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U.S. DEPARTMENT OF COMMERCE/National Bureau of Standards

# The Resource Recovery Planning Model: A New Tool for Solid Waste Management

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# The Resource Recovery Planning Model: A New Tool for Solid Waste Management

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## PREFACE

This research was conducted under the sponsorship of the Office of Recycled Materials, National Measurement Laboratory, National Bureau of Standards (NBS), by the Operations Research Division, Center for Applied Mathematics, National Engineering Laboratory, NBS. The Resource Recovery Planning (RRPLAN) model described in this report is an outgrowth of a cooperative project between the Office of Recycled Materials, the Operation Research Division, and Edward B. Berman Associates, Inc. The RRPLAN model is designed with three purposes in mind. First and foremost, is the ability to generate a preferred plan for resource recovery. Second, is the capability to evaluate a scenario specified by the decision maker for technical and economic feasibility. Third, is its use as a tool to facilitate the decision making process by providing answers to many what-if questions through an in-depth sensitivity analysis.

The RRPLAN model is a part of a larger program specified for the Office of Recycled Materials in the Resource Conservation and Recovery Act of 1976 (P.L. 94-580). This legislation directs the Secretary of Commerce, acting through NBS, to hold public hearings and publish guidelines for the development of specifications. These specifications are needed for the classification of materials which can be recovered from wastes now destined for disposal.

One of the goals of the Resource Conservation and Recovery Act, as it relates to this project, is to provide a framework for fostering the advances required to promote a more efficient mix of economic and environmental factors associated with the disposal and subsequent recovery and/or reuse of resources contained in municipal solid waste. The RRPLAN model addresses this goal by providing a methodology for the economic assessment of current and potential technologies, market potentials, and institutional barriers to resource conservation and recovery. The model is designed for use by both the public and private sectors in seeking to analyze the economic issues associated with alternative solid waste management programs.

EXECUTIVE SUMMARY

Solid waste management is among the most complex municipal or regional
governmental tasks facing policy makers today. The physical problem of where
to locate the facilities is further complicated by the increasing costs of
disposal, new technologies, environmental regulations and the unavailability
of land for landfill. The problem becomes even more difficult when one notes
that solid waste management facilities may exhibit economies of scale in
construction and processing. This implies that the benefits associated with
lower per unit processing costs can only be achieved through regionalization.
However, the process of regionalization creates two fundamental problems:
(1) the complexity of the regional system design; and (2) the need for
political consensus. Both of these problems have to be addressed by
developing and clearly presenting technical and economic data about the
consequences of various regional approaches. Finally, by opting for
regionalization, decision makers must weigh the benefits of reduced processing
costs against the risk of cost overruns which are inherent in large
construction projects.

Over the past decade, there has been a proliferation of mathematical models
attacking such issues as facility location, vehicle routing and manpower
planning. Due to unrealistic data requirements or the complexity of using and
interpreting the model's results, the application of these models to the solid
waste management problem has often been disappointing. More recent modeling
approaches have attempted to couple the analytical power of the computer with
the ability to organize the thoughts of the decision maker systematically so
that important pieces of information are not overlooked. From these
experiences, it is possible to define a set of criteria that any model which
purports to deal with solid waste management problems should satisfy. At a
minimum, the model should be able to capture explicitly the effects of
alternative financial and cost-sharing arrangements, allow for economies of
scale, and be amenable to sensitivity analysis associated with a well-chosen
set of what-if questions.

Although the general solid waste management problem poses some formidable
difficulties to decision makers, the economics of resource recovery is
significantly more complicated, requiring an in-depth analysis of facility
design and cost as well as market size, structure and location. In order to
address these complicating factors, RRPLAN deals with two interdependent
issues. On the one hand, RRPLAN explicitly incorporates potential economies
of scale in the construction and operation of a solid waste processing
facility. The model is thus able to support the basic tradeoff of savings
from centralized processing versus the costs of additional haul required to
bring it about. On the other hand, RRPLAN uses a detailed cost accounting
system to attack the economic issues, carefully measuring the effects on
overall program costs due to decisions affecting siting, routing, marketing
and financing. By integrating the technical issues of processing with these
four major decision points, RRPLAN permits a wide variety of questions to be
examined carefully.

In reality, RRPLAN is a descendant of two earlier models. These models are known as WRAP (Waste Resource Allocation Program) and RAMP (Recovery And Market Planning). Both models were developed by the Mitre Corporation, the former through funding from the Environmental Protection Agency. There are substantial differences between RRPLAN, WRAP and RAMP, especially regarding their software support systems and their treatment of market structure. The major focus of WRAP is on the identification of a preferred plan which includes the best candidate sites, the appropriate processing and disposal technology at each site, the sizing of each site and all transportation linkages among centers of waste generation, processing sites, and disposal sites. A major weakness of WRAP is its implicit assumption that any market for recoverables (e.g., ferrous products and newsprint) is unlimited. If market saturation is an important consideration, then WRAP's solution would represent an overly optimistic plan which could lead to serious cash flow problems if the plan were implemented. RAMP adds the saturation effect by incorporating both declining price and limited size markets. RRPLAN incorporates all of the capabilities of WRAP and RAMP, as well as numerous enhancements which render its cost accounting system far superior to those used in its predecessors. Furthermore, its more reasonable data requirements than WRAP's coupled with the type and nature of its output should permit RRPLAN to greatly facilitate the regional planning and decision making processes. RRPLAN adds a sophisticated cost model, built-in source-separation options, an automatic dedicated transfer station function, user-defined cost, energy, and commodity categories, and an extensive analysis of costs by source and site (including a projected full-cost tipping fee for each site).

A case study of a hypothetical region is used to carefully illustrate the types of analysis which can be performed by RRPLAN. Once the user has worked through the case study presented in this report, they should be able to handle a wide variety of solid waste management problems.

It is anticipated that the use of this model should result in significant savings in costs and physical resources. An additional benefit associated with the use of RRPLAN is its ability to help decision makers weigh the risks associated with alternative regional plans. For example, the repeated use of the model, based on a carefully formulated set of what-if questions, may point to areas where potential savings running into the tens of millions of dollars over a typical planning period could accrue to the community, and what risks the comunity would have to accept to achieve these savings.

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# 1. INTRODUCTION

## 1.1 BACKGROUND

The problem of identifying cost-effective methods for processing a region's solid waste stream goes beyond the identification of sites which are politically feasible. As fiscal pressures on communities increase, the economics of waste disposal becomes an ever more important issue. Resource recovery may be an attractive alternative, providing planners with the potential for reducing the costs of processing the region's waste stream while conserving valuable land, material and energy resources. The economics of resource recovery is significantly more complicated than other alternatives however, requiring an in-depth analysis of facility design and cost as well as market size, structure and location.

The Resource Recovery Planning (RRPLAN) model was especially designed to address the complicating factors mentioned above. On the one hand, RRPLAN explicitly incorporates potential economies of scale in the construction and operation of a solid waste processing facility. The model is thus able to support the basic tradeoff of savings from centralized processing versus the costs of additional haul required to bring it about. On the other hand, RRPLAN uses a detailed cost accounting system to attack the economic issues, carefully measuring the effects on overall program costs due to decisions affecting siting, routing, marketing and financing. By integrating the technical issues of processing with these four major decision points, RRPLAN permits a wide variety of questions to be examined carefully.

RRPLAN was developed in a cooperative program under the sponsorship of the National Bureau of Standards' Office of Recycled Materials by Edward B. Berman Associates, Inc., with the direct support of the NBS's Center for Applied Mathematics. RRPLAN has been tested extensively through pilot study applications to data from the State of Louisiana, central Mississippi, the California Solid Waste Management Board, and New York City. Members of the NBS team met with representatives of each region studied to discuss the implications that the use of the model would have on project planning and implementation. The clarity with which the implications of various assumptions could be measured stimulated numerous discussions, indicating that the model may be used extensively by solid waste management officials. A series of mini-tutorials on the model were presented to officials from Mississippi, New York and California. A two-day workshop for a broad cross section of solid waste management officials was presented in September of 1982. The workshop was sponsored by NBS, the Association of State and Territorial Solid Waste Management Officials, the Government Refuse Collection and Disposal Association, Inc., and the U.S. Conference of Mayors.

## 1.2  Purpose

The purpose of this report is to present a non-technical description of the RRPLAN computer program.  The model was designed to handle a full range of solid waste management problems, ranging from the basic landfill option to complex marketing arrangements for recoverables as special cases.  The basic philosophy behind the model is one of optimization.  This approach was taken because it permits the economic and engineering data associated with the problem (e.g., waste generation rates and the location of processing facilities) to be organized in an objective manner.  Although the model can focus on energy as its main objective, we believe that the minimization of the costs of processing a region's solid waste stream will be the objective most often emphasized by decision makers.  To a certain degree, one could think of RRPLAN as a sieve which reveals those policy scenarios which have the greatest potential for reducing costs.  Once a scenario, or series of scenarios, have been identified, the group carrying out the study can perform a detailed analysis of its various components (e.g., fleet composition and vehicle routing).  It is important to point out that the use of the model, as envisioned by its developers, is iterative.  Thus, whenever the model is exercised, the user should formulate a number of questions which represent variations about some baseline scenario.  In this way the user can gain valuable insights into how changing circumstances or assumptions affect costs and processing decisions.

## 1.3  Scope and Approach

The documentation for the RRPLAN computer program is divided into two parts, a User's Manual and a Programmer's Manual, each of which is designed to be self-contained and hence may be used independently.  The first part, which includes this document, is designed to serve as a User's Manual.  This approach was taken because most users are not concerned with the internal workings of the program.  On the other hand, it is frequently useful for the programmer, who has the responsibility of both setting up the program on the host system as well as making changes to the source code which reflect user demands or peculiarities of the operating system, to have access to the User's Manual so that changes can be made in the most efficient manner.

The RRPLAN computer program is outlined in chapter 2.  A description of the philosophy and methodology behind RRPLAN is given first, followed by a discussion of the data requirements, the various options available to the user, as well as some of the limitations of the program.

Chapter 3 consists of a detailed example in which all inputs to the RRPLAN computer program are carefully discussed.  The chapter uses a hypothetical evaluation of several communities in the Northeastern portion of the Commonwealth of Massachusetts as a means of illustration.  A complete set of

worksheets designed especially for the RRPLAN computer program are then presented. The chapter includes a sample input deck of computer cards as well as a discussion of what each item means and where it should be placed in the input deck.

The output associated with the example constructed in chapter 3 is analyzed in chapter 4. This chapter aims at both illustrating the types of output reports produced by RRPLAN as well as a line-by-line description of what the output means. Three major categories of output reports will be analyzed.

The fifth chapter provides a set of guidelines for making efficient use of the RRPLAN computer program. Topics discussed which are thought to be of interest to a large group of users include: (1) how to effectively find and correct input errors when they occur; (2) when and how to use a particular combination of options; (3) how to handle large or unusually complex problems; and (4) how to batch runs so that a sensitivity analysis can be performed both quickly and efficiently.

The report also includes two technical appendices which describe each input variable in greater detail than permitted in chapter 3 and provide a cross walk between the worksheets and the input deck.

The companion report[1], which serves as a Programmer's Manual, focuses on the more technical aspects of the RRPLAN program documentation. A mathematical discussion of the computer program serves to introduce the basic philosophy behind the algorithm. Each routine is described, focusing on such topics as: (1) purpose; (2) calling sequence; (3) common blocks used; and (4) reports produced. A functional description of the model is used to facilitate the task of setting up RRPLAN on a user's computer system. A series of tests are outlined which should permit programmers to verify if the model produces correct solutions. The program is written in FORTRAN and complies with the guidelines set down in the ANSI X3.9-1978 software standard.[2]

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[1]E.B. Berman, R.E. Chapman and H.K. Hung, <u>Program Documentation for the Resource Recovery Planning Model</u>, National Bureau of Standards, NBSIR (in preparation).

[2]American National Standards Institute, <u>American National Standard Programming Language FORTRAN</u>, ANSI X3.9-1978, New York, 1978.

## 2. THE RESOURCE RECOVERY PLANNING (RRPLAN) MODEL

### 2.1 OVERVIEW

Solid waste management is among the most complex municipal or regional governmental tasks facing policy makers today. The nonhomogeneous composition of the waste stream has resulted in a proliferation of approaches for handling the problem. Finding the best approach is complicated by noting that some communities have used mathematical models and met with little success whereas others have not and were able to achieve some reasonable solution. Over the last decade, many mathematical models have been developed and implemented with varying degrees of success.[1] Although small communities would not need an elaborate model, techniques from engineering economics based on life cycle costing can still be quite useful in containing costs.[2] Perhaps the greatest advantage offered by models however, is the way in which they help organize the thoughts of the decision maker so that important pieces of information are not overlooked. More recent modeling approaches have focused on this point; consequently, reliance on these models should produce useful results in dealing with the overall problem.

The RRPLAN model described in this report may be thought of as a descendant of two earlier models. These models are known as WRAP (Waste Resource Allocation Program) and RAMP (Recovery And Market Planning). Both models were developed by the Mitre Corporation, the former through funding from the Environmental Protection Agency.[3] There are substantial differences between the two models, especially regarding their software support systems and their treatment of market structure. Both models use the same optimizer as RRPLAN. In WRAP, as in RRPLAN, a front end is available to build the equations for input into the optimizer, and a back end is available to interpret the solution. In RAMP, a more sophisticated equation structure is available, including the full market structure in RRPLAN, but the user must prepare equations for direct input into the optimizer, and must interpret its solution. The major focus of WRAP is on the identification of a preferred plan which includes the best candidate sites, the appropriate processing and disposal technology at each site, the sizing of each site and all transportation linkages among centers of waste generation, processing sites, and disposal sites. A major weakness of WRAP is

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[1]J.C. Liebman, "Models in Solid Waste Management," in S. Gass and R. Sisson, A Guide to Models in Governmental Planning and Operations, (Potomac, Maryland: Sauger Books, 1975), pp. 139-164.

[2]Analysts who wish to study a small region should consult the report by Barton and MacAuley before attempting to use the RRPLAN model. (D.R. Barton and P. MacAuley, An Economic Analysis of Resource Recovery Facilities and Waste Newspaper Recycling, Bureau of Industrial Economics, U.S. Department of Commerce, August 1982.)

[3]Documentation for WRAP is included in the following reports: E.B. Berman, WRAP-A Model for Regional Solid Waste Planning: User's Guide, U.S. Environmental Protection Agency, SW-574, 1977; and V. Hensey, WRAP-A Model for Regional Solid Waste Planning: Programmer's Manual, U.S. Environmental Protection Agency, SW-573, 1977. All documentation for RAMP is included in the following report: Use of RAMP (Recovery And Market Planning) For The Evaluation of Policy Issues in Resource Recovery, mimeo, undated.

its implicit assumption that any market for recoverables (e.g., ferrous products and newsprint) is unlimited. If market saturation is an important consideration, then WRAP's solution would represent an overly optimistic plan which could lead to serious cash flow problems if the plan were implemented. RAMP adds the saturation effect by incorporating both declining price and limited size markets.

As the description of the RRPLAN model unfolds, it will become evident that it incorporates all of the capabilities of WRAP and RAMP, as well as numerous enhancements which render its cost accounting system far superior to those used in its predecessors. Furthermore, its more reasonable data requirements than WRAP coupled with the type and nature of its output should permit RRPLAN to greatly facilitate the regional planning and decision making processes. RRPLAN adds a sophisticated cost model, built-in source-separation options, an automatic dedicated transfer station function, user-defined cost, energy, and commodity categories, an extensive analysis of costs by source and site (including a projected full-cost tipping fee for each site), four new optimizing modes, and two new forcing modes. These will all be described in detail in this manual.

2.2  METHODOLOGY

RRPLAN is a computer model designed with three purposes in mind. First and foremost, is the ability to generate a preferred plan for resource recovery. Second, is the capability to evaluate a scenario specified by the decision maker for technical and economic feasibility. Third, is its use as a tool to facilitate the decision making process by providing answers to many what-if questions through an in-depth sensitivity analysis.

The model has five basic modes of optimization. Each mode serves to define the type of objective which is to be minimized or maximized. The first two modes of optimization minimize the total cost of the regional plan over a specified planning period. If both the timing and magnitude of cash flows are important, then the discounted costs of the regional plan should be minimized. If only the magnitude of cash flows is important, then undiscounted costs should be minimized. It is important to note that the choice of discounted rather than undiscounted costs, or vice versa, may cause both the costs of the plan and the physical flows within the system to differ. The first mode, minimize lifetime discounted cost, is the preferred criterion for plan selection and evaluation. The third mode of operation seeks to maximize the net energy (energy produced (saved) from (due to) resource recovery activities minus all other energy inputs) of the regional plan. Such an objective function might be useful in comparing various waste-to-energy programs. The fourth mode of operation seeks to minimize a linear form (weighted sum) of program cost and net energy categories. This approach might prove useful in comparing mixtures of traditional and waste-to-energy programs if some form of matching formula for funds was in effect and will permit the user to weight cost or energy categories other than equally. The final mode of operation focuses on the topic of scenario evaluation. For example, a region may have a proposed plan which needs to be evaluated from the viewpoint of technical and economic feasibility. Typical questions addressed under this mode of operation would include the following. Are all facilities able to process

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the indicated waste stream without exceeding their rated capacity, or that of plants down the line which they feed into? Can resources be reallocated so that overall costs are reduced?

In order to handle the five types of objectives just discussed, RRPLAN includes a set of cost categories, energy categories, and commodities. Cost categories are the heart of RRPLAN's accounting system. They are included so that the differential impacts of the regional plan on the various segments of the population, as well as financial transfers into the region from marketing activities, can be measured. Individual cost categories are classified as either operating (i.e. annual recurring costs) or capital. Each cost category has a cost growth scenario (differential inflation rate) associated with it, so that it may increase more (or less) rapidly than the general rate of inflation. Financial arrangements are explicit in all capital cost accounting. All capital items, except those currently in use, are assumed to be purchased at the beginning of the planning period. Replacements which occur within the planning period are inflated by the differential inflation rate from the first year of the planning period to the year of replacement. A standard amortization calculation is used to generate an annual cost for each year of the capitalization of the loan. That cost is deflated by the general inflation rate from the year of cost to the year of purchase to represent the decline in constant dollars through time after the cost is fixed in current dollars by the act of purchase. A series of cost summation categories permit the user to aggregate cost categories having differential inflation rates, useful lives, etc., into a single cost summation category for further analysis. Energy categories may be handled in a similar manner. The model greatly facilitates the process of performing a detailed cost analysis, once a solution has been found, by leaving the user ample opportunity to define the types of commodities processed and sold (e.g., municipal solid waste (MSW) and steam). The use of separate commodity categories also permits one to measure the effects of differential transportation costs (e.g., handling MSW versus newsprint) as well as cost-sharing arrangements for processing and/or revenue-sharing arrangements among municipalities for marketing activities.

The basic structure of RRPLAN consists of a set of equations and activities relating sources of solid wastes, sites where the wastes can be processed and markets for energy or recovered materials. The model begins with the sources of solid waste (e.g., a community in a region or a district in a metropolitan area). Each source has associated with it a location, an estimated waste generation figure, a series of options for preseparating paper, glass and cans, and a set of transportation linkages to sites where the waste is processed. Sites, as used in RRPLAN, may contain a landfill, a transfer station, an incinerator without heat recovery, or a resource recovery facility. Each site has associated with it a location, the type of processes it can accommodate (referred to as site-process combinations), the operating and capital costs required to process the wastes, capacity considerations, outputs of wastes and marketable items, and transportation linkages. The model can handle markets with downward sloping demand curves, and with constraints on capacity, as well as ones which can receive unlimited quantities of recoverables. Each market has associated with it a location, a

revenue schedule, and transportation linkages. The equations require all wastes to be transported to a site for processing, all wastes arriving at a site to be processed, all outputs of a site to be processed or sold, and that no capacities are exceeded. The activities in the model represent physical flows (e.g., the amount of waste incinerated at a particular site).

