LNK1     2                                                                       830
PRCOST 11                         293                                            830
SIPROC 710 810    01                                   0
SIPROC 720 820    C1                                   0
SIPROC 730 830    01                                   0
TRANS 1 100 100 710      34.4   172 300
TRANS 1 101 101 710      18.0    95 300
TRANS 1 102 102 710      36.8   184 300
TRANS 1 200 20C 720      12.4    62 300
TRANS 1 201 201 720      19.8    99 300
TRANS 1 300 300 730      17.6    88 300
TRANS 1 301 301 730      15.2   126 300
TRANS 1 302 302 730       8.2    41 300
TRANS 1 303 3C3 730      12.0    60 300
TRANS 1 304 304 730      27.4   187 3CC
TRANS 1 305 305 730      35.4   172 300
TRANS 1 306 306 730      36.4   182 300
TRANS 1 307 307 730      19.0    95 300
/*
```

Figure F.7

Output Run 2

S U M M A R Y   O F   W R A P   O P T I M I Z A T I O N

M A T R I X   S I Z E

NUMBER OF ROWS = 19
NUMBER OF COLUMNS = 36
NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX = 38
THE ACTUAL SIZE OF THE (A) MATRIX IS 76 ELEMENTS

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

JOB TITLE

PRESENT SITUATION SEDGWICK-HARVEY-RENO CO. REGION

EXECUTION MODE 1 *STATIC* 1 MODEL PERIODS
TOTAL PLANNING PERIOD IS 1 YEARS
MODEL PERIOD 1 HAS 1 YEARS
LAST PHASE=4 FORCING METHOD=1
STEEPEST DESCENT=1 TURNAROUND TIME= 20.0
NUMBER OF SOURCES 13
NUMBER OF SITES 3
NUMBER OF PROCESSES 3
NUMBER OF SITE/PROCESSES 3
NUMBER OF TRANSPORTATION 13

***** SITE DATA INPUT *****

CODE	NAME	LONGITUDE DEG MIN	LATITUDE DEG MIN	SITE TYPE	PROC	COST	LAND
T10	RENO CO. LANDFILL	98 0.0	38 2.3	0	1	0.0	616
T20	HARVEY CO. L'FILL	97 23.0	38 0.5	0	1	0.0	1060
T30	BROCKS TRACT	97 23.1	37 45.4	0	1	0.0	14000

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
T10	810	1	0	0.0	0.0	0.0	0.0	0
T20	820	1	0	0.0	0.0	0.0	0.0	0
T30	830	1	0	0.0	0.0	0.0	0.0	0

F.7 continued

W R A P

WASTE RESOURCE ALLOCATION PLANNING

STATIC MODEL RESULTS

OBJECTIVE VALUE IS 3482.6096 IN THOUSANDS OF DOLLARS PER YEAR INCLUDING ALL COSTS FROM LOADING OF PACKER TRUCKS

TOTAL TONNAGE IS 410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS 8.4838 PER TON

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO ULTIMATE FACILITY PAIR(S)
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I D	DESTINATION NAME	I D	ACTIVITY LEVEL *	MODEL PERIOD
WEST RENO CO.	100	RENO CO. LANDFILL	110	5.4000	1
HUTCHINSON CITY	101	RENO CO. LANDFILL	110	31.9000	1
SE RENO CO.	102	RENO CO. LANDFILL	110	4.1000	1
WEST HARVEY CO.	200	HARVEY CO. L'FILL	120	5.8000	1
NEWTON/E. HARVEY	201	HARVEY CO. L'FILL	120	10.9000	1
NE WICHITA CITY	300	BROOKS TRACT	130	58.1000	1
SE WICHITA CITY	301	BROOKS TRACT	130	43.2000	1
NW WICHITA CITY	302	BROOKS TRACT	130	64.6000	1
SW WICHITA CITY	303	BROOKS TRACT	130	54.9000	1
DERBY CITY	304	BROOKS TRACT	130	44.2000	1
GODDARD CITY	305	BROOKS TRACT	130	42.2000	1
NE SEDGWICK CO.	306	BROOKS TRACT	130	11.8000	1
NW SEDGWICK CO.	307	BROOKS TRACT	130	26.8000	1

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

SITE NAME	I D	PROCESS NAME	I D	ACTIVITY LEVEL *	LINEAR SEGMENT
RENO CO. LANDFILL	110	LANDFILL	810	41.4000	1
HARVEY CO. L'FILL	120	LANDFILL	820	16.7000	1
BROOKS TRACT	130	LANDFILL	830	352.3994	1

Figure F.8

Simulation of Present Situation -- Run 3

```
CONTRL  I 4 1 2 2 I I 1 0 0 1 I  I3   2 2   2  I3  0    20  I  I               5 I9
TITLE PRESENT SITUATICN W/O RENO CO. L*FILL CROWFLY OPTION I ***RUN3***
CRWFLY  100  79  30
SOURCE100 WEST RENG CC.      981503T581    54                    I00
SOURCEI01 HUTCHINSON CITY    9T55038023   319                    I00
SOURCE102 SE RENC CO.        9T4653T54I    41                    I00
SOURCE200 WEST HARVEY CO.    9730038000    58                    I20
SOURCE201 NEWTON/E. HARVEY   97I5038023   109                    120
SOURCE300 NE WICHITA CITY    9T17337423   587                    120
SOURCE30I SE WICHITA CITY    971T337400   432                    120
SOURCE302 NW WICHITA CITY    9T22337423   646                    I20
SOURCE303 SW WICHITA CITY    972233T400   549                    I20
SOURCE304 OERBY CITY         9T16137323   442                    I20
SOURCE305 GOOCARO CITY       9T3433T400   422                    I20
SOURCE306 NE SEOGWICK CO.    971503T52I   1T8                    I20
SOURCE307 NW SEOGWICK CO.    9T3233T493   268                    I20
SITE T20 HARVEY CO. L*FILL     1 9T230 38C05 I              1060
SITE 730 BROOKS TRACT          I 9T23I 3T454 I             14000
PRC1     820 LANOFILL                0 I
PRC2  2        I               I                                           820
LNKI    2                                                                  820
PRCOST 11                    530                                           820
PRCI     830 LANOFILL                0 1
PRC2  2        I               I                                           830
LNKI    2                                                                  830
PRCOST 1I                    293                                           830
SIPROC 720 820    0I                            0
SIPROC T30 830    0I                            0
TRANS I I00 100 T30
TRANS 1 I01 101 730
TRANS 1 102 102 T30
TRANS 1 200 20C 720
TRANS 1 201 201 T20
TRANS 1 300 300 T30
TRANS 1 301 301 T30
TRANS 1 302 302 T30
TRANS I 303 303 T30
TRANS 1 304 304 T30
TRANS 1 305 305 T30
TRANS 1 306 306 T30
TRANS 1 307 30T 730
```

Figure F.9

Output Run 3

S U M M A R Y   O F   W R A P   O P T I M I Z A T I O N
****

M A T R I X   S I Z E
****

NUMBER OF ROWS = 17
NUMBER OF COLUMNS = 33
NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX = 34
THE ACTUAL SIZE OF THE (A) MATRIX IS 68 ELEMENTS

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

JOB TITLE

PRESENT SITUATION W/O RENO CO. L'FILL CROWFLY OPTION 1 ***RUN3***

EXECUTION MODE 1 *STATIC* 1 MODEL PERIODS
TOTAL PLANNING PERIOD IS 1 YEARS
MODEL PERIOD 1 HAS 1 YEARS
LAST PHASE=4 FORCING METHOD=1
STEEPEST DESCENT=1 TURNAROUND TIME= 20.0
NUMBER OF SOURCES 13
NUMBER OF SITES 2
NUMBER OF PROCESSES 2
NUMBER OF SITE/PROCESSES 2
NUMBER OF TRANSPORTATION 13
CROWFLY OPTION IN EFFECT 1
CONVERSION FACTOR 0.790
MAXIMUM RADIUS 100
STANDARD SPEED 30

***** SITE DATA INPUT *****

CODE	NAME	LONGITUDE DEG MIN	LATITUDE DEG MIN	SITE TYPE	PROC	COST	LAND
720	HARVEY CO. L'FILL	97 23.0	38 0.5	0	1	0.0	1060
730	BROOKS TRACT	97 23.1	37 45.4	0	1	0.0	14000

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
720	820	1	0	0.0	0.0	0.0	0.0	0
730	830	1	0	0.0	0.0	0.0	0.0	0

F.9 continued

W R A P

WASTE RESOURCE ALLOCATION PLANNING

STATIC MODEL RESULTS

OBJECTIVE VALUE IS 3046.5010 IN THOUSANDS OF DOLLARS PER YEAR INCLUDING ALL COSTS FROM LOADING OF PACKER TRUCKS

TOTAL TONNAGE IS 410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS 7.4215 PER TON

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO ULTIMATE FACILITY PAIRS)
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I D	DESTINATION NAME	I D	ACTIVITY LEVEL *	MODEL PERIOD
WEST RENO CO.	100	BROOKS TRACT	730	5.4000	1
HUTCHINSON CITY	101	BROOKS TRACT	730	31.9000	1
SE RENO CO.	102	BROOKS TRACT	730	4.1000	1
WEST HARVEY CO.	200	HARVEY CO. L'FILL	720	5.8000	1
NEWTON/E. HARVEY	201	HARVEY CO. L'FILL	720	10.9000	1
NE WICHITA CITY	300	BROOKS TRACT	730	58.7000	1
SE WICHITA CITY	301	BROOKS TRACT	730	43.2000	1
NW WICHITA CITY	302	BROOKS TRACT	730	64.6000	1
SW WICHITA CITY	303	BROOKS TRACT	730	54.9000	1
DERBY CITY	304	BROOKS TRACT	730	44.2000	1
GODDARD CITY	305	BROOKS TRACT	730	42.2000	1
NE SEDGWICK CO.	306	BROOKS TRACT	730	17.8000	1
NW SEDGWICK CO.	307	BROOKS TRACT	730	28.8000	1

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

SITE NAME	I D	PROCESS NAME	I D	ACTIVITY LEVEL *	LINEAR SEGMENT
HARVEY CO. L'FILL	720	LANDFILL	820	16.7000	1
BROOKS TRACT	730	LANDFILL	830	393.7993	1

Figure F.10

Optimal Landfill -- Run 4