The model approaches the difficult problem of siting and sizing solid waste processing facilities by first approximating non linearities in the capital and operating cost functions with up to three linear segments. Each segment has an intercept (a fixed charge) and a slope (an incremental cost associated with increased processing activities). The introduction of fixed charges imposes certain complications, causing the solution domain to be lumpy. This requires a specially designed optimization technique to generate meaningful solutions. The technique used in RRPLAN involves a fixed-charge linear programming algorithm with a forcing procedure to insure that the model can pass over an area of temporarily increasing cost in the solution domain (i.e., a lump) to find the true optimum.[1] RRPLAN adds new methods of forcing representing a significant improvement over methods used in other models[2] in which each site (or site-process combination) which was in the solution is forced out of the solution and vice versa. This approach permits the solution domain to be searched in a more coordinated way by operating on all activities (e.g., transportation, processing, marketing) associated with a particular site (or site-process combination).

Figure 2.1 shows the major physical system details, where it can be seen that the physical flows represented in the model include the basic concepts discussed earlier: sources; sites; markets; and transportation linkages. Figure 2.1 is, however, merely a capsule summary of the overall problem because it focuses on the management of a single source's wastes. In reality there are numerous sources, causing the array of linkages to become inter-twined.

The first point of interest in the figure is the source of waste, or "waste generation zone." At this point RRPLAN permits the user to offer two types of source separation for consideration or to ship the mixed MSW directly to a processing facility. Under the first source separation scenario, it is assumed that all paper, glass and cans are removed from the waste stream, sent to a central collection point, and then shipped to the respective market. This option is referred to as unconditional source separation. Under the second source separation scenario, paper, glass and cans are always removed

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[1] W.E. Walker, "A Heuristic Adjacent Extreme Point Algorithm for the Fixed Charge Problem," Management Science, Vol. 22 (1976), pp. 587-596.

[2] RRPLAN approaches the forcing issue in a more coherent manner than does WRAP. WRAP's method of single or double column (i.e., activity) forcing are of questionable efficiency, particularly where a site is linked to three or more sources or other sites. Column forcing operates from within the optimizer, and is therefore blind in the sense that there is no information within the optimizer on what the various columns (activities) represent.

Figure 2.1   How RRPLAN Addresses the Economics of Resource Recovery
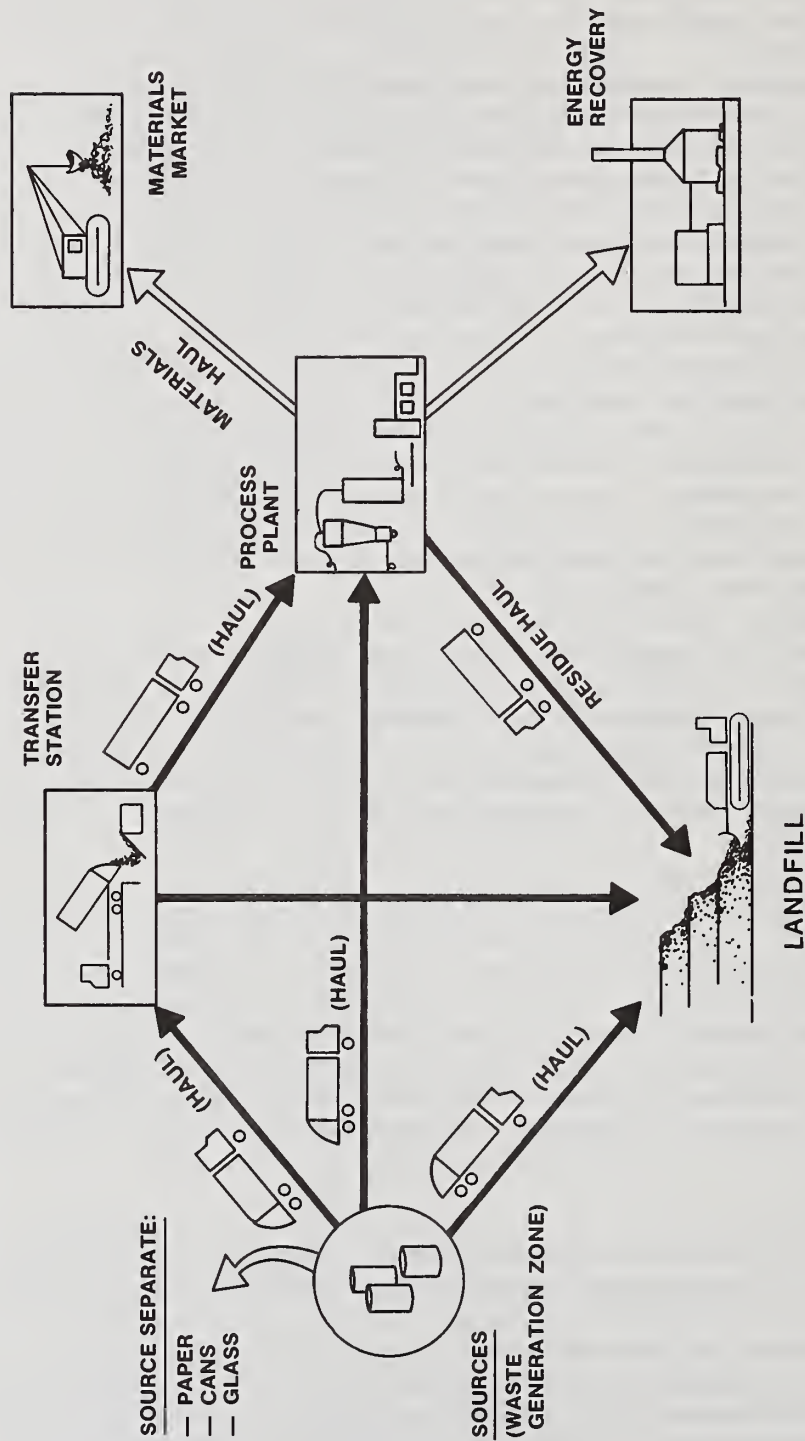
but paper is treated separately. As in the previous scenario, cans and glass are sent to the central collection point and marketed. Paper, on the other hand, is put to two possible uses which reflect both its fiber value in recycling and its energy value in combustion. This option is referred to as conditional source separation. The rationale behind this scenario is as follows. If the price of paper exceeds some prespecified price (up to five such "trigger" prices are available) then it will be marketed for its fiber value; otherwise the paper will be burned.[1] If multiple options are offered at a source, the model picks the preferred source-separation option. The transportation linkages emanating from the source are coded to represent whether the link is carrying wastes or recoverables. The same coding system is used throughout the diagram. If source separated paper, cans and glass (or any other marketable commodity) are to be shipped to the market, then they flow along the clear linkage. If, on the other hand, mixed MSW or the residue from source separation is to be shipped, then it flows along the shaded linkage. Note that all wastes generated enter into transportation. From a source, it is assumed that all wastes are hauled to either a transfer station, a processing plant, or a landfill. The mode of transportation is assumed to be in a packer having a capacity of approximately 5 tons. At the sites where processing occurs, the wastes and/or processed residues can be loaded onto larger vehicles referred to as vans. These vehicles are used with high volume transport because they have significantly lower costs per ton mile of haul.

Turning now to the sites where processing takes place, it can be seen that the transfer station collects the wastes from packers and loads it onto vans for shipment either to a processing plant or a landfill. The landfill is the ultimate disposal site, receiving wastes hauled from the sources in packers and from transfer stations and processing plants in vans. Consider now the processing plant, where, for purposes of illustration, we shall assume some form of resource recovery takes place.[2] The shaded linkages coming into the plant require all wastes which arrive to be processed. Similarly, all commodities which leave the plant must be disposed of (shaded linkage) or sold (clear linkages).

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[1]The facility may have a heat recovery system in which case additional revenues would be generated from the use of waste paper as a fuel supplement.

[2]It is not necessary that any form of resource recovery take place at a site. In fact all wastes can be landfilled. Such an option would represent a meaningful baseline against which resource recovery could be compared. A related point has to do with the number of processing plants which can be placed in series. RRPLAN puts no constraints on one processing plant receiving the output of another. Thus process residue from an incinerator could be reprocessed for use as an additive for road surfacing or for patching material, or for materials recovery.

Each transportation, processing, and marketing activity has associated with it a set of costs. For transportation, this includes the periodic replacement of the rolling stock as well as the cost of physically hauling the wastes or recoverables. The facilities where processing takes place require greater care in cost accounting. For example, there may be site preparation costs (e.g., access roads) on top of the plant construction costs and the normal costs of day-to-day operations. Whereas no economies of scale are assumed in transportation, they are admissible for both facility construction and all future processing activities. Cost curves representing economies of scale can be approximated by up to three linear segments, each with a slope and an intercept. In this way the model can capture the basic trade off of savings from centralized processing versus the costs of additional haul required to bring it about. In addition to costs, each processing plant can be capacitated.[1] The setting of a capacity could be based on either political or technical constraints. Setting a capacity could thus prevent the model from shipping to a single site more waste than would be technically or politically feasible.

Two types of markets are also shown in the diagram. RRPLAN treats the markets for energy (e.g., steam or electricity) and materials in a much more comprehensive manner than WRAP. RRPLAN can handle four types of market structure. These structures are: (1) unlimited fixed price markets; (2) capacitated fixed price markets; (3) declining price markets with no upper limit; and (4) capacitated declining price markets. An example of an unlimited fixed price market might be an electric utility which will purchase any amount of electricity from the plant at a flat rate of 4¢ per kWh. An example of a capacitated declining price market might be a nearby industrial facility which will purchase process steam for $3 per K (thousand) lbs for the first 900 M (million) lbs; but will pay only $2 per K lbs for the next 900 M lbs; and can not productively use the steam above 1800 M lbs. The market is considered saturated at 1800 M lbs. RRPLAN also permits revenue sharing arrangements among municipalities to be incorporated into the market analysis.

Figure 2.2 provides a capsule summary of the way the RRPLAN model is organized. As a first step, the values of all major variables are initialized prior to the reading of any user input data. The input, as will be shown in detail in the next chapter, is divided into three files. All three files are represented as a single deck of cards on the flowchart. Data from the first (case study) file are read in a special sequence. These cards include information which sets control values, provides data on cost and energy categories, the types of waste and recoverable commodities considered, data on sources, sites, landfills, processing options and markets, as well as directions for extracting data from the packer and van distance files. After each card is read, the MAIN program checks the critical variables to determine if they are within tolerance and in the proper sequence. If either of these error types (i.e., out of tolerance or improper sequence) is encountered, a

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[1] A plant (or market) which is capacitated has an upper limit on the amount of wastes (recoverables) that can be processed in a given unit of time (e.g., 1000 tons per day).

message will be written out to the user which should facilitate the process of finding and correcting it. The program will then stop. If no problem was encountered, the input data are formatted and printed back for the user. In this way the user can verify inputs as well as distinguish among a series of runs for the same case. The model reads each major type of data from a series of loops within the MAIN program. The ranges on the loops are specified by the information on the control card. Once all data from the case study file have been read, screened, and output, the packer and van distance files will be read. This portion of the MAIN program matches up the directions from the case study file with the distances[1] in the packer and van distance files. If a distance is missing (e.g., the case study file indicated that shipments from source A to site X were to take place but no distance from A to X was recorded) then the program writes a message to that effect and stops. The message should enable the user to find the location causing the problem. The specific problem can then be isolated by reviewing the data contained in the files. Transportation linkages are input in the case study file and are specified as: (1) source-to-site; (2) site-to-site; and (3) site-to-market. After the files are read, the source-to-site category is expanded. The degree of its expansion depends on the source separation options offered and the type of paper market prevailing in the region.

The application problem, referred to hereafter as the A matrix, is then constructed from the input data. Each row of the A matrix corresponds to an equation; each column corresponds to an activity. The rows and columns of the A matrix are defined in tables 2.1 and 2.2, respectively. If a data inconsistency or sizing error results, a message is written to the user to facilitate debugging and the program stops. If no error results, the MAIN program calls the optimizer to solve the problem stored in the A matrix.

The optimizer (or linear programming module) which is contained in the rectangular box of figure 2.2 consists of numerous subroutines. Those readers who wish a detailed description of the optimizer are referred to the Programmer's Manual.

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[1]As shown in section 3.3, the distances are measured in terms of miles, minutes, thousands of dollars per commodity unit, or dollars per ton as selected by the user.

Figure 2.2  Model Organization



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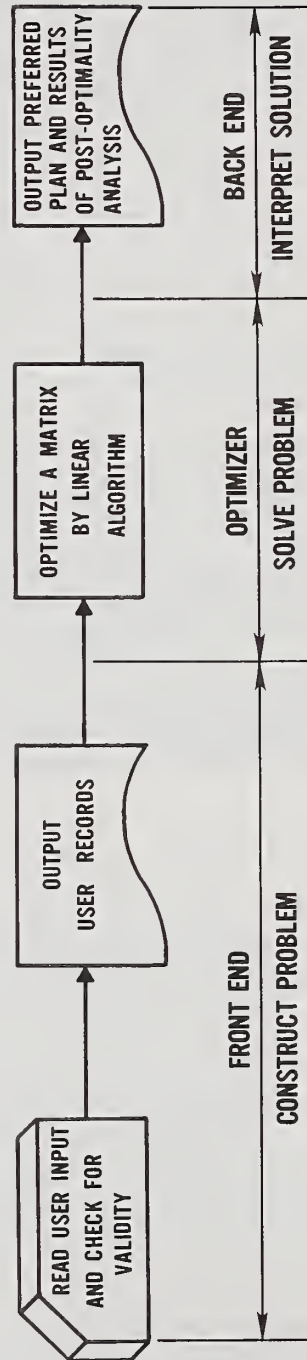
Table 2.1  Equations Used by RRPLAN

| Equation Type | Purpose |
|---|---|
| Source balance equations | Requires all waste generated at each source to be entered into transportation. |
| Source paper balance equations | Requires all source-separated paper to be entered into transportation. |
| Site input residue balance equations | Generates a residue activity at a site equal to the residue arriving at the site. |
| Site input paper balance equations | Generates a paper activity at a site equal to the paper arriving at the site. |
| Site input balance equations for MSW and other commodities | Requires the total amount of MSW and other commodities arriving at a site to equal the amount of processing activity at the site. |
| Site output balance equations | Generates transportation activities of a commodity from a site equal to the process output of the commodity at that site. |
| Market input balance equations | Generates a total market activity equal to the amount of the commodity arriving at the market. |
| Site capacity constraints | Insures that processing at a site does not exceed capacity. |
| Land capacity constraints | Insures that land use does not exceed land available at any landfill. |
| Market bounds | Requires the sum of activity at a market in segments less than or equal to the jth ($1 \leqslant j \leqslant 5$) segment to be less than or equal to the jth cumulative bound for the market. |
| Constraint on artificial processing activities | Provides an upper bound for artificial activities. |

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Table 2.2  Activities Considered by RRPLAN

| Activity | Purpose |
| --- | --- |
| Transportation category 2 | Site-to-site shipments. |
| Transportation category 3 | Site-to-market shipments. |
| Transportation category 4 | Source-to-site shipments of unseparated MSW. |
| Transportation category 5 | Source-to-site shipments of unconditional source separated MSW (national paper market). |
| Transportation category 6 | Source-to-site shipments of unconditional source separated MSW (local paper market). |
| Transportation category 8 | Source-to-site shipments of preseparated paper (local paper market). |
| Transportation category 9 | Source-to-market shipments of preseparated paper (local paper market). |
| Transportation categories 11-15 | Source-to-site shipments of conditional source separated MSW (national paper market with 1 to 5 trigger prices). |
| Residue activities | Measures thousands of tons per year of source-separated residue arriving at a site. |
| Paper activities | Measures thousands of tons per year of source-separated paper arriving at a site. |
| Process activities | Measures number of commodity units processed per year per linear segment at a site. |
| Market activities | Measures number of commodity units purchased per year per linear segment at a market. |
| Artificial processing activities | Take on epsilon values to preserve structure. |
| NZ | Relieves infeasibilities associated with an advanced starting point. |
| NZX | Relieves infeasibilities when evaluating a prespecified plan. |

The final symbol shown in figure 2.2 represents the output of solutions found by the optimizer. All logic for this portion of the model is contained in the MAIN program. Since the outputs will be discussed in detail in chapter 4, only the major points will be touched upon in this section. The first solution output consists of transportation activities in the solution. These activities are printed out according to their transportation category number (see table 2.2). The output includes the category number, the origin location, the destination location, the commodity shipped, and the number of commodity units shipped per year (e.g. M lbs of steam).

The second output summarizes the process activity levels. Pass-through processing (the residue from source separation or source-separated paper) is listed first followed by a site-by-site description of processing. This information includes the site name and number, the process name and number, the location where processing is carried out, the linear segment on the cost function where processing takes place, the commodity and number of commodity units processed, and, if appropriate, the percent of capacity at which the plant operates. Information on dedicated transfer stations[1] and landfills are then presented.

The third type of solution output is concerned with the market activities appearing in the solution. Summary data for each market are output in sequence. A separate line of output is given for each segment of the market demand function (there may be up to five market segments). Cumulative sales and cumulative revenues for each market are also given. Information on sales and revenue of source-separated paper, cans and glass are then given. Implicit revenues (e.g., revenues from recoverables not explicitly traded or marketed by the model) are then presented by site. A revenue summary showing yearly averages for explicit commodities net of haul to the market (e.g. gross revenues minus haul costs), source separated recoverables net of haul to the market, implicit (net) revenues and total net revenues is then printed out. Both discounted and undiscounted values are output for the revenue categories just mentioned. The fourth solution output is an analytical summary. It contains such items as the total tons of waste handled, the lifetime cost (both discounted and undiscounted), an accounting of costs by category and, if appropriate, information on energy categories.

RRPLAN also includes tracing. Tracing was incorporated into RRPLAN because three types of splits may occur in the solution due to site capacity constraints, landfill contraints and market limits. First, sources may be split among offload sites. Second, sites may be split among the processes offered. Finally, commodities arising from outputs of a process may be split among offload sites and markets. Optional routing requests are also included

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[1]The model will consider siting a transfer station at each source in order to reduce the overall costs of the plan. For large communities this may be a wise approach because the savings in haul costs may greatly exceed the capital costs of the facility. The user has the option to suppress the dedicated transfer station logic if so desired. The choice of a dedicated transfer station at a source does not affect the size of the matrix.

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in tracing. For example, consider a site where wastes can be processed. In this case, the procedure will trace all site splits, through the output coefficients of each process, and commodity splits, to a series of sites and markets. The final tracing output summarizes source and site costs. These costs include linkage and offload costs for sources and on-site and net off-site costs. The site cost is a projected full-cost tipping fee for each site in the solution.

## 2.3  ASSUMPTIONS AND LIMITATIONS

The purpose of this section is to review RRPLAN's major technical under-pinnings and to alert potential users to certain issues which, if ignored, could reduce the usefulness of the model's output. The two most important assumptions are related to the mathematical structure of the problem and the concept of "forcing". Two related, but less important, assumptions are concerned with the allocation of fixed charges (costs) among the various activities and the model's basic waste generation scenario. All other topics discussed in this section are associated with limitations on the size of the problem which RRPLAN can handle.

The model provides for increasing returns to scale (i.e., declining costs -- economies of scale) in the process cost functions, and provides for decreasing returns to scale in the market revenue functions. The model edit-checks the latter, but for the former, the user should make sure, for a multiple-segment process, that: (1) a higher segment has a higher intercept cost; (2) that a higher segment has a lower slope cost; (3) that all intercepts are non-negative (actually the sum of site preparation cost and the intercept should be non-negative); (4) the crossing point between the first and second segment functions is at a positive scale, and the crossing point between the second and third segment functions is to the right of that (i.e., at a greater scale).

Chapter 5 provides two procedures for the case of a process cost function which shows first increasing and then decreasing returns to scale. The second of which is fully consistent with a single-run application for optimal plan generation.

The forcing concept as used in RRPLAN points out an important difference between pure and approximate methods of optimization. In pure optimization the emphasis is on finding a single solution which can be proven to be better than all alternatives. Approximate optimization methods use rules which exploit the mathematical structure of the problem but do not necessarily find the "best" solution. Such methods are referred to as heuristics. The forcing technique employed by RRPLAN uses such an approach to explore the solution domain systematically.

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The choice of the optimization method is dictated by both processing costs and the required accuracy of the solution. With regard to processing costs, it is not uncommon that solutions generated by heuristics will cost only a quarter as much as those generated by a pure optimization technique. Consequently, if the heuristic is also likely to produce a solution which is nearly optimal, then the reduced costs to users would probably far outweigh the loss of precision associated with not finding the "best" solution. In an earlier study,[1] the original version of the optimizer, which lacked the enhancements incorporated into RRPLAN, was used to solve a wide range of fixed charge problems. For this set of case studies, the original heuristic was shown to be from 2 to 835 times faster than a typical pure optimization method. The heuristic failed to get the optimum solution in only two of the problems posed. In both cases however, the minimum cost solution produced by the heuristic differed by less than 2 percent from the true optimum.

Although RRPLAN uses a fixed charge algorithm to generate a preferred regional plan, the cost functions of most activities do not have any fixed charges associated with them. Within the framework of RRPLAN it is assumed that only site-specific or site-process specific cost functions have fixed charges. It is not necessary for site-specific or site-process specific costs to contain any fixed charges. The program overhead required for including them is available, however. The cost functions associated with all other activities are precluded from using fixed charges by the program overhead. Thus the cost functions associated with any transportation activities (e.g., source-to-site shipments of MSW) consist only of variable costs. This assumption can easily be justified.[2]

Although RRPLAN explicitly allows for cost growth due to inflation, the rate at which wastes are generated is assumed to remain constant over the entire planning period.[3] This may strike some users as odd, especially if the region's resources for processing the waste stream are nearly saturated. The no growth scenario does however avoid a major pitfall; namely oversizing a

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[1]W.E. Walker, op. cit.

[2]The rolling stock associated with transportation activities are mobile (hence easily moved to and from a market), they have short useful lives, and a large and active resale market. Acquiring them does not represent a commitment in the same way as acquiring immobile, inflexible, long useful-life facilities and equipment. Furthermore, rolling stock is too mobile to build up economy-of-scale relations with any one link in the model.

[3]Tonnage growth can only be provided within the context of a dynamic model. Such models are extremely demanding on matrix size, however. The use of a comparative static approach permits cost growth scenarios to be incorporated without requiring the addition of any rows or columns. The fixed tonnages can represent early period tonnages, late period tonnages, or anything in between.

facility on the belief that operation and maintenance costs will be falling over time as the plant draws in even larger volumes of MSW. This may in fact be the case for some regions. On the other hand, the costs of resource recovery, and hence any comparative advantage it may have over the status quo, are likely to be highly sensitive to two factors. These factors are the level of waste processed (which affects both operation and maintenance costs as well as marketing opportunities) and the capital cost of the facility. If the facility was oversized based on projected growth rates and these rates were not experienced (say due to an aggressive source separation program prompted by local demand) the costs per ton could become excessive. Such problems could render resource recovery economically unattractive. Techniques for analyzing growth scenarios through a series of runs within which the overall planning period is subdivided are discussed in chapter 5.

As a means of protecting the optimizer from ill-formed problems, the model edit-checks almost all of the variables input by the user. However, special attention is given to those variables which affect the size of the problem (through the construction of the A matrix) or the model's cost accounting system. Since chapter 3 will consist of a line-by-line discussion of the inputs, including their permissible range, this section will focus on only those variables which have the greatest impact on the size of the problem.

The A matrix is currently sized for a maximum of 90 rows (equations) and 360 columns (activities). The types of equations and activities which make up the A matrix were defined in tables 2.1 and 2.2; a formula for computing each dimension of the A matrix is presented and described in chapter 5. The matrix is designed to be sparse (mostly zeroes) but it may have up to 8100 non-zero elements. If the user wishes to exercise the double column forcing option, then the maximum size of the A matrix is 50 rows by 100 columns. This limitation can be relaxed to 90 rows by 360 columns with the use of an override control. Since the site or site-process forcing options are almost certainly superior to double column forcing, the use of the override is not recommended for large problems. The input variable names, their purpose and allowable values are given in table 2.3. It is important to point out that if several of the key input variables are set at their maximum value during the course of a single run, the maximum size of the A matrix is likely to be exceeded. It is for this reason that a formula for computing the size of the A matrix prior to execution is included in chapter 5. With regard to transportation activities, linkages must be provided from each source and to each market. If unconditional source separation is offered in a region with a local paper market, then the linkages to the local paper market will be generated by the model. Process input linkages to each site must be provided as well as process output linkages designated for shipment to other sites for additional processing or disposal.

Table 2.3 Allowable Ranges for Key Variables Affecting Problem Size

| Input Variable Name | Purpose of Variable | Minimum Value | Maximum Value |
|---|---|---|---|
| NSU | Number of sources | 1 | 60 |
| NSI | Number of sites | 1 | 50 |
| NPR | Number of processes | 2[a] | 30 |
| NSEG(J) | Number of segments per process | 1 | 3 |
| NCOF(J) | Number of output coefficients[b] | 0 | 7 |
| NSP | Number of site-process combinations | 1 | 80 |
| NLA | Number of landfills | 0[c] | 30 |
| NMK | Number of markets | 0[d] | 30 |
| NSGMK(J) | Number of segments per market | 1 | 5 |
| --- | Number of transportation activities[e] | 1 | 300 |

[a]The first process must be a new transfer station.

[b]By products of processing (e.g., incinerated ferrous or ash).

[c]There must be at least one landfill for each location at which a land-using process is offered (see section 3.2 for additional details).

[d]There must be at least one market if source separation is offered and the region contains a local paper market.

[e]After expansion (see section 3.3 for additional details).

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## 3. INPUT DATA REQUIREMENTS

There are three basic types of data required as inputs in order to run RRPLAN. The first type specifies the level of detail in the cost accounting system and the interrelationships among sources, sites/processes, and markets. The second and third types are distance tables for packer and van hauls, respectively. Once all data have been collected and collated, each of the three data types just mentioned may be referred to as a file. Such a file could represent either a deck of cards which the user would input each time it was desired to run the program, or a mass storage data file which the operating system would call and read.

### 3.1 DATA COLLECTION AND MAINTENANCE FOR THE RRPLAN MODEL

by
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In order to insure that the values for the input files are accurate, it was necessary to design a set of data collection worksheets which describes each part of the data set including how it fits into the overall pattern. It is important to point out that most data is either region specific or generic. For example, the amount of MSW generated by each source and the transportation network are region specific whereas the techniques used for procesing MSW are generic. This has an important consequence for data collection. Based on past experiences where solid waste management officials cooperated with the NBS team in order to exercise the model, the common concern focused on the accuracy of the cost estimates for constructing and operating the processing facilities. In almost every other case it was concluded that the region specific data required to run the model could be obtained with only a modest commitment of time and resources. With regard to the data on construction and operating costs however, it is possible to utilize information on similar projects which have been planned or built as a starting point.[1] These generic data should serve to reveal those processes which are economically the most attractive. From that point, it then becomes possible to perform a series of engineering studies where one or more target configurations are explored in detail. This approach should lead to more successful applications because it serves to allocate engineering funds to areas where they will have the greatest payoff rather than using a shotgun approach which may not allocate enough time and energy to get the required detail to differentiate among competing designs. As more precise data become available, the model can be rerun, and used to examine the answers to such questions as the effect on the plan associated with a change in the financing rate or changes in the composition of the waste stream.

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[1] If generic cost data are used it will most likely be necessary to adjust not only for regional price differentials in the markets for labor services and building materials, but also to adjust for cost growth over time. All three types of cost factors are readily available from construction industry publications.

The way in which the information collected on the worksheets would be organized into a complete input deck is illustrated through reference to a hypothetical case example treating some communities in Northeastern Massachusetts. This example will be used in various capacities throughout the remainder of the report. The example is deliberately kept simple to reinforce the major concepts. It is recommended that each user try and reconstruct the data files for this example and run it prior to performing any studies of their own. This should permit the users to gain confidence in finding errors due to incorrect alignment, data transpositions, etc., where a known correct deck can serve as a standard reference point. It will also help the user to see how the various components of the output fit together when viewed as a single unit. A line-by-line description of the input deck is given in order to promote a more complete understanding of how the model reads, checks and organizes the input data.

The following discussion presents a hypothetical case designed to test the program. Figures should not be taken as indicative of any processing or contractual arrangements. The four communities of Lynn, Marblehead, Salem, and Revere were considered the four sources of MSW for the entire region. The region also included two waste-to-steam site-processes — one at Saugus, the other at Worcester. Each of these processes has an associated steam market — the General Electric Company's River Works Division at Lynn for the Saugus site and the City of Worcester for the Worcester site. The Saugus site includes a secondary processor which recovers materials from the residue and an on-site landfill for burying residues left from the two Saugus processes and for any inputs that can not be accepted by the waste-to-steam facility. The region has one landfill available — the Amesbury Landfill. There is also an unlimited market available for incinerated ferrous materials in New York City.

In order to utilize the model effectively, users must research, collect, and record in an orderly fashion various types of input data. A series of thirteen data collection worksheets have been developed for aiding this purpose and are presented in this section of the report. The presentation of the data collection worksheets is divided into two parts. Each worksheet is presented along with a brief description on its use in the form of an interpretation or guideline. A technical appendix illustrates how the worksheets look when completed for the Northeastern Massachusetts case example.

When completing the worksheets shown as exhibits 3.1 through 3.13, some care must be exercised in order to insure that all units are compatible. The flexibility given to the user to select the commodities which will be analyzed by the model requires careful planning regarding transportation flows and processing and marketing activities. Both costs and net energy are likely to be sensitive to the commodities being hauled, processed or marketed. Therefore, in order to provide a common basis for approaching the specific information on the worksheets, a brief description will be presented which aims at classifying the data requested on each of the worksheets.

The basic units of the model are thousand tons and thousand dollars. Most cost inputs may be entered in dollars per ton because that is equivalent to thousand dollars per thousand tons. The two exceptions are:

(1) intercept costs must be entered in thousands of dollars; and

(2) if the user has defined the unit of a commodity in other than thousand tons, the cost inputs into its process should be in thousands of dollars per commodity unit.

For better correspondence with cost inputs, it is recommended that the energy equivalent of the various cost-per-ton inputs be one-thousandth of the energy unit per ton, with two exceptions corresponding to the two cost exceptions:

(1) intercept energy inputs must be entered in full energy inputs; and

(2) if the user has defined the unit of a commodity in other than thousand tons, the energy inputs into a process of which it is the input commodity should be in full energy units per commodity unit.

The first worksheet relates to general information about various indices, the composition of MSW, its heat value, collection costs and market prices for source separated commodities. All information related to the discount rate and the inflation rate is to be recorded in percent per year, whereas information on the composition of the solid waste stream is to be recorded as what percent of the total a particular component (e.g., glass) accounts for. All energy values recorded on the first part of Worksheet I are to be in million BTU (MBTU) per ton. The energy requirements for all other questions are determined by the energy categories declared under question 13 of the second part of Worksheet I. The cost categories associated with these costs and revenues are declared under question 14. Question 9 requires a set of ratios where the costs of processing a ton of source separated paper and residue are used as the numerator and the cost of processing a ton MSW as the denominator.

The second worksheet deals with paper market data. The basic unit of measure used throughout this worksheet is dollars per ton. The third worksheet deals with cost categories. The types of information deal with differential inflation rates in percent per year and a variety of financial data for capital assets. The fourth worksheet deals with energy categories. Although no units are specified, users should exercise care when accumulating commodities into an energy category to insure that the units defined by the commodities are consistent.

The fifth worksheet deals with commodity categories. The definition of commodities requires special care due to their impact on transportation, processing and marketing costs. Worksheet VI deals with source data. Data on the rate of waste generation in thousands of tons per year (KTPY) are recorded along with the cost per ton for hauling source separated recoverables to the market. All other data deal with source separation options and cost and energy categories for use in accumulation. Worksheet VII deals with site data. Here it is important to recognize the relationship between data recorded on this worksheet with that on IX (processes) and X (site processes). The model checks for inconsistencies in assignment which will result in an aborted run (see section 5.1). Care should therefore be exercised in order to match the input commodities. The eighth worksheet deals with landfills, where the number of acre feet remaining must be recorded.

The process data worksheet (IX) provides for entry of data specific to various generic processes. Worksheet X defines what processes are to be offered at what sites, and provides information that is site-process specific. The market data worksheet (XI) provides for entry of relevant information about marketing this commodity defined as (explicit) process outputs. It is on these three worksheets where the cost and energy units must be reconciled with regard to inputs, outputs and interlocational flows.

The last two worksheets deal with cost summation data (XII) and transpartation data (XIII). In specifying cost summation categories, as with aggregating commodities into a cost category, users should exercise care to insure that the resultant figures convey the intended meaning. Transportation data are related closely to the packer and van distance files. As will be shown in section 3.3, the distances are measured in terms of miles, minutes, thousands of dollars per commodity unit, or dollars per ton as selected by the user.

Users may have to refer to other sources for certain types of input data which may not be available in their local jurisdictions. Additional references[1,2] provide possible sources for such generic information.

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[1] Columbia University Urban Technology Center, Resource Recovery Technology for Urban Decision Makers, January 1976.

[2] NBSIR 81-2417, Technical Activities 1981: Office of Recycled Materials; NBS, November 1981.

Exhibit 3.1  Worksheet I:  General Information

This worksheet relates to general information and data needed for the study
about various indices, the composition of MSW and its heat value, collection
costs and market prices for source separated commodities.  Percentages by
weight for the different elements in the waste stream should be given
according to how much can be source separated.  Residue is defined as anything
that is not recoverable paper, glass, or cans.  Figures are generally
available for BTU content of paper, but the BTU value of residue (as defined
above) and MSW as a whole may vary from one area to the next.  The average
price at the market for glass, paper and cans is the price received at the
market, with the cost of haul not included.  The cost of collection includes
only the cost up to the point the truck is filled (or until the waste
collected is hauled to be processed), plus the cost of turnaround for
unloading.  The source point is the central point of a community which is
considered the source of waste generated for that community for the purposes
of measuring distances.  The cost of collection can be considered the cost of
getting the waste to that point from where it will be hauled to the waste
processing facility.  The incremental cost of source separation is the cost in
dollars per ton of pre-separated MSW.  The cost of source separation includes
the cost of source separation collection for paper, glass and cans if all of
these are to be separated.  If a municipality is not source separating all of
these, then the incremental cost of source separation should only include the
cost of the items being source separated.  For any source separation program
to be successful, the public must be educated.  This added cost should be
included in the incremental cost of source separation.


1.  a.  Base year for all cost comparisons: _____.
    b.  Number of years in the planning period: _____.
2.  Discount rate: _____.
3.  Inflation rate: _____.
4.  Waste stream composition (by weight):
    a.  Paper: _____.        b.  Glass: _____.
    c.  Cans: _____.         d.  Residue: _____.
5.  Energy values of key commodities in millions of Btu per ton (when
    processed as waste):
    a.  MSW: _____.          b.  Paper: _____.  c.  Residue: _____.
6.  Source separation options:
    a.  No source separation is to be offered for at least one source? _____.
    b.  Source separation of paper, glass and cans is to be considered for at
        least one source? _____.
7.  Expected revenue per ton for source separated commodities when delivered
    at the market:
    a.  Paper: _____.        b.  Glass: _____.        c.  Cans: _____.
8.  Collection costs:
    a.  Total cost per ton: _____.
    b.  Added cost per ton due to source separation: _____.

Exhibit 3.1  Worksheet I:  General Information (Continued)

Since RRPLAN provides a mix of inputs for MSW-receiving sites and processes, plus source-separation residue, plus paper, under the control of the selected set of source separation alternatives, it becomes necessary to provide a method for generating the correct costs and energy impacts over a range of input mixes.  Two processing ratios, RPRPAP and RPRRES (questions 9.a and 9.b), translate the costs of processing paper and residue to those of processing MSW.  A third term, ALLO (question 9.c), applies only to paper processing, and reflects the fact that in conditional source separation, paper will be diverted suddenly, and in large quantities, between the recycled paper market and the solid waste processing facility, as a function of whether the current price in the paper market is above or below the trigger price selected by the model.  Therefore it is appropriate for the user to consider what part of the cost of processing paper as solid waste is generated by the potential of processing paper, and what part by the actual processing of paper.  An ALLO at its upper limit of 1.0 will generate all of the cost from actual paper processed through the trigger price system.  An ALLO at its lower limit of 0. will generate all of the cost from paper potentially processed through the trigger price system.

9.    Cost conversion:
    a.  Ratio of the cost of processing a ton of paper to the cost of
        processing a ton of MSW:  _____.
    b.  Ratio of the cost of processing a ton of residue to the cost of
        processing a ton of MSW:  _____.
    c.  Allocation of paper processing cost (due to higher capacity
        requirements) to actual paper processed as waste:  _____.
10.   Energy values of source separated commodities (recycled at the market):
    a.  Paper:  _____.      b.  Glass:  _____.      c.  Cans:  _____.
11.   Energy requirements associated with collection:
    a.  Net energy required to collect a ton of MSW:  _____.
    b.  Additional net energy required due to source-separation:  _____.
12.   Energy conversions:
    a.  Energy required per dollar of haul cost to market for paper:  _____.
    b.  Energy required per dollar of haul cost to market for glass:  _____.
    c.  Energy required per dollar of haul cost to market for cans:  _____.
13.   Energy categories:
    a.  Paper at the market:  _____.        b.  Glass at the market:  _____.
    c.  Cans at the market:  _____.         d.  BTU differentiation:  _____.
    e.  Collection (net                      f.  Source separation
          energy):  _____.                        (net energy):  _____.
14.   Cost categories:
    a.  Paper at the market:  _____.        b.  Glass at the market:  _____.
    c.  Cans at the market:  _____.         d.  Collection:  _____.
    e.  Source separation:  _____.

Exhibit 3.2  Worksheet II:  Paper Market Data

The market data for source separated paper requires a worksheet separate from that used for other markets because paper is treated differently.  Source separated paper may either be sold for its fiber content or burned for its BTU value, subject to user inputs on source separation options and the market for recycled paper.  This worksheet provides an opportunity to examine the paper market in detail.  Question 1 addresses the scope of the available markets for selling paper.  A local paper market is one that is small enough to be affected by quantities generated within the model.  A national market is not. Questions 2, 3 and 4 provide data for construction of a price-frequency distribution for paper sold in a national market.  The price-frequency distribution shows how often the price of paper falls within each price interval.