```
CONTRL  1 4 1 2 2 1 1 2 0 0 1 1  13   4 4   4   0  0    20 10 10                  5 19
TITLE PRESENT SIIUATICN OPTIMIZE LANDFILL CONFIGURATION        ***RUN4***
CRWFLY  100  79  30
SOURLE100 WEST RENO CO.         9615037581   54              100
SOURCE101 HUTCHINSON CITY       9755038023  319              100
SOURCE102 SE RENO CO.           9746537541   41              100
SOURCE200 WEST HARVEY CO.       9730038000   58              120
SOURCE201 NEWTON/E. HARVEY      9715038023  109              120
SOURCE300 NE WICHITA CITY       9717337423  587              120
SOURCE301 SE WICHITA CITY       9717337400  432              120
SOURCE302 NW WICHITA CITY       9722337423  646              120
SOURCE303 SW WICHITA CITY       9722337400  549              120
SOURCE304 DERBY CITY            9716137323  442              120
SOURCE305 GODDARD CITY          9734337400  422              120
SOURCE306 NE SEDGWICK CO.       9715037521  178              120
SOURCE307 NW SEDGWICK CO.       9732337493  268              120
SITE 710 RENO CO. LANDFILL       1 98000 38023 1          616
SITE 720 HARVEY CO. L*FILL       1 97230 38005 1         1060
SITE 730 BROOKS TRACT            1 97231 37454 1        14000
SITE 510 DUMMY TS                1 97073 37223 1 0
PRC1     810 LANDFILL                  0 1
PRC2   2       1              1                                            810
LNK1     2 890    0                                                        810
PRCOST 11                      1190                                        810
PRC1     820 LANDFILL                  0 1
PRC2   2       1              1                                            820
LNK1     2 890    0                                                        820
PRCOST 11                        530                                       820
PRC1     830 LANDFILL                  0 1
PRC2   2       1              1                                            830
LNKI     2 890    0                                                        830
PRCOST 11                        293                                       830
PRC1     890 DUMMY TRANSFER STA.     A 2100      750 030
PRC2   2       1              2                                            890
LNK1     2   0                                                             890
LNKO   810 820 830    0                                                    890
PRCOST 11      570          55        85          303                      890
PRCOST 12      323         248        85          303                      890
SIPROC 710 810    01                                   0
SIPROC 720 820    01                                   0
SIPROC 730 830    01                                   0
SIPROC 510 890    12                                   A
/*
```

Figure F.11

Output Run 4

S U M M A R Y   O F   W R A P   O P T I M I Z A T I O N

M A T R I X   S I Z E

NUMBER OF ROWS = 21
NUMBER OF COLUMNS = 82
NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX = 126
THE ACTUAL SIZE CF THE (A) MATRIX IS 252 ELEMENTS

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

JOB TITLE

PRESENT SITUATION OPTIMIZE LANDFILL CCNFIGURATION *** RUN4 **

EXECUTION MODE 1 *STATIC* 1 MODEL PERIODS
TOTAL PLANNING PERIOD IS 10 YEARS
MODEL PERIOD 1 HAS 10 YEARS
LAST PHASE=4 FCRCING METHOD=1
STEEPEST DESCENT=1 TURNARCUND TIME= 20.0
NUMBER OF SOURCES 13
NUMBER CF SITES 4
NUMBER CF PROCESSES 4
NUMBER OF SITE/PRCCESSES 4
NUMBER CF TRANSPORTATION 0
CROWFLY OPTION IN EFFECT 2
CONVERSION FACTOR 0.790
MAXIMUM RADIUS 100
STANDARD SPEED 30

***** SITE DATA INPUT *****

CODE	NAME	LCNGITUDE DEG	LCNGITUDE MIN	LATITUDE DEG	LATITUDE MIN	SITE TYPE	SITE PROC	CCST	LAND
510	DUMMY TS	97	7.3	37	22.3	0	1	C.0	0
710	RENO CC. LANDFILL	98	0.0	38	2.3	0	1	0.0	616
720	HARVEY CO. L*FILL	97	23.0	38	0.5	0	1	0.0	1060
730	BROOKS TRACT	97	23.1	37	45.4	0	1	0.0	14000

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
510	890	12	0	0.0	0.0	0.0	0.0	A
710	810	1	0	0.0	0.0	0.0	0.0	0
720	820	1	0	0.0	0.0	0.0	0.0	0
730	830	1	0	0.0	0.0	0.0	0.0	0

F.11 continued

W R A P

WASTE RESOURCE ALLOCATION PLANNING

STATIC MODEL RESULTS

OBJECTIVE VALUE IS 2978.8208 IN THOUSANDS OF DOLLARS PER YEAR INCLUDING ALL COSTS FROM LOADING OF PACKER TRUCKS

TOTAL TONNAGE IS 410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS 7.2566 PER TON

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO ULTIMATE FACILITY PAIR(S)
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I D	DESTINATION NAME	I D	ACTIVITY LEVEL *	MODEL PERIOD
WEST RENO CO.	100	RENO CO. LANDFILL	710	5.3680	1
WEST RENO CO.	100	HARVEY CO. L'FILL	720	0.0310	1
HUTCHINSON CITY	101	RENO CO. LANDFILL	710	37.9000	1
SE RENO CO.	102	BROOKS TRACT	730	4.1000	1
WEST HARVEY CO.	200	HARVEY CO. L'FILL	720	5.8000	1
NEWTON/E. HARVEY	201	HARVEY CO. L'FILL	720	10.9000	1
NE WICHITA CITY	300	BROOKS TRACT	730	58.7000	1
SE WICHITA CITY	301	BROOKS TRACT	730	43.2000	1
NW WICHITA CITY	302	BROOKS TRACT	730	64.6000	1
SW WICHITA CITY	303	BROOKS TRACT	730	54.9000	1
DERBY CITY	304	BROOKS TRACT	730	44.2000	1
GODDARD CITY	305	BROOKS TRACT	730	42.2000	1
NE SEDGWICK CO.	306	BROOKS TRACT	730	17.8000	1
NW SEDGWICK CO.	307	BROOKS TRACT	730	26.8000	1

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

SITE NAME	I D	PROCESS NAME	I D	ACTIVITY LEVEL *	LINEAR SEGMENT
RENO CO. LANDFILL	710	LANDFILL	810	37.2679	1
HARVEY CO. L'FILL	720	LANDFILL	820	16.7318	1
BROOKS TRACT	730	LANDFILL	830	356.4988	1

Figure F.12

New Landfill -- Run 5

```
CONTRL  1 4 1 2 2 1 1 2 0 0 1 1  13   6 6   6   0  0    20  1010           5 19
TITLE NEW L*FILLS: COLLOC. RENO & N. SEDGWICK CO. CRWFLY2 ***RUN5***
CRWFLY  100  79  30
SOURCE100 WEST RENO CO.        9815037581   54                 100
SOURCE101 HUTCHINSON CITY      9755038023  319                 100
SOURCE102 SE RENO CO.          9746537541   41                 100
SOURCE200 WEST HARVEY CO.      9730038000   58                 120
SOURCE201 NEWTON/E. HARVEY     9715038023  109                 120
SOURCE300 NE WICHITA CITY      9717337423  587                 120
SOURCE301 SE WICHITA CITY      9717337400  432                 120
SOURCE302 NW WICHITA CITY      9722337423  646                 120
SOURCE303 SW WICHITA CITY      9722337400  549                 120
SOURCE304 DERBY CITY           9716137323  442                 120
SOURCE305 GODDARD CITY         9734337400  422                 120
SOURCE306 NE SEDGWICK CO.      9715037521  178                 120
SOURCE307 NW SEDGWICK CO.      9732337493  268                 120
SITE 710 RENO CO. LANDFILL       1 98000 38023 1            616
SITE 720 HARVEY CO. L*FILL       1 97230 38005 1           1060
SITE 730 BROCKS TRACT            1 97231 37454 1          14000
SITE 740 N. SEDGWICK CO.         1 97193 37503 1           5000
SITE 750 COLLOCATED RENO         1 98000 38023 1           1536
SITE 510 DUMMY TS                1 97073 37223 1 0
PRC1     810 LANDFILL                   0 1
PRC2   2        1           1                                            810
LNKI     2 890    0                                                      810
PRCOST  11                   1190                                        810
PRC1     820 LANDFILL                   0 1
PRC2   2        1           1                                            820
LNKI     2 890    0                                                      820
PRCOST 11                     530                                        820
PRC1     830 LANDFILL                   0 1
PRC2   2        1           1                                            830
LNKI     2 890    0                                                      830
PRCOST 11                     293                                        830
PRC1     840 N. SEDGWICK                0 2
PRC2   2        1           2                                            840
LNKI     2 890    0                                                      840
PRCOST 11      244        5       425          30625                     840
PRCOST 12      072       78       272          60                        840
PRC1     850 COLLOCATED RENO            0 2
PRC2   2        1           2                                            850
LNKI     2 890    0                                                      850
PRCOST 11      244        5       425          30625                     850
PRCOST 12      072       78       272          60                        850
PRC1     890 DUMMY TRANSFER STA.    A 2100    750 030
PRC2   2        1           2                                            890
LNKI     2    0                                                          890
LNKO   810 820 830 840 850    0                                          890
PRCOST 11      570       55        85          303                       890
PRCOST 12      323      248        85          303                       890
SIPROC 710 810    01                                 0
SIPROC 720 820    01                                 0
SIPROC 730 830    01                                 0
SIPROC 740 840    12                                 0
SIPROC 750 850    12                                 0
SIPROC 510 890    12                                 A
/*
```

Figure F.13

Output Run 5

W R A P

WASTE RESOURCE ALLOCATION PLANNING

JOB TITLE

NEW L*FILLS: COLLOC. RENO & N. SEDGWICK CO. CRWFLY2 ***RUN5***

```
EXECUTION MODE    1  *STATIC*    1 MODEL PERIODS
TOTAL PLANNING PERIOD IS 10 YEARS
          MODEL PERIOD 1 HAS 10 YEARS
LAST PHASE=4   FORCING METHOD=1
STEEPEST DESCENT=1   TURNAROUND TIME=  20.0
NUMBER OF SOURCES                    13
NUMBER OF SITES                       6
NUMBER OF PROCESSES                   6
NUMBER OF SITE/PROCESSES              6
NUMBER OF TRANSPORTATION              0
CROWFLY OPTION IN EFFECT              2
          CONVERSION FACTOR    0.790
          MAXIMUM RADIUS         100
          STANDARD SPEED          30
```

SUMMARY OF WRAP OPTIMIZATION
****

MATRIX SIZE
****

```
NUMBER OF ROWS     =  25
NUMBER OF COLUMNS  = 118
NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX =  194
THE ACTUAL SIZE OF THE (A) MATRIX IS  388 ELEMENTS
```

***** SITE DATA INPUT *****

CODE	NAME	LONGITUDE DEG	LONGITUDE MIN	LATITUDE DEG	LATITUDE MIN	SITE TYPE	PROC	COST	LAND
510	DUMMY TS	97	7.3	37	22.3	0	1	0.0	0
710	RENO CO. LANDFILL	98	0.0	38	2.3	0	1	0.0	616
720	HARVEY CO. L*FILL	97	23.0	38	0.5	0	1	0.0	1060
730	BROOKS TRACT	97	23.1	37	45.4	0	1	0.0	14000
740	N. SEDGWICK CO.	97	19.3	37	50.3	0	1	0.0	5000
750	COLLOCATED RENO	98	0.0	38	2.3	0	1	0.0	1536

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
510	890	12	0	0.0	0.0	0.0	0.0	A
710	810	1	0	0.0	0.0	0.0	0.0	0
720	820	1	0	0.0	0.0	0.0	0.0	0
730	830	1	0	0.0	0.0	0.0	0.0	0
740	840	12	0	0.0	0.0	0.0	0.0	0
750	850	12	0	0.0	0.0	0.0	0.0	0

F.13 continued

W R A P

WASTE RESOURCE ALLOCATION PLANNING

STATIC MODEL RESULTS

OBJECTIVE VALUE IS 2694.7061 IN THOUSANDS OF DOLLARS PER YEAR INCLUDING ALL COSTS FROM LOADING OF PACKER TRUCKS

TOTAL TONNAGE IS 410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS 6.5645 PER TON

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO ULTIMATE FACILITY PATHS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I O	DESTINATION NAME	I O	ACTIVITY LEVEL *	MODEL PERIOD
WEST RENO CO.	100	COLLOCATED RENO	750	5.3990	1
HUTCHINSON CITY	101	COLLOCATED RENO	750	31.6999	1
SE RENO CO.	102	COLLOCATED RENO	750	4.1000	1
WEST HARVEY CO.	200	HARVEY CO. L'FILL	720	5.4000	1
NEWTON/E. HARVEY	201	HARVEY CO. L'FILL	720	10.9000	1
NE WICHITA CITY	300	BROOKS TRACT	730	58.7000	1
SE WICHITA CITY	301	BROOKS TRACT	730	43.2000	1
NW WICHITA CITY	302	BROOKS TRACT	730	64.6000	1
SW WICHITA CITY	303	BROOKS TRACT	730	54.9000	1
DERBY CITY	304	BROOKS TRACT	730	44.2000	1
GODDARD CITY	305	BROOKS TRACT	730	42.2000	1
NE SEDGWICK CO.	306	BROOKS TRACT	730	17.8000	1
NW SEDGWICK CO.	307	BROOKS TRACT	730	26.8000	1

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

SITE NAME	I O	PROCESS NAME	I O	ACTIVITY LEVEL *	LINEAR SEGMENT
HARVEY CO. L'FILL	720	LANDFILL	820	16.7000	1
BROOKS TRACT	730	LANDFILL	830	352.3991	1
COLLOCATED RENO	750	COLLOCATED RENO	850	41.3989	2

Figure F.14

New Transfer Station -- Run 6