1.  Is the market local or national?  _____.
2.  Critical paper market prices:
    a.  Lower limit on price:  _____.
    b.  Number of intervals in paper price distribution:  _____.
    c.  Size of intervals in paper price distribution (dollars per ton):  _____.
3.  Paper price distribution:

| Interval number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | | | | | | | | | | |

4.  Issues related to the trigger price system:
    a.  Trigger prices to be considered (dollars per ton):
        1. _____; 2. _____; 3. _____; 4. _____; 5. _____.
    b.  Percent of paper burned for each trigger price (optional):
        1. _____; 2. _____; 3. _____; 4. _____; 5. _____.
    c.  Average price of paper sold in the market for each trigger price (optional):
        1. _____; 2. _____; 3. _____; 4. _____; 5. _____.


NOTE:  If trigger prices are being used, enter figures for questions 2, 3 and 4.a, leaving questions 4.b and 4.c blank, (for INPAP = 1); or enter figures for question 4.a-4.c, leaving questions 2 and 3 blank, (for INPAP=0).  See exhibits 3.16, 3.18, and 3.19, for an example of how these data are handled by the model.

Exhibit 3.3  Worksheet III:  Cost Category Data

The worksheet for cost category data identifies who pays what and to whom.
The user must assign a name to each category and determine whether the
category is an operating or capital cost.  Capital costs should be the costs
of construction or of major equipment.  Operating costs include all revenues
from processes and everything not considered a capital cost.  Maintenance
costs, cost of administration, salaries, etc. would all be included under
operating cost.  The weights are used for optimizing in LOPT = 3 and 4 (see
exhibit 3.22).  For each type of category a differential inflation rate should
be given.  The differential inflation rate is the difference between the
general inflation rate and the inflation rate for that particular category
given as either positive (greater increase in prices), negative (a lower
increase in prices, or a decrease) or zero (no difference from general
inflation rate).  This information is needed to determine future costs in
constant dollars, and to give future current costs.  For capital cost
categories, three additional questions must be answered:  useful life of the
category, years to capitalization, and the interest rate.  The useful life of
the category is the length of time that the asset, whose cost is represented
by this category, will be useful to the owner for the purpose intended upon
purchase.  The number of years to capitalization is the number of years
expected to pay off the loan, bond or whatever method was used to borrow the
money.  The years to capitalize may be less than or equal to the useful life.
The interest rate is the expected interest rate on the loan to pay off this
capital category.  The interest rate may be a weighted average of 2 or more
interest rates, since there may be two or more loans used in a capital cost
category.  Two different loans for one facility may also be represented
through two different capital cost categories.


1.  a.  Name of this cost category:  _____.
    b.  Number of this cost category:  _____.
2.  Is this an operating or capital cost category?  _____.
3.  Weight given to this cost category:  _____.
4.  Differential inflation rate (in per cent per year) for this cost
    category:  _____.
5.  Answer sections a through d only if this is a capital cost category:
    a.  Useful life in years:  _____.
    b.  Years to capitalization for the loan:  _____.
    c.  Interest rate for the loan:  _____.
    d.  If this cost category corresponds to capital which was already in use
        at the start of the study period (i.e., existing capital), then give
        the number of years remaining prior to its need for replacement:
        _____.

Exhibit 3.4 Worksheet IV: Energy Category Data

No energy categories are required in order to use the model. If the user does not assign one, the model will create an artificial category for accounting purposes. The name should include the unit of measure of the category. The weights are used for optimizing in LOPT = 3 and 4 (see exhibit 3.24).

1. a. Name of this energy category: _____.
   b. Number of this energy category: _____.
2. Weight given to this energy category: _____.

Exhibit 3.5 Worksheet V: Commodity Category Data

This worksheet provides data on the commodity categories for haul costs and energy haul requirements. Up to 20 commodity categories may be used in the model. The first five are for pre-determined source-origin commodities:
   1. MSW in a packer;
   2. MSW in a van;
   3. Source-separated paper in a van;
   4. Source-separated paper in a packer; and
   5. Source-separated residue in a van.
The remaining fifteen may be freely defined by the user.

1. a. Name of this commodity category: _____.
   b. Number of this commodity category: _____.
2. Haul costs (categories may be used for cost sharing):
   a. First cost category for hauling this commodity: _____.
   b. First cost factor (e.g., cost per ton mile) for hauling this commodity: _____.
   c. Second cost category for hauling this commodity: _____.
   d. Second cost factor for hauling this commodity: _____.
3. Energy haul requirements (energy factors are energy requirements for haul per ton-mile):
   a. First energy category for hauling this commodity: _____.
   b. First energy factor for hauling this commodity: _____.
   c. Second energy category for hauling this commodity: _____.
   d. Second energy factor for hauling this commodity: _____.

Exhibit 3.6  Worksheet VI:  Source Data

The information provided on this worksheet relates to where MSW is generated,
the annual amount, and available options for source separation.  For purposes
of the model, it is assumed that all MSW generated by households, businesses
and industry was generated at the source point or centroid.  A separate
worksheet must be filled out for each source.  A source usually is defined as
including one or more towns, cities, counties or districts.  The source point
or centroid is an exact location within the source area in the geographic or
population center that can be used for distance measurements.  It may be
convenient to consider as the source point a location where a transfer station
is located or the end of a collection route for a packer.  The point chosen is
considered (for the sake of the model) as the point where all collection (and
thus collection costs) end, and where hauling (and thus all haul costs from
the source) begin.  The total region being considered by the model may be
broken into as many as sixty different sources.  We suggest, however, that
the user not call for more than thirty sources, in order to leave space for
other elements in the model.

1.  a.  Name of this source:  _____.
    b.  Number of this source:  _____.
2.  Depth of tracing requested:  _____.
3.  Location of this source:  _____.
4.  Thousands of tons per year (KTPY) of MSW generated by this source _____.
5.  Source separation options:
    a.  No source separation:  _____.
    b.  Unconditional source separation:  _____.
    c.  Conditional source separation market paper according to the
        following set of triggers:
        1. _____; 2. _____; 3. _____; 4. _____; 5. _____.
6.  Marketing considerations:
    a.  Cost category for haul of paper, glass and cans to the market:
        _____.
    b.  Energy category for haul of paper, glass and cans to the market:
        _____.
    c.  Cost per ton to haul paper to the market:  _____.
    d.  Cost per ton to haul glass to the market:  _____.
    e.  Cost per ton to haul cans to the market:  _____.

Exhibit 3.7  Worksheet VII:  Site Data


This worksheet provides information on candidates sites.  A site is a location
where one or more processes is to be offered.  The sites offered may either be
existing or proposed.  A worksheet must be completed for each site.  The entry
for site preparation costs covers the costs incurred when preparing a site for
a facility.  They include roads, fences, and land development costs, but they
do not include costs for construction of the facility itself.  In general,
they are costs which are site-specific rather than process-specific or
site-process-specific.  The information requested on tracing permits the
procedure to trace all site splits to the depth specified, through the output
coefficients of each process, and commodity splits, to a series of sites and
markets.


1.  a.  Name of this site: _____.
    b.  Number of this site:  _____.
2.  Depth of tracing requested:  _____.
3.  Location of this site: _____.
4.  Incoming commodity:  _____.
5.  Site preparation information:
    a.  Cost category for site preparation:  _____.
    b.  Total site preparation costs:  _____.
    c.  Energy category for site preparation:  _____.
    d.  Total energy required for site preparation:  _____.
6.  Capacity considerations:
    a.  Is the site capacitated?  _____.
    b.  Is landfill possible at the site?  _____.




Exhibit 3.8  Worksheet VIII:  Landfill Data


If a land-using process is to be offered at a site, then the information on
this worksheet is required for the location of the site.  Several sites may be
proposed at the same location; if so, they will be subject to the land
availability entered here for that location.  The model does not require the
use of landfills as a primary disposal option.  But provision for residues
from a resource recovery facility must be made.


1.  a.  Name of this landfill:  _____.
    b.  Number of this landfill:  _____.
2.  Location of this landfill:  _____.
3.  Land available at the landfill in acre-feet[a]:  _____.

_____

[a]An acre-foot is a volume of water (or fill) that will cover an area of one
  acre to a depth of one foot (i.e., 43,560 cubic feet or approximately 1610
  cubic yards).

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Exhibit 3.9  Worksheet IX:  Process Data

The process data worksheet provides for entry of data specific to various generic processes to be considered (e.g., a waterwall incinerator is a type of process - not the Fourth Street Incinerator Facility which is a site where that process is used). The data defined for a single process will apply whenever that process is selected. If major differences exist between two processes of the same type, each should be defined as a different process and a full set of information should be provided for each.  In completing questions 6 and 7, the intercepts for the cost and energy functions should be recorded under the column heading "Fixed"; the slopes of these functions should be recorded under the column heading "Variable."


1.  a.  Name of this process:  _____.
    b.  Number of this process:  _____.
2.  Input commodity:  _____.
3.  Was this process in use at the start of the study period?  _____.
4.  If landfill is to performed on site, how many acre feet per
    kiloton of input are required for on-site disposal?  _____.
5.  Output commodities:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Name | | | | | | | |
| Coefficient | | | | | | | |

6.  Cost allocations:
    a.  Number of first cost category:  _____.
    b.  Number of second cost category:  _____.
    c.  Estimated costs for this process:

| | First Segment | | Second Segment | | Third Segmemt | |
|---|---|---|---|---|---|---|
| | Fixed | Variable | Fixed | Variable | Fixed | Variable |
| First Cost Category | | | | | | |
| Second Cost Category | | | | | | |

7.  Energy requirement:
    a.  Number of first energy category:  _____.
    b.  Number of second energy category:  _____.
    c.  Estimated energy for this process:

| | First Segment | | Second Segment | | Third Segment | |
|---|---|---|---|---|---|---|
| | Fixed | Variable | Fixed | Variable | Fixed | Variable |
| First Energy Category | | | | | | |
| Second Energy Category | | | | | | |

Exhibit 3.10  Worksheet X:  Site-Process Combination Data


This worksheet defines what processes are to be offered at what sites, and
provides information that is site-process specific.  The capacity limit
assumes that this process is the only one selected at this site.  The revenues
are net of costs and energy requirements for haul of recoverables to the
market.


1.  a.  Name of candidate site:  _____.
    b.  Number of candidate site:  _____.
2.  a.  Name of candidate process:  _____.
    b.  Number of candidate process:  _____.
3.  Capacity limit:  _____.
4.  Linear segments offered:  1. _____; 2. _____; 3. _____.
5.  Implicit revenues for recoverables not defined through output
    coefficients:
    a.  Number of cost category for process revenues:  _____.
    b.  Process revenues (dollars per ton input):  _____.
    c.  Number of energy category:  _____.
    d.  Energy value of implicit revenues produced by this site-process
        combination:  _____.

Exhibit 3.11  Worksheet XI:  Market Data


The market data worksheet provides for the entry of relevant information about
marketing those commodities defined as (explicit) process outputs.  An example
of a commodity could be process steam or electricity which is sold to an
industrial plant or nearby factory.  A market data worksheet should be
completed for each commodity-location combination.  Cost categories as used
here show where revenues accrue.  Revenues may be thought of as negative
costs.


1.  a.  Name of this market:  _____.
    b.  Number of this market:  _____.
2.  Location of this market:  _____.
3.  Commodity being sold:  _____.
4.  Market structure:
    a.  Market bounds (measured in cumulative commodity units):
        1. _____; 2. _____; 3. _____; 4. _____; 5. _____.
    b.  Number of first cost category:  _____.
    c.  Number of second cost category:  _____.
    d.  Revenue per unit by segment:

|                        | 1 | 2 | 3 | 4 | 5 |
|------------------------|---|---|---|---|---|
| First Cost Category    |   |   |   |   |   |
| Second Cost Category   |   |   |   |   |   |

5.  Energy allocation:
    a.  First energy category for the energy value of the commodity in the
        market:  _____.
    b.  First energy value of the commodity in the market:  _____.
    c.  Second energy category for the energy value of the commodity in the
        market:  _____.
    d.  Second energy value for the commodity in the market:  _____.


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Exhibit 3.12  Worksheet XII:  Cost Summation Data


This worksheet permits the user to differentiate operating costs and capital
costs for any of the inputs, including the weights for optimization, and then
to aggregate them into a single cost summation category for purposes of
reporting costs.  The user may enter up to ten 2-digit cost category numbers
and may list a cost category in more than one cost summation category.  The
user may want to employ separate categories to divide public versus private
costs or municipal versus county or state costs (see exhibit 4.13).  The way
they are divided does not affect the solution or the system summary of costs.
The model does, however, print implications of the solution in terms of the
cost categories and the cost summation categories for the convenience of the
user.


1.  a.  Name of this cost summation category:  _____.
    b.  Number of this cost summation category:  _____.
2.  Cost categories to be aggregated:
    a.  First cost category:  _____.
    b.  Second cost category:  _____.
    c.  Third cost category:  _____.
    d.  Fourth cost category:  _____.
    e.  Fifth cost category:  _____.
    f.  Sixth cost category:  _____.
    g.  Seventh cost category:  _____.
    h.  Eight cost category:  _____.
    i.  Ninth cost category:  _____.
    j.  Tenth cost category:  _____.

Exhibit 3.13  Worksheet XIII:  Transportation Data

There are three types of transportation linkages (see exhibits 3.37 through
3.39).  A type 1 linkage represents a shipment of one of the first five
commodities from a source to a site.  Each card defines a linkage from a
source to a site which can serve as an offload.  There must be at least one
type 1 linkage per source.  A type 2 linkage represents a shipment of a
process output to another site.  For each site, there must be at least one
type 1 or 2 linkage offloading at that site.  A type 3 linkage represents a
shipment of a recoverable from a site to a market.  There must be at least one
input link to each market.  There must be at least one type 2 or 3 linkage per
commodity/origin location combination.  Directions for setting up the distance
files are given in section 3.3.  (Distance measures are:  (a) miles;
(b) minutes; (c) thousands of dollars per commodity unit; or (d) dollars per
ton.)

### Type 1:  Source-to-Site

1.  Origin (source number):  _____.
2.  Destination (site number):  _____.

### Type 2:  Site-to-Site

1.  Origin (location number of site):  _____.
2.  Destination (site number):  _____.
3.  Commodity number of the output hauled along this linkage:  _____.

### Type 3:  Site-to-Market

1.  Origin (location number of site):  _____.
2.  Destination (market number):  _____.
3.  Commodity number of the recoverable hauled along this
    linkage:  _____.

## 3.2 CASE STUDY INPUT FILE

The purpose of this section is twofold. First, and foremost, it is intended to give a line-by-line description of the various inputs which make up the case study file. Second, it is intended to serve as a crosswalk between the data collected on the worksheets described in the previous section and the three input files. The emphasis in this section will be on the case study file referred to here as ACASE and shown as exhibit 3.14.

Two levels of descriptive detail will be used to systematically lay out the inputs to the model. The first level consists of a quick walk through of exhibit 3.14, relating each section of the file to a worksheet. Several simplifications will then be discussed prior to an in-depth analysis of each basic type of data input.

A cursory review of exhibit 3.14 reveals a sequence of numbers going down the left hand side of the page. These line numbers show the position of each type of data within the file. Just to the right of the line number is a two digit number referred to as the read KEY.[1] This number is incremented within the MAIN program and, along with information provided on the first card, controls how all of the case study inputs are read.

It is important to point out that a good deal of the information on the first card was not requested directly on any of the worksheets described in the previous section. There are two reasons for this approach. First, there are five run controls which treat such technical issues as the last phase for the solution, the type of forcing to be used, the forcing override options, the types of outputs desired from the optimizer and finally the optimizing mode itself. Since these controls are the same for all users, they are not data in the same sense as rates of waste generation, mileages, processing costs, etc. It was therefore decided to postpone their discussion until section 5.1 where guidelines for setting up a run are given. Second, practical experience has led us to the conclusion that when the decision to collect data is made, the number of commodities, cost and energy categories, sources, sites, landfills, processes, site-process combinations, markets, and cost summation categories, is not known with any degree of certainty. As the data collection process progresses, questions arise, become resolved and generate new questions and/or issues. Thus the set of data which ends up actually being analyzed by RRPLAN may differ in detail, focus or analytical strategy from that envisioned originally.

---

[1]The cards which define the paper price distribution are the only ones which do not have a read KEY. Line number 8 in the ACASE file defines the paper price distribution for the case study.

Exhibit 3.14    Listing of a Typical Case Study File

```
1        01310030   20 1983    10.  0000  6.        8  4  2  4  4  5  5  2  9  3  1   20.
2        02 TEST CASE
3        03 23.211.8   8. 57.    5.0   6.0  25.49 15.  1 1 20.  1 2.   11131 1 .8  .60 .9
4        04  1 .8        1 .1          .25        .20        .15
5        0520.        12.0       12.0        15.2        2 1 10. 1-999.
6        06      15.  20.  25.
7        07  5  5.  12.
8        10.  20.  30.  20.  10.
9        08  1 MUNICIPAL COST       0  1.       2.
10       08  2 CONTRACTOR OP COST   0  1.      -3.
11       08  3 CONTRACTOR CAP COST  1  1.       1.      20   15 9.
12       08  4 SITE PREP COST       1  1.       0.      50   15 9.
13       09  1 FUEL INPUT, MBTU       -1.
14       09  2 STEAM OUTPUT, MBTU     -1.
15       10  1 MSW IN PKR, KTON      1 1.       1 0.       1 .20       1 0.
16       10  2 MSW IN VAN, KTON      1 1.       1 0.       1 .25       1 0.
17       10  3 S-S PAPER, KTON       1 .7       1 0.       1 .15       1 0.
18       10  4 S-S RES IN PKR, KTON  1 1.       1 0.       1 .20       1 0.
19       10  5 S-S RES IN VAN, KTON  1 1.       1 0.       1 .20       1 0.
20       10  6 STEAM, MLBS           2 1.       2 0.       2 1.        2 0.
21       10  7 PROC RESIDUE, KTON    2 .8       2 0.       1 .20       1 0.
22       10  8 INCIN FERROUS, KTON   2 .7       2 0.       1 .10       1 0.
23       119 1 LYNN                    1 340.        01111   1 1 2.0  1.5  1.2
24       119 2 MARBLEHEAD              2 7.          11            2.2  1.7  1.4
25       119 3 SALEM                   3 120.        01111         2.1  1.6  1.3
26       119 4 REVERE                  4 40.         01            1.9  1.4  1.1
27       129 1 SAUCUS PROC           05    2 10 1  41000.        1250.
28       129 2 WORCESTER PROC        06    2 00 2  41000.        1250.
29       129 3 AMESBURY LANDFILL     07    7 01 1  4200.         150.
30       129 4 SAUGUS SECONDARY PR   05    7 01 1  4400.         1100.
31       13  7 AMESBURY LANDFILL    99800.
32       13  5 SAUGUS LANDFILL      84000.
33       14  1 TRANS STA            20130          2 3 1 1
34       15  1  21.0
35       16  1120.      20.       .8        0.       1.8       1.8       .5        0.
36       16  1240.      35.       .7        0.       .50       .61       .4        0.
37       16  1360.      55.       .6        0.       .26       .24       .3        0.
38       14  2 WATER-WALL INCIN     21310          2 3 1 1
39       15  2  65.48    7.15      8.07
40       16  21300.     0.        70.       0.       7.3       0.        2.        0.
41       14  3 WATER-WALL INCIN     20320          2 3 1 1
42       15  3  65.48    7.15      8.07
43       16  31300.     224.16    80.       0.       7.3       7.0       2.        0.
44       16  321000.    1096.64   170.      0.       5.0       4.236     1.5       0.
45       14  4 LANDFILL             700311.653     2 3 1 1
46       15  4
47       16  4140.      40.       1.6       0.       3.6       3.6       1.0       0.
48       16  4280.      70.       1.4       0.       1.0       1.22      .8        0.
49       16  43120.     110.      1.2       0.       .52       .48       .6        0.
50       14  5 SECONDARY PROC       70021.82       2 3 1 1
51       15  5
52       16  5140.      40.       1.6       0.       2.        2.        1.0       0.
53       16  5280.      70.       1.4       0.       1.        1.        0.8       0.
54       17  1   2 360.      1.0        1     2  1.2
55       17  2   1                    111   2  10.0
56       17  2   3          1.0        11    2  1.3
57       17  3   4                     11    2  10.0
```

Exhibit 3.14   Listing of a Typical Case Study File (Continued)

```
58      17   4   5                3.0        1    2 11.0
59      18   1 GE LYNN STEAM              5   6   2   1   2   1 225.4        -.2
60      19900.   1800.                                                                      1
61      203.0    2.0                              0.      0.                                1
62      18   2 NEW YORK FERROUS          8   8   1   1   2   1 10.2         -.2
63      19                                                                                  2
64      2011.86                                   0.                                        2
65      18   3 WORCESTER STEAM           9   6   2   1   2   1 225.4        -.2
66      192000.   4000.                                                                     3
67      208.0    6.0                              0.      0.                                3
68      21   1 CONTRACTOR COST      2   2   3
69      22 1   1           1
70      22 1   1           2
71      22 1   2           1
72      22 1   2           2
73      22 1   3           1
74      22 1   3           2
75      22 1   4           1
76      22 1   4           2
77      22 2   2    6      1
78      22 2   7    5      3
79      22 2   7    5      4
80      22 2   7    6      3
81      22 2   7    6      4
82      22 3   6    5      1
83      22 3   8    5      2
84      22 3   6    6      3
85      22 3   8    6      2
86      23
```

Keeping this in mind, it can be asserted that most of the data on line numbers 1 through 8 come from the first two worksheets or are based on counting the number of each of the Worksheets III through XII which were filled out. The relationship between Worksheets III through XIII and the entries on line numbers 9 through 86 can be brought into sharp focus, and will be described in some detail. Referring to line numbers 9 through 12 and 13 and 14 in exhibit 3.14, similarities between the information recorded on Worksheet III and IV respectively begin to emerge. In this case, Worksheet III would be filled out four times, one time for each distinct cost category; whereas, Worksheet IV would be filled out twice, once for FUEL INPUT and once for STEAM OUTPUT. The relationship between specific items on the worksheet and in the file become explicit when exhibits 3.15 through 3.39 are examined in the latter part of this section.