```
CONTRL  1 4 1 2 2 1 1 2 0 0 1 1  13   4 4   4   0  0    20 10 10          5 19
TITLE NEW  TRANSFER STATION IN HAVEN W/CROWFLY OPTION 2  ***RUN6***
CRWFLY  100  79  30
SOURCE100 WEST RENO CO.      9815037581   54                 100
SOURCE101 HUTCHINSON CITY    9755038023  319                 100
SOURCE102 SE RENO CO.        9746537541   41                 100
SOURCE200 WEST HARVEY CO.    9730038000   58                 120
SOURCE201 NEWTON/E. HARVEY   9715038023  109                 120
SOURCE300 NE WICHITA CITY    9717337423  567                 120
SOURCE301 SE WICHITA CITY    9717337400  432                 120
SOURCE302 NW WICHITA CITY    9722337423  646                 120
SOURCE303 SW WICHITA CITY    9722337400  549                 120
SOURCE304 DERBY CITY         9716137323  442                 120
SOURCE305 GODDARD CITY       9734337400  422                 120
SOURCE306 NE SEDGWICK CO.    9715037521  178                 120
SOURCE307 NW SEDGWICK CO.    9732337493  268                 120
SITE 710 RENO CO. LANDFILL     1 98000 38023 1            616
SITE 720 HARVEY CO. L*FILL     1 97230 38005 1           1060
SITE 730 BROOKS TRACT          1 97231 37454 1          14000
SITE 501 HAVEN TS              1 97465 37541 1 0
PRC1    810 LANDFILL               D 1
PRC2  2        1            1                                              810
LNKI    2 890   0                                                          810
PRCOST 11                  1190                                            810
PRC1    820 LANDFILL               0 1
PRC2  2        1            1                                              820
LNKI    2 890   0                                                          820
PRCOST 11                   530                                            820
PRC1    830 LANDFILL               0 1
PRC2  2        1            1                                              830
LNKI    2 890   0                                                          830
PRCOST 11                   293                                            830
PRC1    890 HAVEN TRANSFER STA.    A 2100     750 030
PRC2  2       -1            2                                              890
LNKI    2   0                                                              890
LNKO  810 820 830   0                                                      890
PRCOST 11    570          55       85         303                          890
PRCOST 12    323         248       85         303                          890
SIPROC 710 810   01                                  D
SIPROC 720 820   01                                  O
SIPROC 730 830   01                                  D
SIPROC 501 890   12                                  A
/*
```

Figure F.15

Output Run 6

S U M M A R Y   O F   W R A P   O P T I M I Z A T I O N
****

M A T R I X   S I Z E
****

NUMBER OF ROWS   = 21
NUMBER OF COLUMNS   = 82
NUMBER OF NON-ZERO ELEMENTS OF THE IA) MATRIX = 126
THE ACTUAL SIZE OF THE IA) MATRIX IS 252 ELEMENTS

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

JOB TITLE

NEW TRANSFER STATION IN HAVEN W/CROWFLY OPTION 2 ***RUN6***

EXECUTION MODE   1 *STATIC*   1 MODEL PERIODS
TOTAL PLANNING PERIOD IS 10 YEARS
MODEL PERIOD 1 HAS 10 YEARS
LAST PHASE=4   FORCING METHOD=1
STEEPEST DESCENT=1   TURNAROUND TIME= 20.0
NUMBER OF SOURCES 13
NUMBER OF SITES 4
NUMBER OF PROCESSES 4
NUMBER OF SITE/PROCESSES 4
NUMBER OF TRANSPORTATION 0
CROWFLY OPTION IN EFFECT 2
CONVERSION FACTOR 0.790
MAXIMUM RADIUS 100
STANDARD SPEED 30

***** SITE DATA INPUT *****

CODE	NAME	LONGITUDE DEG MIN	LATITUDE DEG MIN	SITE TYPE	PROC	COST	LAND
501	HAVEN TS	97 46.5	37 54.1	0	1	0.0	0
710	RENO CO. LANDFILL	98 0.0	38 2.3	0	1	0.0	616
720	HARVEY CO. L'FILL	97 23.0	38 0.5	0	1	0.0	1060
730	BROOKS TRACT	97 23.1	37 45.4	0	1	0.0	14000

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
501	890	12	0	0.0	0.0	0.0	0.0	A
710	810	1	0	0.0	0.0	0.0	0.0	0
720	820	1	0	0.0	0.0	0.0	0.0	0
730	830	1	0	0.0	0.0	0.0	0.0	0

F.15 continued

W R A P

W A S I E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

STATIC MOOEL RESULTS

OBJECTIYE VALUE IS 2938.6650 IN THOUSANDS OF OOLLARS PER YEAR INCLUDING ALL COSTS FRON LOAOING OF PACRER TRUCRS

TOTAL TONNAGE IS 410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS T.I5RR PER TON

TRANSPORTATION ACTIVITY LEVEL DATR FOR THE SOURCE TO ULTIMATE FACILITY PAIRIS)
*ACTIVITY LEVELS ARE IN THOUSANOS OF TONS PER YEAR

ORIGIN NAME	I O	OESTINATION NAME	I O	ACTIVITY LEVEL *	MOOEL PERIUO
WEST HARVEY CO.	200	HARVEY CO. L*FILL	T20	5.8000	I
NEWTON/E. HARVEY	201	HARVEY CO. L*FILL	T20	10.9000	I
NE WICHITA CITY	300	BROORS TRACT	T30	5R.T000	I
SE WICHITA CITY	301	BROORS TRACT	T30	43.2000	I
NW WICHITA CITY	302	BROOKS TRACT	T30	64.6000	I
SW WICHITA CITY	303	BROOKS TRACT	T30	54.9000	I
OERBY CITY	304	BROUKS TRACT	T30	44.2000	I
GODDARD CITY	305	RROOKS TRACT	T30	42.2000	I
NE SEDGWICK CO.	306	RROOKS TRACT	T30	17.8000	I
NW SEDGWICK CO.	30T	RROOKS TRACT	T30	26.8000	I

TRANSPORTATION ACTIVITY LEVEL OATA FOR THE INTERMEOIATE TO ULTIMATE FACILITY PAIRIS)
*ACIIVITY LEVELS ARE IN THOUSANOS OF TONS PER YEAR

ORIGIN SITE NAME	I O	ORIGIN PROCESS NAME	I O	OESTINATION SITE NAME	I O	ACTIVITY LEVEL *
HAYEN TS	501	HAVEN TRANSFER STA.	R90	RROOKS TRACT	T30	41.39R9

F.15 continued

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO INTERMEDIATE FACILITY PAIR(S)
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I O	DESTINATION NAME	I O	ACTIVITY LEVEL *	MODEL PERIOD
WEST RENO CO.	100	HAVEN TS	501	5.4000	1
HUTCHINSON CITY	101	HAVEN TS	501	31.9000	1
SE RENO CO.	102	HAVEN TS	501	4.1000	1

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

SITE NAME	I O	PROCESS NAME	I O	ACTIVITY LEVEL *	LINEAR SEGMENT
HAVEN TS	501	HAVEN TRANSFER STA.	890	41.3990	1
HARVEY CO. L'FILL	720	LANDFILL	820	16.7000	1
BROOKS TRACT	730	LANDFILL	830	393.7980	1

Figure F.16

Modular Incinerator with Private Financing
Run 7