Continuing with exhibit 3.14, line numbers 15 through 22 correspond to information on the eight commodity categories to be analyzed in the run. Recall that the first five commodity categories are reserved for source generated wastes. There would be one copy of Worksheet V filled out for each commodity category (i.e., the number of commodity categories defined on card 1 would be 8).

On lines 23 through 26 and 27 through 30 are recorded the data on the four sources and four sites, respectively. Each source would have one Worksheet VI filled out for it; and each site a Worksheet VII. Data on the two landfills would then be recorded from Worksheet VIII.

Information on each process begins at line 33. Notice that the read KEY ranges in value from 14 to 16, reflecting the three types of process data. All data for a given process (e.g., a new transfer station) are recorded on Worksheet IX. In this case, since there are 5 processes, it would be necessary to fill out five such worksheets. Note that the first process must always be a new transfer station, since the model attempts to reduce the overall costs of the plan by siting a transfer station at each source's centroid.

Proceeding down the file, on lines 54 through 58, where the read KEY is equal to 17, is recorded the site-process combination data collected on Worksheet X. Information on each market is similar to that for processes in the sense that all data on a given market is recorded on a single questionaire, Worksheet XI. Data on cost summation categories follows; it is based on the information recorded on Worksheet XII.

Lines 69 through 86 contain information on transportation linkage. To the right of the read KEY is the transportation category. The three transportation categories are: (1) source-to-site; (2) site-to-site; and (3) site-to-market. The first transportation category is expanded once all data have been input. The degree of expansion, as explained in section 3.3, is determined by the various combinations of run controls and source controls governing the source separation options.

The order in which all data from the ACASE file are read, is summarized in table 3.1. For all card types, except the paper market price distribution function data, the column labeled KEY corresponds to the entries in the first two columns of the card. All cards within numbered card types must be entered sequenced by number (e.g. cost category 1, cost category 2, etc.). Except for process cards (KEY 14, 15, and 16) and market cards (KEY 18, 19, and 20), all cards must be entered in order of card type. Transportation cards (KEY 22) must be sequenced by category type (i.e., all category 1 cards should be entered before the first category 2 card, and all category 2 cards should be entered before the first category 3 card). The transportation data must be followed by a single card with 23 entered as the read KEY. Figure 3.1 illustrates how the ACASE file would appear in practice. All card types are labeled. If the input status for a particular card type is conditional, the card is so labeled. The figure also illustrates which card types are composed of a single card and which card types require a block of cards.

The remainder of this section consists of a series of exhibits. Each exhibit has two parts. In part A, the names of the data inputs and their sequence are given. The schematic representation of the card is keyed into the earlier discussion of exhibit 3.14 and the 13 worksheets. The first entry gives the line number in the file whereas the second gives the read KEY. The titles of the exhibits are designed to facilitate reference to the worksheets where variable names can be matched to the questionaire. Part B contains a brief description of the data on the card and its purpose. Also included is a table summarizing such critical factors as the type of variable, where exactly it should appear on the card and its maximum and minimum values.

A brief description of FORTRAN variables will now be presented for those readers who may not be familiar with the variable specifications used in that language. A variable is a symbolic name that identifies a single storage area in which its current value can be found. The size of this storage area and the type of value to be put in that area are determined by the type declared implicitly or explicitly for that variable. The allowed types for variables are: integer, single or double precision real, single or double precision complex, character or logical. RRPLAN uses integer, single precision real and character variables as inputs. All variables which appear in the tables contained in part B of the exhibits are defined as: (1) $I_n$, refers to an n-digit integer; (2) $F_j.k$, refers to a j-digit single precision real number, the value of j is the total field size, with k digits to the right of the decimal point (obviously j is greater than or equal to k)[1]; and (3) $mA_p$, refers to a

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[1]If a decimal is not entered in an F field, it is implied by the value of k, and occupies no space in the field. If a decimal is entered in an F field, it is used as entered (overriding the value of k) but it occupies one space in the field.

Table 3.1  User Input Groups

| KEY | Group Type | Input Status |
|-----|-----------|--------------|
| 01 | Control Card | Required always as first record. |
| 02 | Title Card | Required always as second record. |
| 03 | General Information | Required always as third record. |
| 04 | Source Energy Card | Required always as fourth record. |
| 05 | Energy Factors Card | Required always as fifth record. |
| 06 | Paper Market Data Card | Conditional:  omit if KSEPO=2 or NTRIG=0. |
| 07 | Paper Market Price Distribution Function Header | Conditional:  omit if KSEPO=2 or NTRIG=0. |
| -- | Paper Market Price Distribution Function Data | Conditional:  omit if KSEPO=2 or NTRIG=0, or INPAP=0. |
| 08 | Cost Category Data | Required:  NCC cards must be entered sequenced by number. |
| 09 | Energy Category Data | Conditional:  omit if NEC=0, otherwise NEC cards must be entered sequenced by number. |
| 10 | Commodity Category Data | Required:  NCO cards must be entered sequenced by number. |
| 11 | Source Data | Required:  NSU cards must be entered sequenced by number. |
| 12 | Site Data | Required:  NSI cards must be entered sequenced by number. |
| 13 | Landfill Data | Conditional:  omit if NLA=0, otherwise NLA cards must be entered.  No sequence required, but referred sequence is by location. |
| 14 | First Process Card | Required.[a] |
| 15 | Second Process Card | Required.[a] |
| 16 | Third Process Card | Required. [a,b] |
| 17 | Site-Process Combination Data | Required:  NSP cards must be entered.  No sequence required, but preferred sequence is by process number within site number. |
| 18 | First Market Card | Conditional:  omit if NMK=0.[c] |
| 19 | Second Market Card | Conditional:  omit if NMK=0.[c] |
| 20 | Third Market Card | Conditional:  omit if NMK=0.[c] |
| 21 | Cost Summation Data | Conditional:  omit if NCS=0, otherwise NCS cards must be entered sequenced by number. |
| 22 | Transportation Data | Required:  sequenced by category type. |
| 23 | End Card for Transportation File | Required always as last record. |

[a]Enter the first, second and third process cards sorted by process number (major) and card type (minor).  Enter NPR sets.

[b]The number of third process cards in the set must be equal to NSEG(K), the number of linear segments for the Kth process, entered on the first process card.

[c]Enter the first, second and third market cards sorted by market number (major) and card type (minor).  Enter NMK sets.

Figure 3.1  Organization of the Case Study Input File
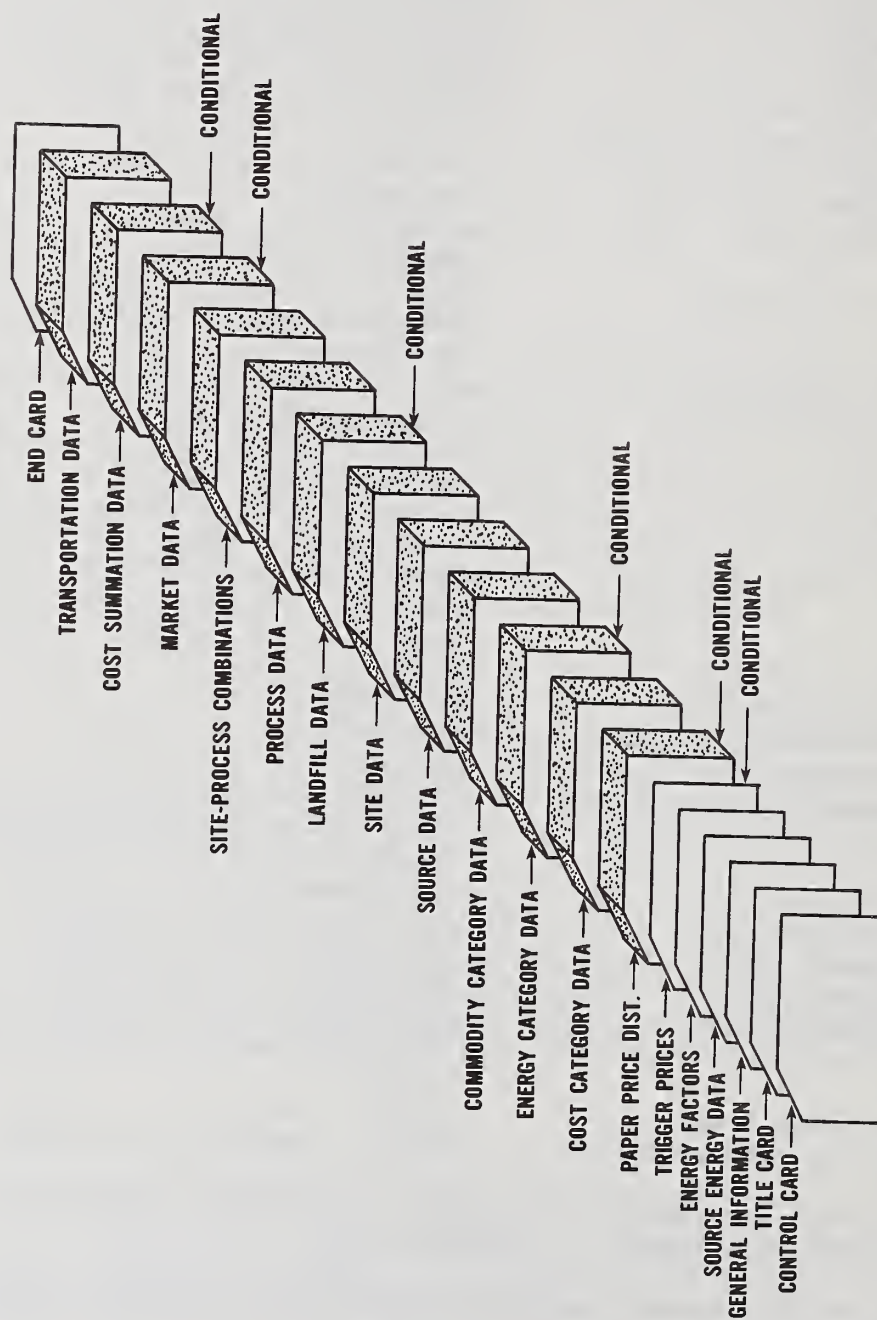
character string with m blocks of p characters (i.e., mp characters). All integer variables must be right justified (i.e., the units digit must be in the right-most column of the field). For example, if the variable specification was given as I3 and the first column on the card which the variable could occupy was 9, then the value must be entered in columns 9, 10 and 11 of the card. If it was desired to enter a value of 17, then the 7 would be placed in column 11 and the 1 in column 10. Column 9 would be left blank. If 1 were entered in column 9 and 7 in column 10, then the number would be read as 170. There is no need to right justify real variables if a decimal point is entered, since the position of the decimal overrides the specification declared on the read statement. In any event, the user should exercise some care to insure that all columns are properly aligned.

In the discussion which follows, all inputs from one card to another are treated as if they are independent. This simplification was made for ease in exposition because it facilitates a thorough analysis of all data which appear on a given card. Within the program, however, some data have more attributes than are indicated on the exhibits. For example, in exhibit 3.31 data on the slope and intercept of the cost functions for processing facilities are presented. In this exhibit, these slopes are referred to as CSLO(1), CSLO(2), CINT(1) and CINT(2), respectively. (Two cost categories are needed because economies of scale may exist in both construction and operation and maintenance costs.) In reality (i.e., within the program) there are two separate slope and intercept pairs for each process and each linear segment within that process. The slopes and intercepts as used within the program, therefore correspond to three dimensional arrays. It was felt that accounting for all such pieces of information might lead to confusion. For those readers who may wish to delve into the source code or just get a better grip on the way in which all of the input data fits together, a technical appendix has been prepared. The appendix lists each input, defines its purpose, provides dimensions for each array, as well as the read KEY and location of the variable on the 80 column card. Additional detail may be found in the Programmer's Manual.

If the reader studies exhibits 3.15 through 3.39 and follows the instructions on the summary tables which appear in part B of each exhibit, even though some of the terms have multi-attributes, problems in setting up the case study file should not be encountered. This statement can be justified by noting that it would be possible to have a completely separate naming convention for all variables when input and when used in data manipulations within the program. Such a convention was not practical for RRPLAN due in part to the number of inputs. As pointed out earlier, users should attempt to reconstruct the data for the ACASE file and run it on their operating system to reinforce their understanding of model. This should be done prior to an analysis of any "real" data with the model.

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Exhibit 3.15  Case Study File:  Program Controls and General Data

Part B.  Interpretation

The first card in the case study file sets the controls for the optimizer
based on the values contained in the six entries LPHASE, NFORC, KOVER, KOPT,
LOPT, KFOUT and KSUPP.  The economic scope of the analysis is determined to a
great degree by NYR, IFIRST, DISCO and FLATO and to a lesser extent by ISQR,
IXDED and PRPAP.  All other entries serve to define end points of do loops
through which much of the remaining data is read in.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 1 | 1 |
| LPHASE | I1 | 3 | 3 | 4 |
| NFORC | I1 | 4 | 1 | 2 |
| KOVER | I2 | 5 | 0 | 99 |
| KOPT | I1 | 7 | 1 | 3 |
| LOPT | I1 | 8 | 0 | 4 |
| NYR | I2 | 12 | 1 | 99 |
| IFIRST | I4 | 15 | - | -- |
| DISCO | F8.4 | 19 | 0.0 | 50.0 |
| ISQR | I1 | 27 | 0 | 1 |
| IXDED | I1 | 28 | 0 | 1 |
| KFOUT | I1 | 29 | 0 | 9 |
| KSUPP | I1 | 30 | 0 | 1 |
| FLATO | F8.4 | 31 | 0.0 | 50.0 |
| NCO | I2 | 40 | 5 | 20 |
| NCC | I2 | 43 | 1 | 50 |
| NEC | I2 | 46 | 0 | 20 |
| NSU | I2 | 49 | 1 | 60 |
| NSI | I2 | 52 | 1 | 50 |
| NPR | I2 | 55 | 2 | 30 |
| NSP | I2 | 58 | 1 | 80 |
| NLA | I2 | 61 | 0 | 30 |
| LSTLO | I3 | 64 | 1 | 999 |
| NMK | I2 | 68 | 0 | 30 |
| NCS | I2 | 71 | 0 | 10 |
| PRPAP | F5.2 | 75 | - | -- |

# Exhibit 3.16 Case Study File: General Information

## Part A: Variable Definitions and Sequencing
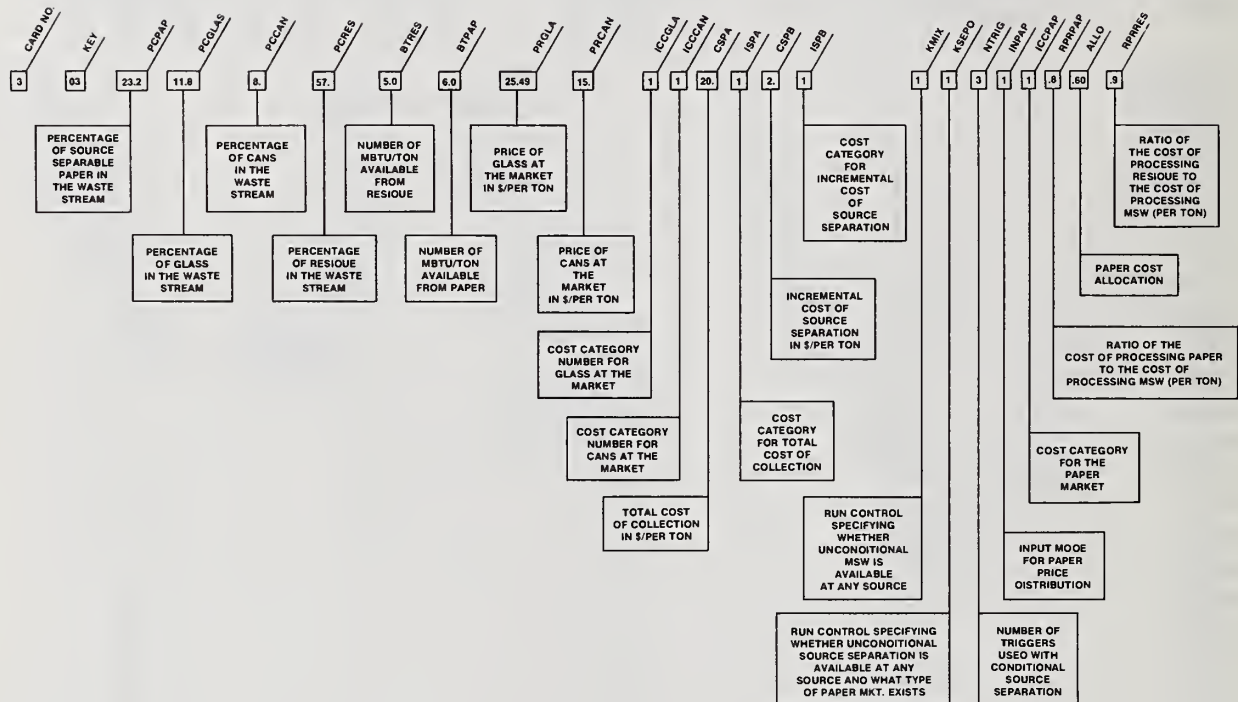
Exhibit 3.16   Case Study File:   General Information

Part B:   Interpretation

This card establishes values for the composition of the solid waste stream and the BTU content of its components.   Information on collection costs, potential revenues and their associated cost allocations are given as well as controls which govern the use of the source separation options for the rest of the analysis.   Two variables which appear on this card have an effect on the turnaround time for unloading.   Both terms, CSPA and CSPB, will be discussed in detail is section 3.3.   The standard turnaround time for unloading a packer should be included in the total cost of collection, CSPA, in the form of a cost per ton.   Since the unit of measure of source-separation alternatives is (thousand) tons of preseparated MSW, there is a saving in turnaround cost in that the packer, now actually carrying source-separation residue, carries a larger payload if measured in equivalent preseparated MSW.   This saving should be reflected in the value of CSPB. The last entries provide information on the relative costs of processing source separated paper and residue.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 3 | 3 |
| PCPAP | F5.2 | 3 | 0.0 | 90.0 |
| PCGLA | F5.2 | 8 | 0.0 | 90.0 |
| PCCAN | F5.2 | 13 | 0.0 | 90.0 |
| PCRES | F5.2 | 18 | 0.0 | 100.0 |
| BTRES | F6.3 | 23 | 0.0 | — |
| BTPAP | F6.3 | 29 | 0.0 | — |
| PRGLA | F5.2 | 35 | 0.0 | 1000.0 |
| PRCAN | F5.2 | 40 | 0.0 | 1000.0 |
| ICCGLA | I2 | 45 | 1 | NCC[a] |
| ICCCAN | I2 | 47 | 1 | NCC |
| CSPA | F5.3 | 49 | 0.0 | 1000.0 |
| ISPA | I2 | 54 | 1 | NCC |
| CSPB | F5.3 | 56 | 0.0 | 1000.0 |
| ISPB | I2 | 61 | 1 | NCC |
| KMIX | I1 | 63 | 0 | 1 |
| KSEPO | I1 | 64 | 0 | 2 |
| NTRIG | I1 | 65 | 0 | 5 |
| INPAP | I1 | 66 | 0 | 1 |
| ICCPAP | I2 | 67 | 1 | NCC |
| RPRPAP | F4.3 | 69 | 0.05 | 20.0 |
| ALLO | F4.3 | 73 | 0.0 | 1.0 |
| RPRRES | F4.3 | 77 | 0.05 | 20.0 |

[a]The value of NCC is entered on the control card (see exhibit 3.15).