```
CCNTRL  1 4 1 2 2 1 1 2 0 0 1 1  13   8 5   8   0  0    20 10 10            5 19
TITLE CPTIMUM MOO INC W/ OUMMY TS 4 SITES HANOLEO PVT FINANCING    * RUN7 *
CRWFLY  100  79  30
SCURCE10C WEST RENO CO.       9815037581   54                 1C0
SCURCE101 HUTCHINSCN CITY     9755038023  319                 1C0
SCURCE102 SE RENO CO.         9746537541   41                 100
SOURCE200 WEST HARVEY CO.     97300380C0   58                 120
SCURCE201 NEWTON/E.HARVEY     9715038C23  109                 120
SCURCE30C NE WICHITA CITY     9717337423  587                 120
SOURCE301 SE WICHITA CITY     9717337400  432                 120
SCURCE302 NW WICHITA CITY     9722337423  646                 120
SCURCE303 SW WICHITA CITY     9722337400  549                 120
SCURCE304 OERBY CITY          9716137323  442                 120
SCURCE305 GCOOARO CITY        97343374C0  422                 120
SOURCE306 NE SEOGWICK CO.     9715037521  178                 120
SOURCE307 NW SEOGWICK CO.     9732337493  268                 120
SITE 510 OUMMY TS              1 97073 37223 1 0
SITE 550 MORTON SALT MI        2 97573 38023 1 0
SITE 560 CENTRAL WICHITA MI    2 97194 37410 1 0
SITE 561 SE WICHITA MI         2 97150 37300 1 0
SITE 564 N WICHITA MI          2 97195 37451 1 0
SITE 710 RENO CO. LANOFILL     1 98000 38023 1            616
SITE 720 HARVEY CO. L*FILL     1 9723C 38005 1           1060
SITE 730 BROOKS TRACT          1 97231 37454 1          14000
PRC1     810 LANOFILL               0 1
PRC2  2         1          1                                            810
LNKI     2 890 900   0                                                  810
PRCOS1 11                   1190                                        810
PRC1     820 LANCFILL               0 1
PRC2  2         1          1                                            820
LNKI     2 890 900   0                                                  82C
PRCOST 11                    530                                        820
PRC1     83C LANCFILL               0 1
PRC2  2         1          1                                            830
LNKI     2 890 900   0                                                  830
PRCOST 11                    293                                        830
PRC1     890 OUMMY TRANSFER ST      A 2100    750 030
PRC2  2         1          2                                            890
LNKI     2   0                                                          890
LNKO  810 820 830 900   0                                               890
PRCCS1 11     570        55      85         303                         890
PRCCST 12     323       248      85         303                         890
PRC1     900 MOOULAR INC. 2001P0    8 2 33   1500 12
PRC2  2         1          1                                            900
LNKI     2 890   0                                                      900
LNKC  81C 820 830   0                                                   900
PRCCS1 11                    832                                        900
SIPRCC 51C 890   12                                 A
SIPRCC 550 900   01   52                            B
SIPRCC 560 900   01   52                            B
SIPRCC 561 900   01   52                            B
SIPRCC 564 900   01   52                            B
SIPRCC 710 81C   01                                 0
SIPRCC 720 820   C1                                 0
SIPRCC 730 830   01                                 0
/*
```

Figure F.17

Output Run 7

```
S U M M A R Y   O F   W R A P   O P T I M I Z A T I O N
*********************************************************

               M A T R I X   S I Z E
               *********************

            NUMBER OF ROWS      =  33
            NUMBER OF COLUMNS   = 166
  NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX =  282
  THE ACTUAL SIZE OF THE (A) MATRIX IS  564 ELEMENTS

                        W  R  A  P

  W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

                      JOB TITLE

OPTIMUM MOD INC W/ DUMMY TS 4 SITES HANDLED PVT FINANCING   *RUN7 *

          EXECUTION MODE   1  *STATIC*   1 MODEL PERIODS
          TOTAL PLANNING PERIOD IS 10 YEARS
                MODEL PERIOD 1 HAS 10 YEARS
          LAST PHASE=4   FORCING METHOD=1
          STEEPEST DESCENT=1   TURNAROUND TIME=  20.0
          NUMBER OF SOURCES                      13
          NUMBER OF SITES                         8
          NUMBER OF PROCESSES                     5
          NUMBER OF SITE/PROCESSES                8
          NUMBER OF TRANSPORTATION                0
          CROWFLY OPTION IN EFFECT                2
                CONVERSION FACTOR    0.790
                MAXIMUM RADIUS         100
                STANDARD SPEED          30
```

***** SITE DATA INPUT *****

CODE	NAME	LONGITUDE DEG	LONGITUDE MIN	LATITUDE DEG	LATITUDE MIN	SITE TYPE	SITE PROC	COST	LAND
510	DUMMY IS	97	7.3	37	22.3	0	1	0.0	0
550	MORTON SALT MI	97	57.3	36	2.3	1	1	0.0	0
560	CENTRAL WICHITA MI	97	19.4	37	41.0	1	1	0.0	0
561	SE WICHITA MI	97	15.0	37	30.0	1	1	0.0	0
564	N WICHITA MI	97	19.5	37	45.1	1	1	0.0	0
710	RENO CO. LANDFILL	98	0.0	38	2.3	0	1	0.0	616
720	HARVEY CO. L'FILL	97	23.0	38	0.5	0	1	0.0	1060
730	BROOKS TRACT	97	23.1	37	45.4	0	1	0.0	14000

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
510	890	12	0	0.0	0.0	0.0	0.0	A
550	900	1	52	0.0	0.0	0.0	0.0	B
560	900	1	52	0.0	0.0	0.0	0.0	B
561	900	1	52	0.0	0.0	0.0	0.0	B
564	900	1	52	0.0	0.0	0.0	0.0	B
710	810	1	0	0.0	0.0	0.0	0.0	0
720	820	1	0	0.0	0.0	0.0	0.0	0
730	830	1	0	0.0	0.0	0.0	0.0	0

F.17 continued

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

STATIC MODEL RESULTS

OBJECTIVE VALUE IS   2935.7891 IN THOUSANDS OF DOLLARS PER YEAR INCLUDING ALL COSTS FROM LOADING OF PACKER TRUCKS

TOTAL TONNAGE IS   410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS   7.157 PER TON

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO ULTIMATE FACILITY PAIR(S)
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I D	DESTINATION NAME	I D	ACTIVITY LEVEL *	MODEL PERIOD
WEST RENO CO.	100	RENO CO. LANDFILL	710	5.4000	1
SE RENO CO.	102	BROOKS TRACT	730	4.0990	1
WEST HARVEY CO.	200	HARVEY CO. L*FILL	720	5.8000	1
NEWTON/E.HARVEY	201	HARVEY CO. L*FILL	720	10.9000	1
NE WICHITA CITY	300	BROOKS TRACT	730	58.7000	1
SE WICHITA CITY	301	BROOKS TRACT	730	43.2000	1
NW WICHITA CITY	302	BROOKS TRACT	730	64.6000	1
SW WICHITA CITY	303	BROOKS TRACT	730	54.9000	1
DERBY CITY	304	BROOKS TRACT	730	44.2000	1
GODDARD CITY	305	BROOKS TRACT	730	42.2000	1
NE SEDGWICK CO.	306	BROOKS TRACT	730	17.8000	1
NW SEDGWICK CO.	307	BROOKS TRACT	730	26.8000	1

F.17 continued

TRANSPONTATION ACIIVIIY LEVEL DATA FOR THE SCURCE TO INTERMEDIATE FACILITY PAIR(S)
*ACIIVITY LEVELS ARE IN THOUSANDS CF TONS PER YEAR

ORIGIN NAME	I D	DESTINATION NAME	I D	ACTIVITY LEVEL *	MODEL PIRIOD
HUTCHINSON CITY	101	MONTON SALT MI	550	31.9000	I

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS CF TONS PER YEAR

SITE NAME	I D	PROCESS NAME	I D	ACTIVITY LEVEL *	LINEAR SEGMENT
MONTON SALT MI	550	MODULAR INC. 200TPD	900	31.9000	I
RENC CO. LANDFILL	710	LANDFILL	810	10.6635	I
HARVEY CO. L'FILL	720	LANDFILL	820	16.7800	I
BRCCKS IRACT	738	LANDFILL	830	356.4985	I

TRANSPORTATION ACTIVIIY LEVEL DATA FOR THE INTERMEDIATE TO ULTIMATE FACILITY PAIR(S)
*ACTIVIIY LEVELS ARE IN THOUSANDS CF TONS PER YEAR

ORIGIN SITE NAME	I D	ORIGIN PRCCESS NAME	I D	DESTINATION SITE NAME	I D	ACTIVITY LEVEL *	MOCEL PERIOD
MONTON SALT MI	550	MODULAN INC. 200TPD	900	RENO CO. 710	710	10.5269	I

Figure F.18

Modular Incinerator with Public Financing
Run 8