Exhibit 3.17  Case Study File:  Source Energy Data

Part B:  Interpretation

The entries shown in part A of exhibit 3.17 establish the values governing all
net energy calculations.  KSPA and ESPA set the value for net energy in
collection and its allocation; whereas KSPB and ESPB determine how much
additional net energy is required for source separation.  RPAH, RGLH and RCAH
are factors to convert the dollar value of haul costs to an equivalent amount
of net energy.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 4 | 4 |
| KSPA | I2 | 4 | 1 | NEC[a] |
| ESPA | F10.3 | 6 | - | ---- |
| KSPB | I2 | 16 | 1 | NEC |
| ESPB | F10.3 | 18 | - | --- |
| RPAH | F10.5 | 28 | - | ---- |
| RGLH | F10.5 | 38 | - | ---- |
| RCAH | F10.5 | 48 | - | ---- |

[a]The value of NEC is entered on the control card (see exhibit 3.15).

Exhibit 3.18  Case Study File:  Energy Factors

Part A:  Variable Definitions and Sequencing
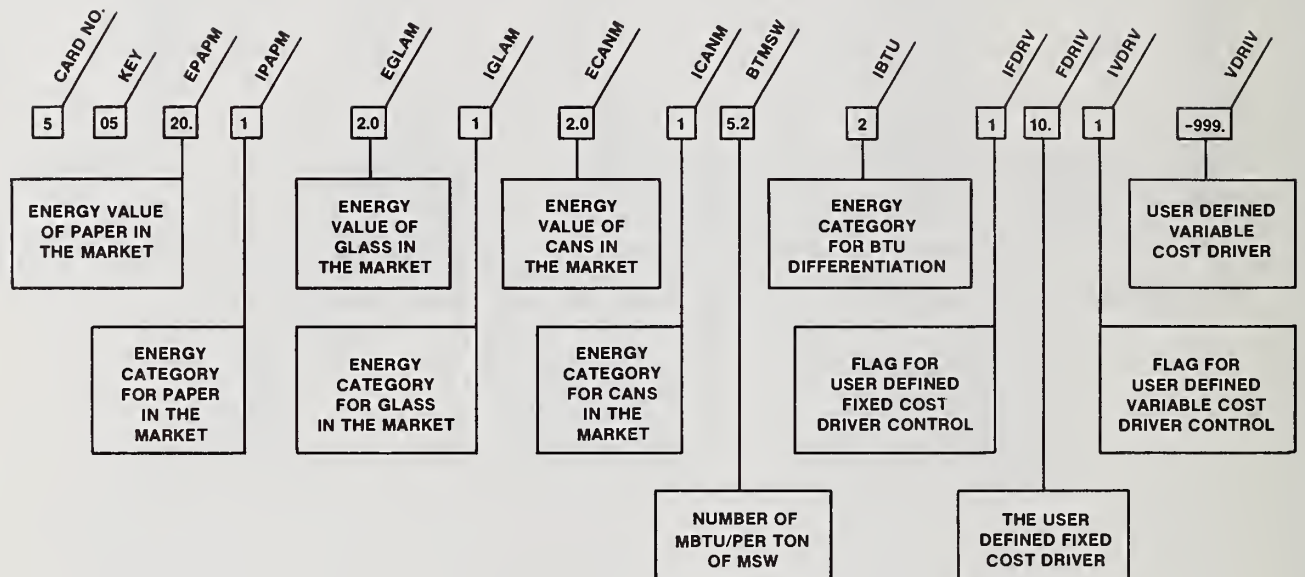
Exhibit 3.18  Case Study File:  Energy Factors

Part B:  Interpretation

The energy values of source separated paper, glass and cans at the market and
the appropriate energy categories are given on this card.  The thermal content
of MSW in millions of BTU are given as well as an energy category for BTU
differentiation among MSW and source separated paper and residue.  The last
four entries are concerned with the forcing procedure.  They permit the user
to set controls for overriding the fixed and variable cost forcing values set
internally.  Some care should be exercised in using the override.  It is
recommended that either no override or the combination entered on part A of
exhibit 3.18 be used prior to any experimentation with other values.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---------------|------------------------|--------------|---------------|---------------|
| KEY   | I2    | 1  | 5    | 5   |
| EPAPM | F10.5 | 3  | -    | --- |
| IPAPM | I2    | 13 | 1    | NEC |
| EGLAM | F10.5 | 15 | -    | --- |
| IGLAM | I2    | 25 | 1    | NEC |
| ECANM | F10.5 | 27 | -    | --- |
| ICANM | I2    | 37 | 1    | NEC |
| BTMSW | F10.5 | 39 | 0.05 | --- |
| IBTU  | I2    | 49 | 1    | NEC |
| IFDRV | I1    | 52 | 0    | 1   |
| FDRIV | F5.2  | 53 | -    | --- |
| IVDRV | I1    | 58 | 0    | 1   |
| VDRIV | F5.2  | 59 | -    | --- |

Exhibit 3.19  Case Study File:  Trigger Prices for Paper Market

Part A:  Variable Definitions and Sequencing
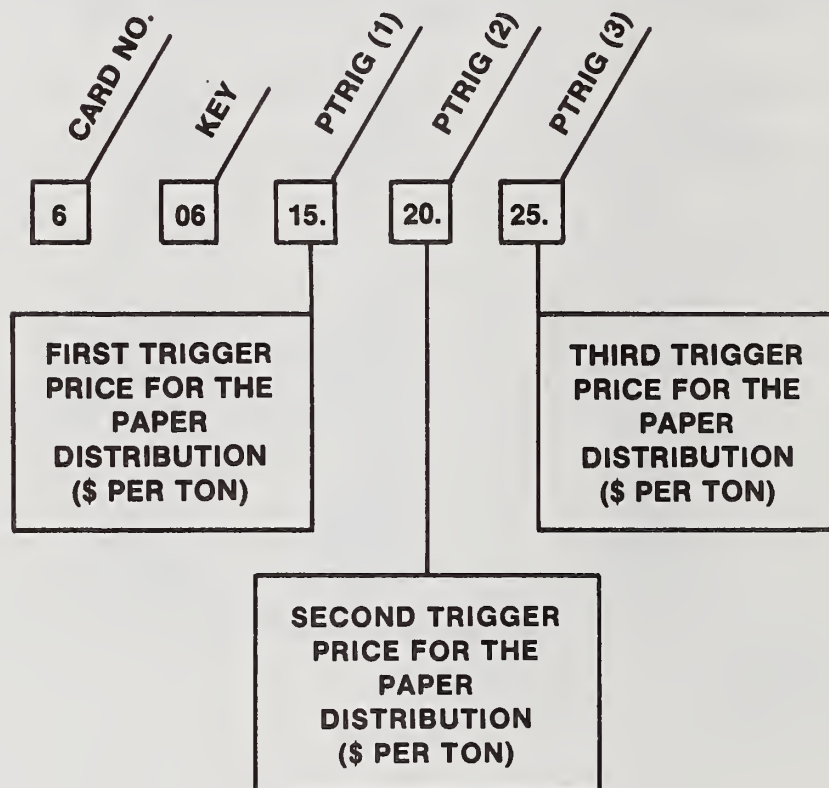
Exhibit 3.19  Case Study File:  Trigger Prices for Paper Market

Part B:  Interpretation

The user has the option to specify a set of trigger prices below which paper
will be burned for its BTU value and above which it will be sold for its fiber
content.  The PTRIG(1) through PTRIG(5) entries establish these trigger
prices.  The value of NTRIG given on card 3 determines how many trigger prices
the user must input.  Note that the trigger prices must be increasing.  The
model will select which trigger price and burn ratio are most appropriate for
each source where they are offered.  The user may also specify how much paper
is burned and what the average sale price is through the values of BTRIG and
ATRIG by setting INPAP equal to zero on card 3.  Both sets of values must be
increasing functions reflecting the fact that as the trigger price is
increased, more paper will be burned and the average value at the market will
be higher.  If the user desires to input a frequency distribution for the
price of paper, then these values are computed internally.  In such a case,
INPAP should be set to one on card 3 and no values should be entered for
either ATRIG or BTRIG.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 6 | 6 |
| PTRIG(1) | F5.2 | 7 | | |
| PTRIG(2) | F5.2 | 12 | | |
| PTRIG(3) | F5.2 | 17 | | a |
| PTRIG(4) | F5.2 | 22 | | |
| PTRIG(5) | F5.2 | 27 | | |
| BTRIG(1) | F4.1 | 32 | | |
| BTRIG(2) | F4.1 | 36 | | |
| BTRIG(3) | F4.1 | 40 | | b |
| BTRIG(4) | F4.1 | 44 | | |
| BTRIG(5) | F4.1 | 48 | | |
| ATRIG(1) | F5.2 | 52 | | |
| ATRIG(2) | F5.2 | 57 | | |
| ATRIG(3) | F5.2 | 62 | | c |
| ATRIG(4) | F5.2 | 67 | | |
| ATRIG(5) | F5.2 | 72 | | |

a   $PTRIG(K) \geq PTRIG(K-1) + 0.001$ for $K > 1$.
b   $BTRIG(K) \geq BTRIG(K-1) + 0.0001$ for $K > 1$.
c   $ATRIG(K) \geq ATRIG(K-1) + 0.0001$ for $K > 1$.

Exhibit 3.20  Case Study File:  Critical Paper Market Prices

Part A:  Variable Definitions and Sequencing
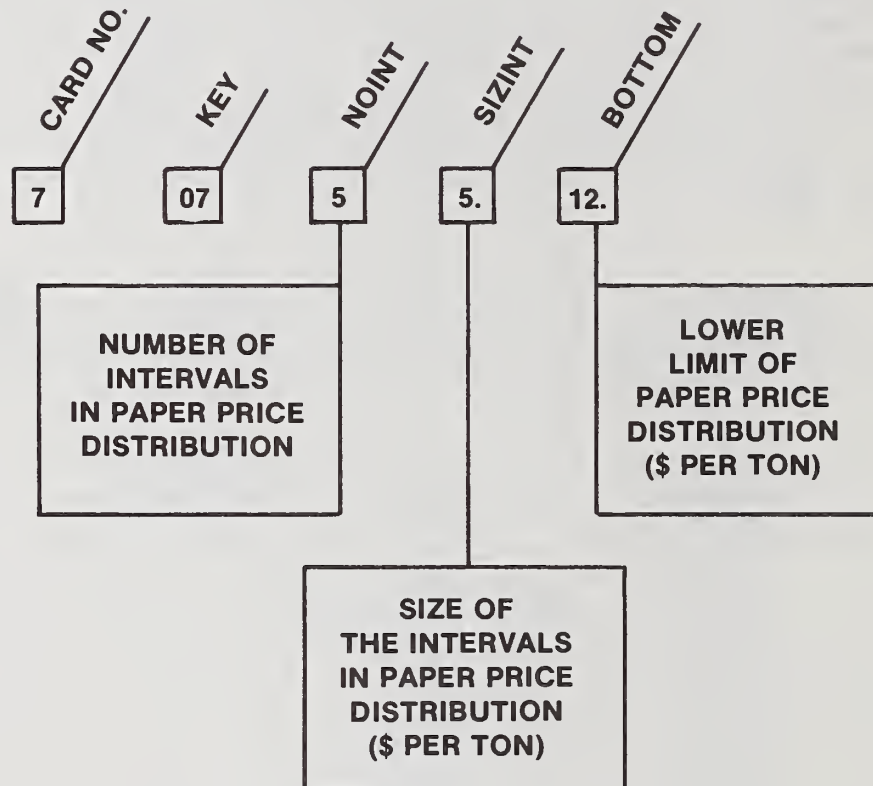
Exhibit 3.20  Case Study File:  Critical Paper Market Prices

Part B:  Interpretation

The data provided on this card define the size and shape of the paper price
distribution.  The minimum price is given by BOTTOM, whereas the maximum price
is equal to the product of NOINT and SIZINT plus BOTTOM.  The minimum width of
the interval on the paper price distribution is defined so that all trigger
prices are contained within the body of the paper price distribution (i.e.,
the maximum price as computed above must be greater than the highest trigger
price).

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---------------|------------------------|--------------|---------------|---------------|
| KEY           | I2                     | 1            | 7             | 7             |
| NOINT         | I3                     | 3            | 1             | 200           |
| SIZINT        | F5.3                   | 6            | a             | 1000          |
| BOTTOM        | F5.2                   | 11           | 0.            | b             |

a  (PTRIG(NTRIG) - BOTTOM)/NOINT.
b  Greater than or equal to PTRIG(1).

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Exhibit 3.21  Case Study File:  Paper Market Price Distribution

Part A:  Variable Definitions and Sequencing

CARD NO.    FREQ (1)    FREQ (2)    FREQ (3)    FREQ (4)    FREQ(5)

8    10.    20.    30.    20.    10.

**FREQUENCY WITHIN FIRST INTERVAL OF PAPER DISTRIBUTION**

**FREQUENCY WITHIN THIRD INTERVAL OF PAPER DISTRIBUTION**

**FREQUENCY WITHIN FIFTH INTERVAL OF PAPER DISTRIBUTION**

**FREQUENCY WITHIN SECOND INTERVAL OF PAPER DISTRIBUTION**

**FREQUENCY WITHIN FOURTH INTERVAL OF PAPER DISTRIBUTION**
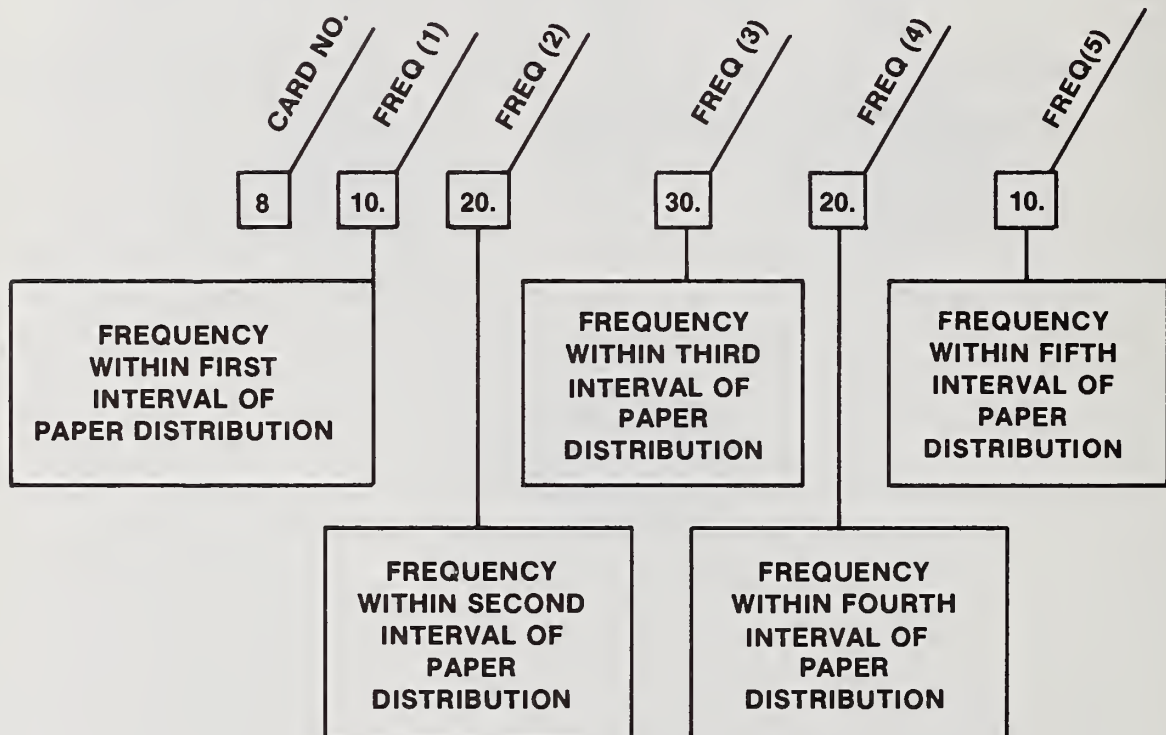
Exhibit 3.21  Case Study File:  Paper Market Price Distribution

The paper price distribution is entered as frequencies over ranges of price in
the market.  The distribution is normalized before use so that the frequencies
may be entered in any form that is convenient to the user (e.g., percentages
of time at various price ranges, or number of days per year in the various
price ranges).

| Variable Name | Variable Specification | First Column | Minimum Value[a] | Maximum Value |
|---|---|---|---|---|
| FREQ(1) | F5.3 | 1 | 0.0 | -- |
| FREQ(2) | F5.3 | 6 | 0.0 | -- |
| FREQ(3) | F5.3 | 11 | 0.0 | -- |
| FREQ(4) | F5.3 | 16 | 0.0 | -- |
| FREQ(5) | F5.3 | 21 | 0.0 | -- |
| FREQ(6) | F5.3 | 26 | 0.0 | -- |
| FREQ(7) | F5.3 | 31 | 0.0 | -- |
| FREQ(8) | F5.3 | 36 | 0.0 | -- |
| FREQ(9) | F5.3 | 41 | 0.0 | -- |
| FREQ(10) | F5.3 | 46 | 0.0 | -- |
| FREQ(11) | F5.3 | 51 | 0.0 | -- |
| FREQ(12) | F5.3 | 56 | 0.0 | -- |
| FREQ(13) | F5.3 | 61 | 0.0 | -- |
| FREQ(14) | F5.3 | 66 | 0.0 | -- |
| FREQ(15) | F5.3 | 71 | 0.0 | -- |
| FREQ(16) | F5.3 | 76 | 0.0 | -- |

a $\sum_{i=1}^{NOINT} FREQ(i) > 0$

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Exhibit 3.22  Case Study File:  Cost Category Data (Operating)