```
CONTRL  1 4 1 2 2 1 1 2.0 0 1 1  13   8 5   8   0  0    20 10 10              5 19
7ITLE OPTIMUM MOO INC W/ OUMMY TS 4 SI7ES HANOLEO PUB FINANCING
CRWFLY  100  79  30
SCURCE100 WEST RENO CO.       9815037581   54                100
SCURCE101 HU7CHINSCN CITY     9755038023  319                100
SCURCE102 SE RENO CO.         9746537541   41                100
SCURCE200 WEST HARVEY CO.     9730038000   58                120
SCURCE201 NEW7CN/E.HARVEY     9715038023  109                120
SCURCE300 NE WICHITA CITY     9717337423  587                120
SOURCE301 SE WICHI7A CI7Y     9717337400  432                120
SCURCE302 NW WICHI7A CI7Y     9722337423  646                120
SCURCE303 SW WICHI7A CITY     9722337400  549                120
SOURCE304 OERBY CI7Y          9716137323  442                120
SCURCE305 GOOOARO CI7Y        9734337400  422                120
SOURCE306 NE SEOGWICK CO.     9715037521  178                120
SCURCE307 NW SEOGWICK CO.     9732337493  268                120
SITE 510 OUMMY 7S               1 97073 37223 1 0
SI7E 550 MOR7ON SALT MI         2 97573 38023 1 0
SI7E 560 CEN7RAL WICHI7A MI     2 97194 37410 1 0
SITE 561 SE WICHITA MI          2 97150 37300 1 0
SI7E 584 N WICHI7A MI           2 97195 37451 1 0
SITE 710 RENO CO. LANOFILL      1 98000 38023 1             616
SI7E 720 HARVEY CO. L*FILL      1 97230 38005 1            1060
SI7E 730 BROOKS 7RAC7           1 97231 37454 1           14000
PRC1    810 LANCFILL                   0 1
PRC2  2        1               1                                            810
LNK1    2 890 900    0                                                      810
PRCOST 11                       1190                                        810
PRC1    820 LANOFILL                   0 1
PRC2  2        1               1                                            820
LNK1    2 890 900    C                                                      820
PRCOS7 11                        530                                        820
PRC1    830 LANOFILL                   0 1
PRC2  2        1               1                                            830
LNK1    2 890 900    0                                                      830
PRCOS7 11                        293                                        830
PRC1    890 OUMMY 7RANSFER S7      A 2100     750 030
PRC2  2        1               2                                            890
LNK1    .2   0                                                              890
LNKO  810 820 830 900    0                                                  890
PRCOS7 11     570       55      85        303                               890
PRCOS7 12     323      248      85        303                               890
PRC1    900 MOOULAR INC. 200TPO    8 2 33    1500 12
PRC2  2        1               1                                            900
LNK1    2 890    0                                                          900
LNKO  810 820 830    0                                                      900
PRCOST 11                       1483                                        900
SIPRCC 510 890   12                                        A
SIPRCC 550 900   01    52                                  8
SIPROC 560 900   01    52                                  8
SIPRCC 561 900   01    52                                  8
SIPRGC 564 900   01    52                                  8
SIPRCC 710 810   01                                        0
SIPRCC 720 820   01                                        0
SIPRGC 730 830   01                                        0
/*
```

Figure F.19

Output Run 8

S U M M A R Y   O F   W R A P   O P T I M I Z A T I O N
****

M A T R I X   S I Z E
****

NUMBER OF ROWS = 33
NUMBER OF COLUMNS = 166
NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX = 282
THE ACTUAL SIZE OF THE (A) MATRIX IS 564 ELEMENTS

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

JOB TITLE

OPTIMUM MOD INC W/ DUMMY TS 4 SITES HANDLED FUB FINANCING   *RUN8*

EXECUTION MODE 1 *STATIC* 1 MODEL PERIODS
TOTAL PLANNING PERIOD IS 10 YEARS
MODEL PERIOD 1 HAS 10 YEARS
LAST PHASE=4   FORCING METHOD=1
STEEPEST DESCENT=1   TURNAROUND TIME= 20.0
NUMBER OF SOURCES 13
NUMBER OF SITES 8
NUMBER OF PROCESSES 5
NUMBER OF SITE/PROCESSES 8
NUMBER OF TRANSPORTATION 0
CROWFLY OPTION IN EFFECT 2
CONVERSION FACTOR 0.790
MAXIMUM RADIUS 100
STANDARD SPEED 30

***** SITE DATA INPUT *****

CODE	NAME	LONGITUDE DEG MIN	LATITUDE DEG MIN	SITE TYPE	PROC	COST	LAND
510	DUMMY TS	97 7.3	37 22.3	0	1	0.0	0
550	MORTON SALT MI	97 57.3	38 2.3	1	1	0.0	0
560	CENTRAL WICHITA MI	97 19.4	37 41.0	1	1	0.0	0
561	SE WICHITA MI	97 15.0	37 30.0	1	1	0.0	0
564	N WICHITA MI	97 19.5	37 45.1	1	1	0.0	0
710	RENO CO. LANDFILL	98 0.0	38 2.3	0	1	0.0	616
720	HARVEY CO. L*FILL	97 23.0	38 0.5	0	1	0.0	1060
730	BROOKS TRACT	97 23.1	37 45.4	0	1	0.0	14000

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
510	890	12	0	0.0	0.0	0.0	0.0	A
550	900	1	52	0.0	0.0	0.0	0.0	B
560	900	1	52	0.0	0.0	0.0	0.0	B
561	900	1	52	0.0	0.0	0.0	0.0	B
564	900	1	52	0.0	0.0	0.0	0.0	E
710	810	1	0	0.0	0.0	0.0	0.0	D
720	820	1	0	0.0	0.0	0.0	0.0	D
730	830	1	0	0.0	0.0	0.0	0.0	D

F.19 continued

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

STATIC MODEL RESULTS

OBJECTIVE VALUE IS   2978.1227 IN THOUSANDS OF DOLLARS PER YEAR INCLUDING ACC COSTS FROM LOADING OF PACKER TRUCKS

TOTAL TONNAGE IS   410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS   1.2563 PER TON

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO ULTIMATE FACILITY PAIRS)
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I D	DESTINATION NAME	I D	ACTIVITY LEVEL *	MODEL PERIOD
WEST RENO CO.	100	RENO CO. LANDFILL	710	5.4000	1
HUTCHINSON CITY	101	RENO CO. LANDFILL	710	31.8679	1
HUTCHINSON CITY	101	BROOKS TRACT	730	0.0321	1
SE RENO CO.	102	BROOKS TRACT	730	4.0981	1
WEST HARVEY CO.	200	HARVEY CO. L*FILL	720	5.8000	1
NEWTON/E.HARVEY	201	HARVEY CO. L*FILL	720	10.9000	1
NE WICHITA CITY	300	BROOKS TRACT	730	58.7000	1
SE WICHITA CITY	301	BROOKS TRACT	730	43.2000	1
NW WICHITA CITY	302	BROOKS TRACT	730	64.6000	1
SW WICHITA CITY	303	BROOKS TRACT	730	54.9000	1
DERBY CITY	304	BROOKS TRACT	730	44.2000	1
GODDARD CITY	305	BROOKS TRACT	730	42.2000	1
NE SEDGWICK CO.	306	BROOKS TRACT	730	11.8000	1
NW SEDGWICK CO.	307	BROOKS TRACT	730	26.8000	1

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

SITE NAME	I D	PROCESS NAME	I D	ACTIVITY LEVEL *	LINEAR SEGMENT
RENO CO. LANDFILL	710	LANDFILL	810	37.2618	1
HARVEY CO. L*FILL	720	LANDFILL	820	16.7000	1
BROOKS TRACT	730	LANDFILL	830	356.5258	1

Figure F.20

Eight System Modular Incinerator Option
Run 9

```
CCNTRL  1 4 1 2 2 1 1 2 0 0 0 1 1  13  12 5  12   0  0    20 10 10             5 19
TITLE OPTIMUM MOO INC W/ OUMMY TS 8 SITES HANOLEO PVT FINANCING
CRWFLY  100  T9  30
SCURCE100 WEST RENO CO.       9815037581   54                 100
SOURCE101 HUTCHINSON CITY     9755038023  319                 100
SCURCE102 SE RENO CC.         9746537541   41                 100
SCURCE200 WEST HARVEY CO.     9730038000   58                 120
SCURCE201 NEW7CN/E.HARVEY     9715038023  109                 120
SCURCE300 NE WICHITA C17Y     9717337423  587                 120
SCURCE301 SE WICHITA C17Y     971733T400  432                 120
SCURCE302 NW WICHITA C17Y     9722337423  646                 120
SCURCE303 SW WICH17A C17Y     9722337400  549                 120
SOURCE304 OERBY CITY          9716137323  442                 120
SCURCE305 GOCOARC CITY        9734337400  422                 120
SCURCE306 NE SECGWICK CC.     9715037521  178                 120
SCURCE307 NW SECGWICK CC.     9732337493  268                 120
SITE 510 OUMMY TS               1 97C73 37223 1 0
SITE 550 MCRTCN SAL7 M1         2 97573 38023 1 0
SITE 551 CAREY SAL7 M1          2 97535 38030 1 0
SITE 552 CARGILL SALT M1        2 97551 38023 1 0
S17E 560 CENTRAL WICH17A M1     2 97194 37410 1 0
S17E 561 SE WICHITA M1          2 9715G 37300 1 0
S17E 562 SCUTH WICH17A M1       2 97190 37381 1 0
SITE 563 SW WICHITA M1          2 97225 37391 1 0
S17E 564 N WICH17A M1           2 9T195 3T451 1 0
SITE T10 RENC CC. LANCFILL      1 9600C 38023 1             616
SITE 720 HARVEY CO. L'FILL      1 9723C 38005 1            1060
S17E T30 BROCKS 7RACT           1 97231 37454 1           14000
PRC1     810 LANCFILL                 0 1
PRC2  2        1              1                                               810
LNK1     1 900    0                                                           810
PRCOST 11                      1190                                           810
PRC1     820 LANOFILL                 0 1
PRC2  2        1              1                                               820
LNK1     1 900    0                                                           820
PRCOST 11                        530                                          82C
PRC1     830 LANCFILL                 C 1
PRC2  2        1              1                                               830
LNK1     1 900    0                                                           830
PRCOST 11                        293                                          830
PRC1     890 OUMMY TRANSFER S7        A 2100    750 030
PRC2  2        1              2                                               89C
LNK1     2    C                                                               890
LNKO  900     C                                                               690
PRCOST 11     5T0        55       85         303                              89C
PRCOS7 12     323       248       85         303                              89C
PRC1     900 MOOULAR INC. 200TPO    8 2 33   1500 12
PRC2  2        1              1                                               900
LNK1     2 890    0                                                           900
LNKO  810 820 83C     0                                                       9C0
PRCOS7 11                        832                                          900
SIPRCC 510 850    12                                    A
SIPRCC 55C 9CC    01    52                              B
SIPRCC 551 9C0    01    52                              B
SIPRCC 552 9C0    C1    52                              B
SIPRCC 560 9CC    C1    52                              B
SIPRCC 561 9CC    01    52                              B
SIPRCC 562 9CC    01    52                              B
SIPRCC 563 9CC    01    52                              B
SIPRCC 564 9C0    C1    52                              B
SIPROC T10 810    01                                    0
SIPRCC T20 820    01                                    0
SIPRCC T30 830    01                                    0
/*
```

Figure F.21

Output Run 9

```
S U M M A R Y   O F   W R A P   O P T I M I Z A T I O N
*******************************************************



              M A T R I X   S I Z E
              *********************


         NUMBER OF ROWS      =  45
         NUMBER OF COLUMNS   = 208
   NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX =  354
   THE ACTUAL SIZE OF THE (A) MATRIX IS  708 ELEMENTS