Part A:  Variable Definitions and Sequencing
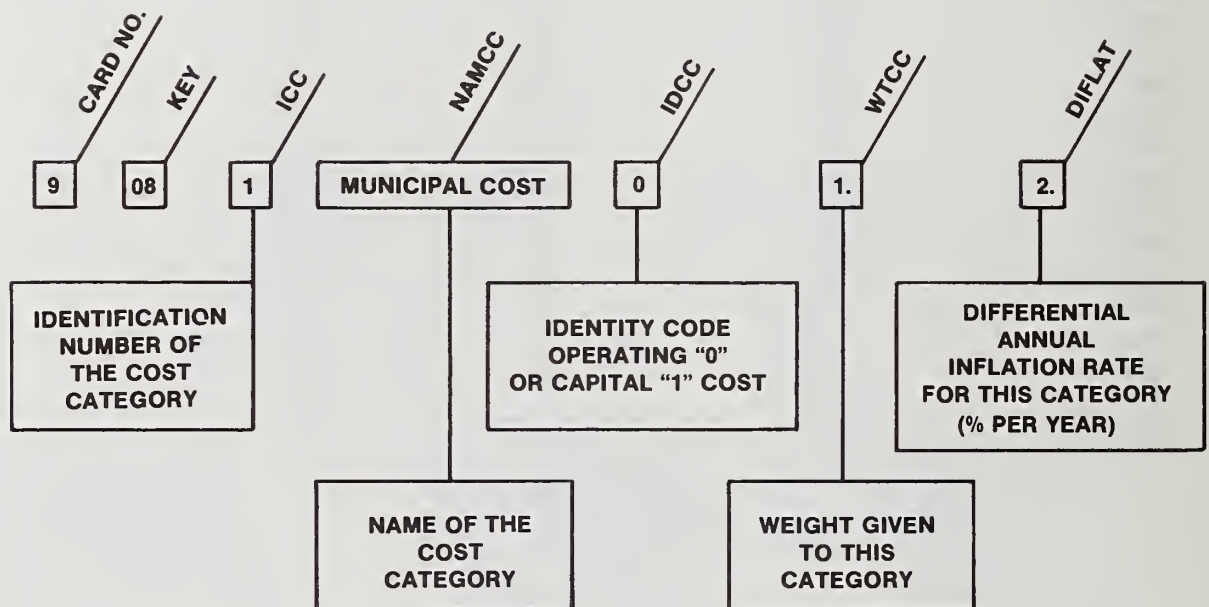
Exhibit 3.22   Case Study File:   Cost Category Data (Operating)

Part B:   Interpretation

This is one of the NCC cost category cards; it deals with annual recurring costs referred to within the model as operating costs.  The name of the cost category is stored in the alphanumeric variable NAMCC.  IDCC is set equal to zero indicating that this is an operating cost.  Operating costs include such categories of costs as collection and transportation as well as facility operation and maintenance and revenues. Operating costs are inflated from the first year of the study period to the year in which they ocur through use of the differential inflation rate DIFLAT.  Note that the WTCC and DIFLAT entries are not edit checked.  Values for WTCC are only necessary if LOPT is equal to 3 or 4 in which case positive weights for WTCC are required.  At least one weight must be non zero for LOPT equal to 3.  In the LOPT equal to 4 case, the weights are not checked, but the model will select among alternatives randomly if at least one weight is not entered.  The LIFU, LIFC, RATE and NREM entries are not required for an operating cost, so they should be left blank.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 8 | 8 |
| ICC | I2 | 5 | 1 | NCC[a] |
| NAMCC | 5A4 | 8 | – | --- |
| IDCC | I1 | 29 | 0 | 0 |
| WTCC | F8.3 | 31 | – | --- |
| DIFLAT | F5.3 | 39 | – | --- |
| LIFU[b] | I3 | 45 | – | --- |
| LIFC[b] | I3 | 49 | – | --- |
| RATE[b] | F4.1 | 52 | – | --- |
| NREM[b] | I2 | 56 | – | --- |

[a]The value of NCC is entered on the control card (see exhibit 3.15).

[b]Input value is irrelevant.  Used only for capital costs.

Exhibit 3.23   Case Study File:   Cost Category Data (Capital)

Part A:   Variable Definition and Sequencing
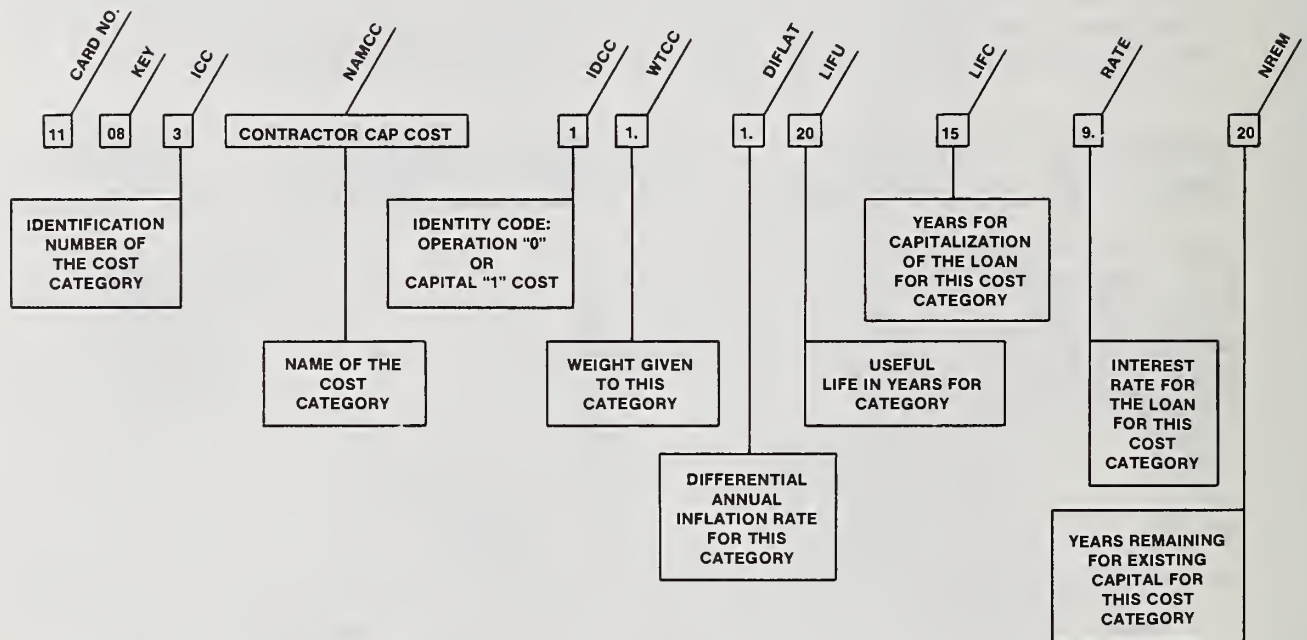
Exhibit 3.23  Case Study File:  Cost Category Data (Capital)

Part B:  Interpretation

Capital items are assumed to be purchased at the beginning of every useful
life cycle, displaced by years of life remaining for existing assets (NREM),
with the cost being inflated by the differential inflation rate (DIFLAT) from
year 1 to the year of purchase (LIFU+1).  A standard amortization calculation
is used to generate an annual cost for each year of the capitalization of the
loan based on the values of RATE and LIFC.  That cost is deflated by the
general inflation rate from the year of the cost to the year of purchase to
represent the decline in constant dollars through time after the cost is
"fixed" in current dollars by the act of purchase.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 8 | 8 |
| ICC | I2 | 5 | 1 | NCC |
| NAMCC | 5A4 | 8 | – | --- |
| IDCC | I1 | 29 | 1 | 1 |
| WTCC | F8.3 | 31 | – | --- |
| DIFLAT | F5.3 | 39 | – | --- |
| LIFU | I3 | 45 | 1 | 200 |
| LIFC | I3 | 49 | 1 | LIFU |
| RATE | F4.1 | 52 | 0.05 | 80.0 |
| NREM | I2 | 56 | 0 | 99 |

Exhibit 3.24   Case Study File:   Energy Category Data

Part A:   Variable Definitions and Sequencing



| CARD NO. | KEY | IEC | NAMEC | WTEC |
|:---:|:---:|:---:|:---:|:---:|
| 13 | 09 | 1 | FUEL INPUT, MBTU | -1. |
| | | IDENTIFICATION NUMBER FOR ENERGY CATEGORY | NAME OF ENERGY CATEGORY | WEIGHT GIVEN TO THIS ENERGY CATEGORY |
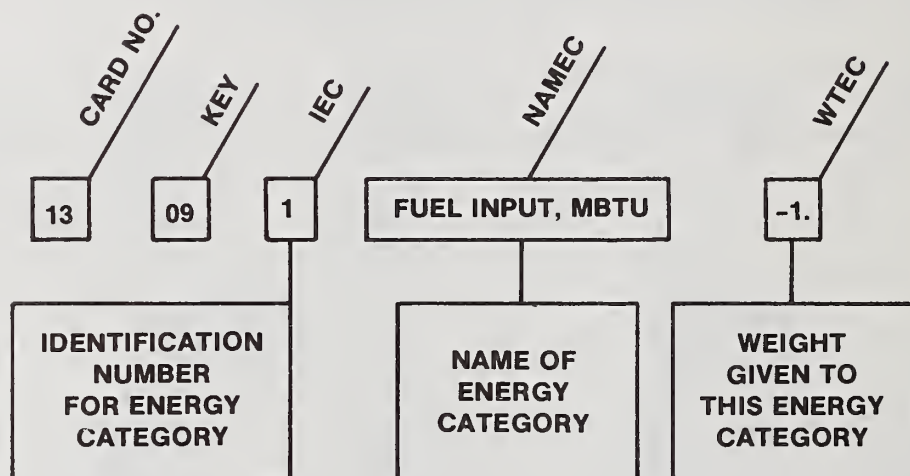
Exhibit 3.24   Case Study File:   Energy Category Data

Part B:   Interpretation

This is one of NEC energy cards.  If NEC was listed as zero on card 1, then no
cards are to be entered; the model will however, create an artificial energy
category for accounting purposes.  All energy categories represent net energy;
thus a negative energy value in the analytical summary (see section 4.1)
implies a net requirement for energy.  In entering energy requirements,
however, the user should enter positive data since the sign is changed within
the model for all such inputs.  Note that WTEC should have weights entered
which are negative or zero whether the category is expected to show a net
energy surplus or a net energy requirement.  Recall that for LOPT equal to 3
or 4 at least one weight should be non zero.  For better correspondence with
cost inputs, it is recommended that the energy equivalent of the various
cost-per-ton inputs be one-thousandth of the energy unit per ton, with two
exceptions.  First, intercept energy inputs must be entered in full energy
units.  These include CEPREP (see exhibit 3.27) and the intercepts, EINT (see
exhibit 3.31), on the third process card.  Second, if the user has defined the
unit of a commodity in other than thousand tons, the energy inputs into a
process of which it is the input commodity including ESLO (see exhibit 3.31)
and EREVSP (see exhibit 3.32) should be in full energy units per unit defined
for the commodity.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---------------|------------------------|--------------|---------------|---------------|
| KEY           | I2                     | 1            | 9             | 9             |
| IEC           | I2                     | 5            | 1             | NEC           |
| NAMEC         | 5A4                    | 8            | –             | ---           |
| WTEC          | F8.3                   | 29           | –             | ---           |

Exhibit 3.25  Case Study File:  Commodity Category Data

Part A:  Variable Definitions and Sequencing



CARD NC  KEY  ICO  NAMCO  ICOCC (1)  CCOCC (1)  ICOCC (2)  CCOCC (2)  ICOEC (1)  CCOEC (1)  ICOEC (2)  CCOEC (2)

| 15 | 10 | 1 | MSW IN PKR, KTON | 1 | 1. | 1 | 0. | 1 | .20 | 1 | 0. |

IDENTIFICATION NUMBER FOR COMMODITY CATEGORY

NAME OF COMMODITY CATEGORY

FIRST COST CATEGORY FOR HAULING THE COMMODITY

SECOND COST CATEGORY FOR HAULING THE COMMODITY

FIRST ENERGY CATEGORY FOR HAULING THE COMMODITY

SECOND ENERGY CATEGORY FOR HAULING THE COMMODITY

COST FACTOR FOR FIRST COST CATEGORY

COST FACTOR FOR SECOND COST CATEGORY

COST FACTOR FOR FIRST ENERGY CATEGORY

COST FACTOR FOR SECOND ENERGY CATEGORY

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Exhibit 3.25   Case Study File:   Commodity Category Data

Part B:   Interpretation

The commodity is numbered by the assignment of ICO on the commodity category
cards; there are NCO such cards.  The first five commodities must be:

1.  Mixed MSW in a packer in KTPY (kilotons per year);
2.  Mixed MSW in a van in KTPY;
3.  Source-separated paper in a van in KTPY;
4.  Source-separated residue in a packer in KTPY; and
5.  Source-separated residue in a van in KTPY.

Once identified, commodities are referenced by number for site inputs, process
inputs and outputs, market inputs, and transportation.  Haul cost multipliers
CCOCC(1) and CCOCC(2) and energy multipliers CCOEC(1) and CCOEC(2) are also
entered on this card.  These multipliers are applied against the packer and
van distance file entries (van applies if ICO is other than 1 or 4).

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 10 | 10 |
| ICO | I2 | 5 | 1 | NCO[a] |
| NAMCO | 5A4 | 8 | -- | --- |
| ICOCC(1) | I2 | 28 | 1 | NCC |
| CCOCC(1) | F8.3 | 30 | 0.00001 | 1000.0 |
| ICOCC(2) | I2 | 38 | 1 | NCC |
| CCOCC(2) | F8.3 | 40 | 0.0 | 1000.0 |
| ICOEC(1) | I2 | 48 | 0 | NEC |
| CCOEC(1) | F8.3 | 50 | -- | --- |
| ICOEC(2) | I2 | 58 | 0 | NEC |
| CCOEC(2) | F8.3 | 60 | -- | --- |

[a]The value of NCO is entered on the control card (see exhibit 3.15).

Exhibit 3.26  Case Study File:  Source Data

Part A:  Variable Definitions and Sequencing

Exhibit 3.26  Case Study File:  Source Data

Part B:  Interpretation

This is one of NSU source cards.  The second entry is designed for tracing
activities to be carried out once the optimization has been completed.  The
next four entries show the source number, its name, location and rate of waste
generation (in KTPY).  All remaining entries are associated with the source
separation options to be considered for this source.  Any combination of the
seven entries IMIXSU through ITRIGS(5) may be offered.  It is important to
note that the source controls are dominated by the run controls (KMIX,KSEPO
and NTRIG) listed on card 3.  If the run control indicates that the
alternative was not to be considered, then the corresponding source control
will be read but will not be functional.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 11 | 11 |
| ISUREQ | I1 | 3 | 0 | 9 |
| ISU | I2 | 5 | 1 | NSU[a] |
| NAMSU | 5A4 | 8 | -- | --- |
| LSU | I3 | 29 | 1 | LSTLO[a] |
| TSU | F10.3 | 32 | 0.001 | --- |
| IMIXSU | I1 | 43 | 0 | 1 |
| ISEPSU | I1 | 44 | 0 | 2 |
| ITRIGS(1) | I1 | 45 | b | 1 |
| ITRIGS(2) | I1 | 46 | b | 1 |
| ITRIGS(3) | I1 | 47 | b | 1 |
| ITRIGS(4) | I1 | 48 | b | 1 |
| ITRIGS(5) | I1 | 49 | b | 1 |
| IHCSEP | I2 | 50 | 0 | NCC |
| IHESEP | I2 | 52 | 0 | NEC |
| CHPA | F5.2 | 54 | 0.0 | 1000.0 |
| CHGL | F5.2 | 59 | 0.0 | 1000.0 |
| CHCA | F5.2 | 64 | 0.0 | 1000.0 |

[a]The values of NSU and LSTLO are entered on the control card (see exhibit
3.15).

[b]If NTRIG=0 on the general information card (see exhibit 3.16), then no value
should be entered.  If NTRIG$\geq$1, then ITRIGS(K)=0 or 1 for K$\leq$NTRIG.  ITRIGS(K)
should be left blank for K>NTRIG.

Exhibit 3.27   Case Study File:   Site Data

Part A:   Variable Definitions and Sequencing
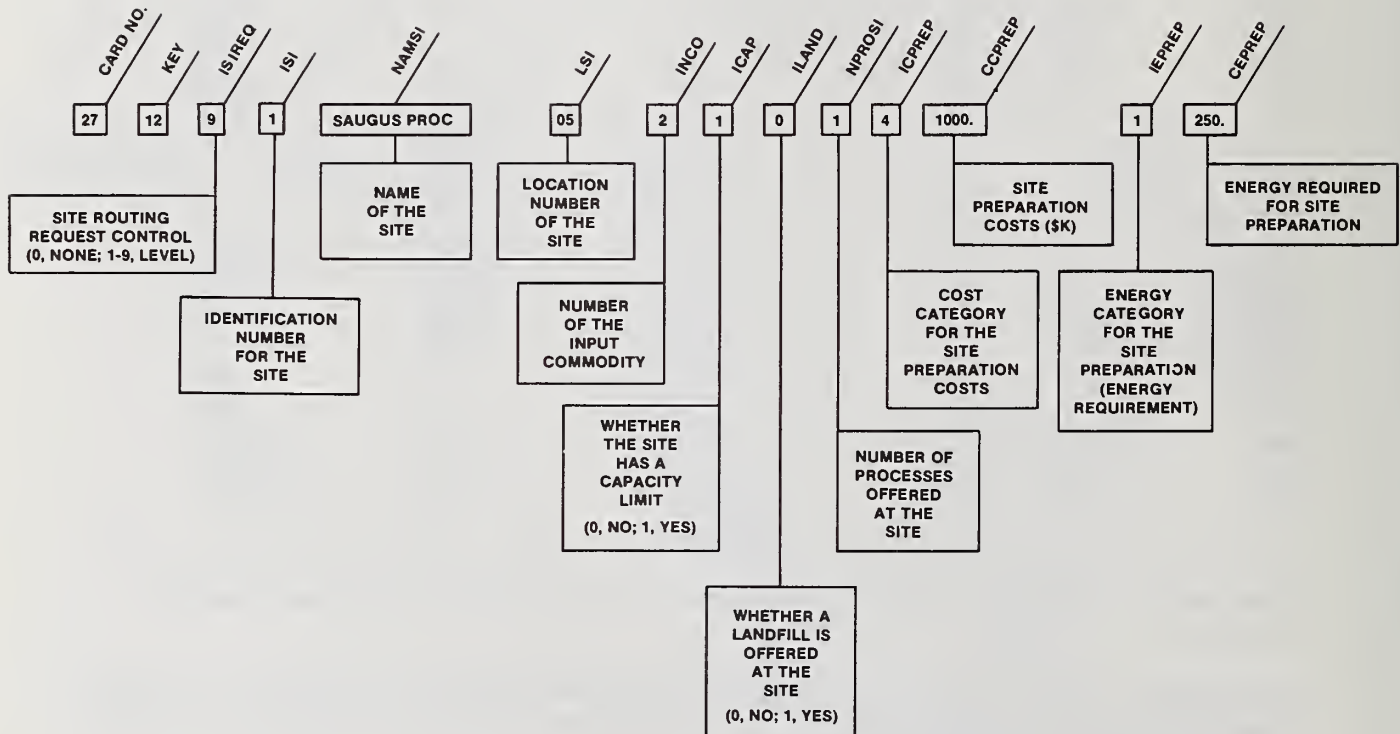
Exhibit 3.27  Case Study File:  Site Data

Part B:  Interpretation

This is one of NSI site cards.  As for sources, the second entry is designed
for tracing activities to be carried out once the optimization has been
completed.  The next three entries show the site number, name and location.
The incoming commodity is then given.  With the exception of a site receiving
MSW, each site must receive exactly one commodity.  For an MSW receiving site,
enter 2 for INCO.  If the site is not MSW receiving, INCO must be greater than
5, since the first five commodities are various forms of source generated
waste.  The next three entries determine if the site is capacitated, has land
available for landfilling, and the number of processes to be considered.  The
last four entries deal with site preparation activities.  It is important to
note that site preparation costs, CCPREP, are in thousands of dollars and site
preparation energy requirements, CEPREP, are denominated in the units declared
on the energy category data cards (see exhibit 3.24).