                            W   R   A   P

   W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

                            JOB TITLE

 OPTIMUM MOD INC W/ DUMMY TS 8 SITES HANDLED PVT FINANCING   *RUN9 *


          EXECUTION MODE   1  *STATIC*   1 MODEL PERIODS
          TOTAL PLANNING PERIOD IS 10 YEARS
                  MODEL PERIOD 1 HAS 10 YEARS
          LAST PHASE=4   FORCING METHOD=1
          STEEPEST DESCENT=1   TURNAROUND TIME=  20.0
          NUMBER OF SOURCES                    13
          NUMBER OF SITES                      12
          NUMBER OF PROCESSES                   5
          NUMBER OF SITE/PROCESSES             12
          NUMBER OF TRANSPORTATION              0
          CROWFLY OPTION IN EFFECT              2
                  CONVERSION FACTOR   0.790
                  MAXIMUM RADIUS        100
                  STANDARD SPEED         30
```

F.21 continued

***** SITE DATA INPUT *****

CODE	NAME	LONGITUDE DEG	LONGITUDE MIN	LATITUDE DEG	LATITUDE MIN	SITE TYPE	SITE PROC	COST	LAND
510	DUMMY TS	97	7.3	37	22.3	0	1	0.0	0
550	MORTON SALT MI	97	57.3	38	2.3	1	1	0.0	0
551	CAREY SALT MI	97	53.5	38	3.0	1	1	0.0	0
552	CARGILL SALT MI	97	55.1	38	2.3	1	1	0.0	0
560	CENTRAL WICHITA MI	97	19.4	37	41.0	1	1	0.0	0
561	SE WICHITA MI	97	15.0	37	30.0	1	1	0.0	0
562	SOUTH WICHITA MI	97	19.0	37	38.1	1	1	0.0	0
563	SW WICHITA-MI	97	22.5	37	39.1	1	1	0.0	0
564	N WICHITA MI	97	19.5	37	45.1	1	1	0.0	0
710	RENO CO. LANDFILL	98	0.0	38	2.3	0	1	0.0	616
720	HARVEY CO. L'FILL	97	23.0	38	0.5	0	1	0.0	1060
730	BROOKS TRACT	97	23.1	37	45.4	0	1	0.0	14000

***** SITE/PROCESS DATA INPUT *****

SITE CODE	PROC CODE	SEG	CAPACITY	REVENUE $/PERIOD 1	2	3	4	LEVEL
510	890	12	0	0.0	0.0	0.0	0.0	A
550	900	1	52	0.0	0.0	0.0	0.0	B
551	900	1	52	0.0	0.0	0.0	0.0	B
552	900	1	52	0.0	0.0	0.0	0.0	B
560	900	1	52	0.0	0.0	0.0	0.0	B
561	900	1	52	0.0	0.0	0.0	0.0	B
562	900	1	52	0.0	0.0	0.0	0.0	B
563	900	1	52	0.0	0.0	0.0	0.0	B
564	900	1	52	0.0	0.0	0.0	0.0	B
710	810	1	0	0.0	0.0	0.0	0.0	D
720	820	1	0	0.0	0.0	0.0	0.0	D
730	830	1	0	0.0	0.0	0.0	0.0	D

F.21 continued

W R A P

W A S T E   R E S O U R C E   A L L O C A T I O N   P L A N N I N G

STATIC MODEL RESULTS

OBJECTIVE VALUE IS   6391.4258 IN THOUSANDS OF DOLLARS PER YEAR INCLUDING ALL COSTS FROM LOADING OF PACKER TRUCKS

TOTAL TONNAGE IS   410.4993 IN THOUSANDS OF TONS PER YEAR

AVERAGE SYSTEM COST IS   15.569   PER TON

TRANSPORTATION ACTIVITY LEVEL DATA FOR THE SOURCE TO INTERMEDIATE FACILITY PAIR(S)
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

ORIGIN NAME	I D	DESTINATION NAME	I D	ACTIVITY LEVEL *	MODEL PERIOD
WEST BEND CO.	100	MORTON SALT MI	550	5.4000	1
HUTCHINSON CITY	101	CARGILL SALT MI	552	31.9000	1
SE BEND CO.	102	MORTON SALT MI	550	4.1000	1
WEST HARVEY CO.	200	CAREY SALT MI	551	5.8000	1
NEWTON/E.HARVEY	201	CAREY SALT MI	551	10.9000	1
NE WICHITA CITY	300	CENTRAL WICHITA MI	560	44.9981	1
NE WICHITA CITY	300	SOUTH WICHITA MI	562	13.7018	1
SE WICHITA CITY	301	SE WICHITA MI	561	7.8017	1
SE WICHITA CITY	301	SOUTH WICHITA MI	562	35.3982	1
NW WICHITA CITY	302	CARGILL SALT MI	552	5.5980	1
NW WICHITA CITY	302	CENTRAL WICHITA MI	560	7.0019	1
NW WICHITA CITY	302	N WICHITA MI	564	52.0000	1
SW WICHITA CITY	303	SOUTH WICHITA MI	562	2.9000	1
SW WICHITA CITY	303	SW WICHITA MI	563	51.9999	1
DERBY CITY	304	SE WICHITA MI	561	44.1984	1
GODDARD CITY	305	MORTON SALT MI	550	36.9980	1
GODDARD CITY	305	CARGILL SALT MI	552	5.2020	1
NE SEDGWICK CO.	306	CAREY SALT MI	551	17.8000	1
NW SEDGWICK CO.	307	CAREY SALT MI	551	11.5000	1
NW SEDGWICK CO.	307	CARGILL SALT MI	552	9.3000	1

F.21 continued

ORIGIN SITE NAME	I O	ORIGIN PROCESS NAME	I O	DESTINATION SITE NAME	I O	ACTIVITY LEVEL *	MODEL PERIOD
MORTON SALT WI	550	MODULAR INC. 2001PO	900	RENO CO. LANDFILL	710	15.3442	1
CAREY SALT WI	551	MODULAR INC. 2001PO	900	RENO CO. LANDFILL	710	17.1599	1
CARGILL SALT WI	552	MODULAR INC. 2001PO	900	RENO CO. LANDFILL	710	17.1599	1
CENTRAL WICHITA WI	560	MODULAR INC. 2001PO	900	BROOKS TRACT	730	17.1599	1
SE WICHITA WI	561	MODULAR INC. 2001PO	900	BROOKS TRACT	730	17.1600	1
SOUTH WICHITA WI	562	MODULAR INC. 2001PO	900	BROOKS TRACT	730	17.1599	1
SW WICHITA WI	563	MODULAR INC. 2001PO	900	BROOKS TRACT	730	17.1599	1
N WICHITA WI	564	MODULAR INC. 2001PO	900	BROOKS TRACT	730	17.1600	1

PROCESSING ACTIVITY LEVELS
*ACTIVITY LEVELS ARE IN THOUSANDS OF TONS PER YEAR

SITE NAME	I O	PROCESS NAME	I O	ACTIVITY LEVEL *	LINEAR SEGMENT
MORTON SALT WI	550	MODULAR INC. 2001PO	900	46.4979	1
CAREY SALT WI	551	MODULAR INC. 2001PO	900	51.9999	1
CARGILL SALT WI	552	MODULAR INC. 2001PO	900	51.9998	1
CENTRAL WICHITA WI	560	MODULAR INC. 2001PO	900	51.9999	1
SE WICHITA WI	561	MODULAR INC. 2001PO	900	52.0000	1
SOUTH WICHITA WI	562	MODULAR INC. 2001PO	900	51.9999	1
SW WICHITA WI	563	MODULAR INC. 2001PO	900	51.9999	1
N WICHITA WI	564	MODULAR INC. 2001PO	900	52.0000	1
RENO CO. LANDFILL	710	LANDFILL	810	24.8319	1
BROOKS TRACT	730	LANDFILL	830	42.9000	1

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APPLICATION OF THE WASTE RESOURCES ALLOCATION PROGRAM (WRAP) IN THE SEDGWICK-RENO-HARVEY COUNTY REGION

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ABSTRACT

Approximately 175 million tons of solid waste were generated by American consumers and commercial interests in 1980. The rising costs of disposal and collection, the increasing cost and decreasing supply of land, elimination of the Resource Conservation and Recovery (RCRA) grants to aid in implementation and planning of comprehensive solid waste management programs and the complex and confusing array of altenatives that resource recovery planning impose on local decision-makers give rise to strong pressures towards the regionalization of solid waste management functions. Acknowledging technical and political issues becomes a basis for accepting a regional resource recovery plan.

A tool available to city planners to use in assessing resource recovery plans is the Waste Resources Allocation Program (WRAP). WRAP is a fixed-charge linear programming model that determines a minimum cost solution for a centralized resource recovery plan. The model balances the economies of scale of centralization of capacitated processes versus the costs of transportation which increase relative to the size of the region.

The WRAP model was applied to the Sedgwick-Reno-Harvey County region which is located in south-central Kansas. The counties had actively investigated the study of resource recovery as an alternative to landfilling of municipal solid wastes. Modular incinerators were suggested as an alternative method of resource recovery.

The WRAP model indicated that the addition of a new landfill in Reno County would be the least cost solution. Modular incinerators were also recommended by the model for Reno County, but not in the remainder of the region. The low cost of landfilling in those other areas probably accounts for this fact.

WRAP is a powerful planning tool, but with limitations. Process and haul costs, and total amounts of solid wastes generated in the region must be determined by the user. This data set can take considerable time and money to collect. However, the user can apply data previously calculated, as long as the assumptions of that data set are clearly understood and presented.