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 12 | 12 |
| ISIREQ | I1 | 3 | 0 | 9 |
| ISI | I2 | 5 | 1 | NSI[a] |
| NAMSI | 5A4 | 8 | -- | ---- |
| LSI | I3 | 29 | 1 | LSTLO |
| INCO | I2 | 34 | 2 | NCO |
| ICAP | I1 | 37 | 0 | 1 |
| ILAND | I1 | 38 | 0 | 1 |
| NPROSI | I2 | 39 | 1 | NPR[a] |
| ICPREP | I2 | 42 | 0 | NCC |
| CCPREP | F10.3 | 44 | -- | ---- |
| IEPREP | I2 | 54 | 0 | NEC |
| CEPREP | F10.3 | 56 | -- | ---- |

[a]The values of NSI and NPR are entered on the control card (see exhibit
3.15).

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Exhibit 3.28  Case Study File:  Landfill Data

Part A:  Variable Definitions and Sequencing
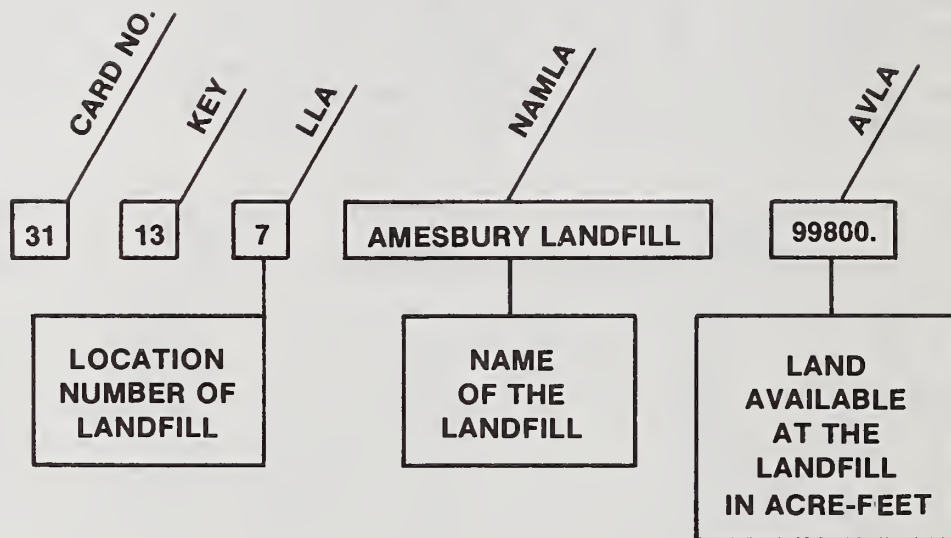
Exhibit 3.28  Case Study File:  Landfill Data

Part B:  Interpretation

The model allows for numerous ways for combining processing and landfilling. This card defines a landfill, gives its location and an estimate of the land available in acre feet.  If the number of landfills, NLA, was listed as zero on card 1, then no cards of this type should be entered.  There should be one card per location at which ILAND on the site card was coded equal to one.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---------------|------------------------|--------------|---------------|---------------|
| KEY | I2 | 1 | 13 | 13 |
| LLA | I3 | 4 | 1 | LSTLO |
| NAMLA | 5A4 | 8 | -- | --- |
| AVLA | F10.3 | 29 | 0.001 | --- |

Exhibit 3.29  Case Study File:  Process Data (1)

Part A.  Variable Definitions and Sequencing
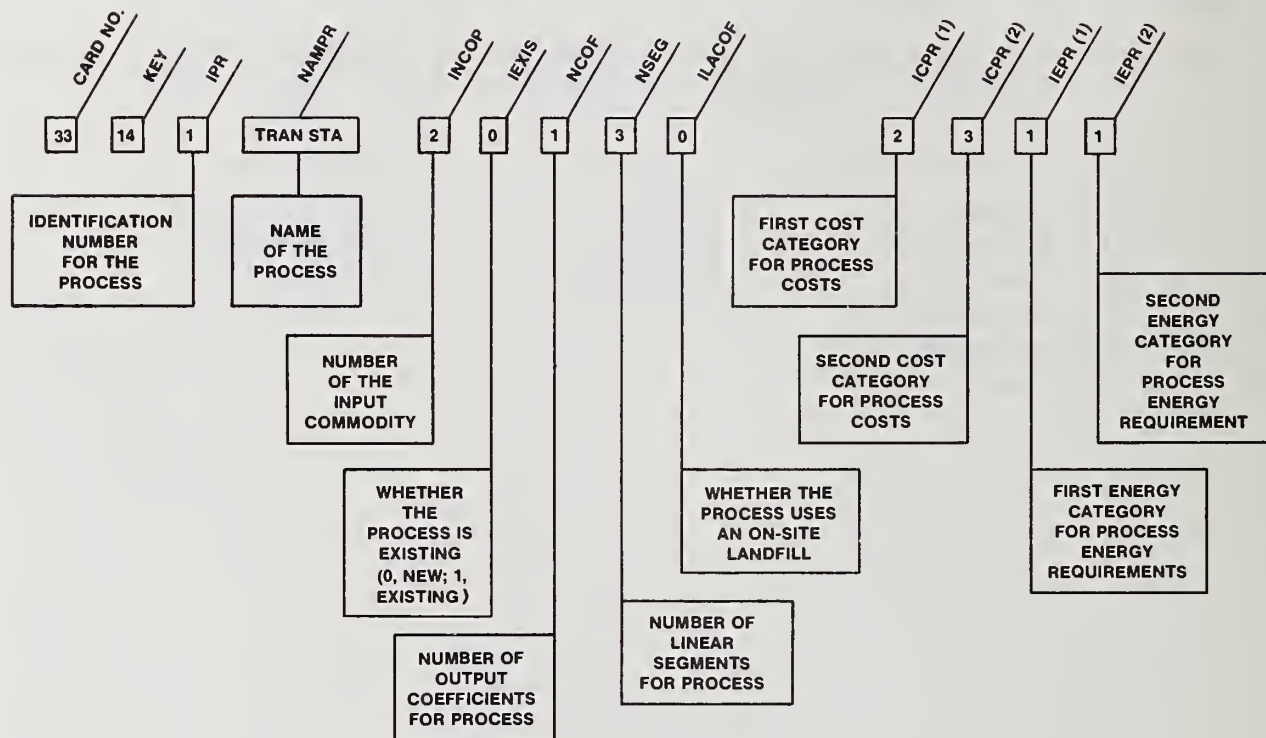
Exhibit 3.29   Case Study File:   Process Data (1)

Part B:   Interpretation

Each process is identified by a process number, IPR, and by its position in
the sequence 1 through NPR.  With the exception of a process receiving MSW,
each process must receive exactly one commodity.  The process input commodity,
INCOP, should be coded as 2 if it is MSW receiving; otherwise a value greater
than 5 must be entered.  If the process was in existence at the beginning of
the study period IEXIS should be coded as 1.  The number of commodities output
and the number of segments in the cost function are then given.  The next two
entries establish a means for recording landfill activites.  The last four
variables are designed for allocating costs (and energy) among two distinct
categories (e.g., for costs, operation and maintenance versus capital).  It is
important to note that the first process must be a transfer station
characterized by both inputting and outputting MSW.  A single output
coefficient of 1.0 is required.  This first process is used by the model in
performing the dedicated transfer station analysis.  Other transfer station
processes may also be entered and assigned any process number greater than
one.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 14 | 14 |
| IPR | I2 | 5 | 1 | NPR |
| NAMPR | 5A4 | 8 | -- | --- |
| INCOP | I2 | 29 | 1 | NCO |
| IEXIS | I1 | 31 | 0 | 1 |
| NCOF | I1 | 32 | 0 | 7 |
| NSEG | I1 | 33 | 1 | 3 |
| ILACOF | I1 | 34 | .0 | 1 |
| USLA | F8.5 | 35 | a | --- |
| ICPR(1) | I2 | 44 | 1 | NCC |
| ICPR(2) | I2 | 46 | 1 | NCC |
| IEPR(1) | I2 | 48 | 0 | NEC |
| IEPR(2) | I2 | 50 | 0 | NEC |

a   If ILACOF = 0, then the value is irrelevant.
    If ILACOF = 1, then the minimum is 0.0001.

Exhibit 3.30  Case Study File:  Process Data (2)

Part B:  Interpretation

For each process there is a card identifying which commodities are output and in what quantity as a function of the amount of waste processed.  All outputs are measured in the units appropriate for that commodity (e.g., MBTU per unit input).  As pointed out earlier, for the first process (a transfer station) there must be a single output of MSW coded as 2 with an output coefficient of 1.0.  This card must be entered even if the process does not produce an output (e.g., disposal in a landfill).  In such a case the only entries are KEY and KEMP; they serve as placeholders.  Enter a number of ICOF(K) and COF(K) equal to NCOF read on KEY 14.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 15 | 15 |
| KEMP | I2 | 5 | 1 | NPR |
| ICOF(1) | I2 | 8 | 1 | NCO |
| COF(1) | F8.5 | 10 | a | --- |
| ICOF(2) | I2 | 18 | b | NCO |
| COF(2) | F8.5 | 20 | a | --- |
| ICOF(3) | I2 | 28 | b | NCO |
| COF(3) | F8.5 | 30 | a | --- |
| ICOF(4) | I2 | 38 | b | NCO |
| COF(4) | F8.5 | 40 | a | --- |
| ICOF(5) | I2 | 48 | b | NCO |
| COF(5) | F8.5 | 50 | a | --- |
| ICOF(6) | I2 | 58 | b | NCO |
| COF(6) | F8.5 | 60 | a | --- |
| ICOF(7) | I2 | 68 | .b | NCO |
| COF(7) | F8.5 | 70 | a | --- |

[a] If NCOF=0, then no value should be entered.  If NCOF>1, then COF(K)> 0.00001 for K <NCOF.  COF(K) should be left blank for K>NCOF.

[b] If NCOF=0, then no value should be entered.  If NCOF>1, then ICOF(K)>1 for K<NCOF.  ICOF(K) should be left blank for K>NCOF.

Exhibit 3.31  Case Study File:  Process Data (3)

Part A:  Variable Definitions and Sequencing
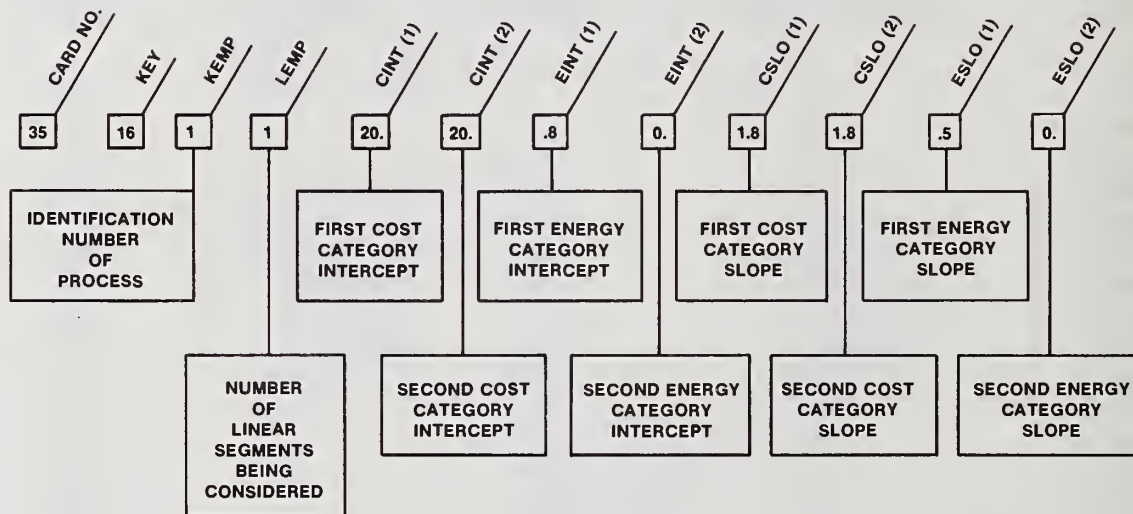
Exhibit 3.31   Case Study File:   Process Data (3)

Part B:   Interpretation

Basic processing costs are entered on the third process card as slopes and
intercepts for each linear segment of the process.   There are NSEG such cards
for each process.   Two cost categories (and two energy categories) are
provided, enabling the user to handle a wide variety of nonlinearities in the
cost (and net energy) functions.   The basic units of the model are thousand
tons and thousand dollars.   Most cost inputs may therefore be entered in
dollars per ton because that is equivalent to thousand dollars per thousand
tons.   There are two exceptions.   First, intercept costs must be entered in
thousands of dollars.   These include the site preparation cost, CCPREP (see
exhibit 3.27), and the two cost function intercepts, CINT(1) and CINT(2).
Note that there will be NSEG values for CINT(1) and CINT(2).   Second, if the
user has defined the unit of a commodity in other than thousand tons, the cost
inputs into its process, including CSLO(1) and CSLO(2) and REVSP (see exhibit
3.32), of the commodity, must be in thousands of dollars per defined unit of
the commodity.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 16 | 16 |
| KEMP | I2 | 5 | 1 | NPR |
| LEMP | I1 | 7 | 1 | 3 |
| CINT(1) | F9.2 | 8 | -- | ---- |
| CINT(2) | F9.2 | 17 | -- | ---- |
| EINT(1) | F9.2 | 26 | -- | ---- |
| EINT(2) | F9.2 | 35 | -- | ---- |
| CSLO(1) | F9.6 | 44 | -- | ---- |
| CSLO(2) | F9.6 | 53 | -- | ---- |
| ESLO(1) | F9.6 | 62 | -- | ---- |
| ESLO(1) | F9.6 | 71 | -- | ---- |

Exhibit 3.32  Case Study File:  Site-Process Combination Data

Part A:  Variable Definitions and Sequencing
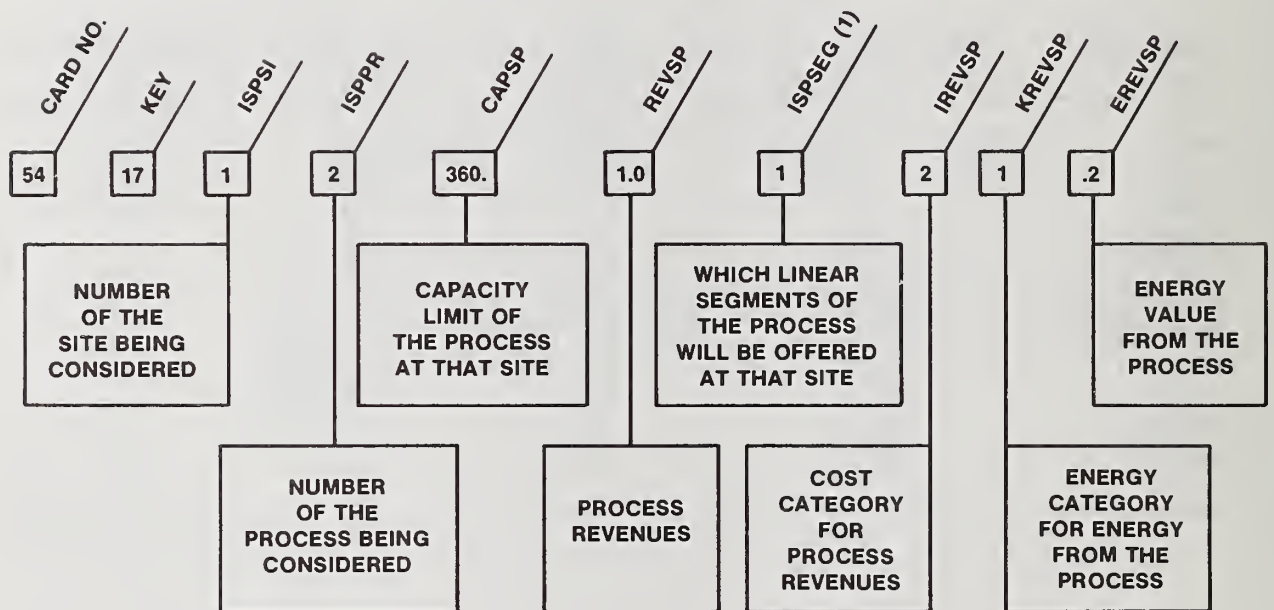
Exhibit 3.32   Case Study File:   Site-Process Combination Data

Part B:   Interpretation

The SIPROC or site-process cards offer processes at sites.   There are NSP such
cards.   Each SIPROC offers one process at one site.   An existing process
(IEXIS = 1, see exhibit 3.29) must be the only process at its site, but any
number of new processes may be offered at the same site.   Implicit revenues
net of haul to the market for recoverables not specified through output
coefficients and commodities are entered on this card.   A similar arrangement
is made for the energy values of recoverables not declared elsewhere.   Due to
the location of a site, its intended shipments, or for other reasons, it may
be necessary to set an upper limit on capacity.   The entry on CAPSP limits the
scale of operations for the process activities at a candidate site.   CAPSP
assumes that the entire site is devoted to this process.   The offering of an
ISPSEG(K) at a site-process does not limit the scale of activity at the site.
However, since each ISPSEG(K) generates a column in the matrix, these controls
give the user an opportunity to eliminate unnecessary columns which may render
certain scales of operation economically unattractive at the site.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 17 | 17 |
| ISPSI | I2 | 5 | 1 | NSI |
| ISPPR | I2 | 9 | 1 | NPR |
| CAPSP | F9.3 | 12 | a | --- |
| REVSP | F9.3 | 22 | -- | --- |
| ISPSEG(1) | I1 | 32 | b | 1 |
| ISPSEG(2) | I1 | 33 | b | 1 |
| ISPSEG(3) | I1 | 34 | b | 1 |
| IREVSP | I2 | 36 | 0 | NCC |
| KREVSP | I2 | 39 | 0 | NEC |
| EREVSP | F10.5 | 41 | -- | --- |

a   If  ICAP(ISPSI) = 1, then the minimum is 0.0001.
    If  ICAP(ISPSI) = 0, then the value is irrelevant.
b   ISPSEG(K) will be functional only if K≤NSEG on the first
    process card.   The sum of functional ISPSEG(K) for a
    site-process combination must be greater than or equal to 1.

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Exhibit 3.33  Case Study File:  Market Data (1)

Part A:  Variable Definitions and Sequencing
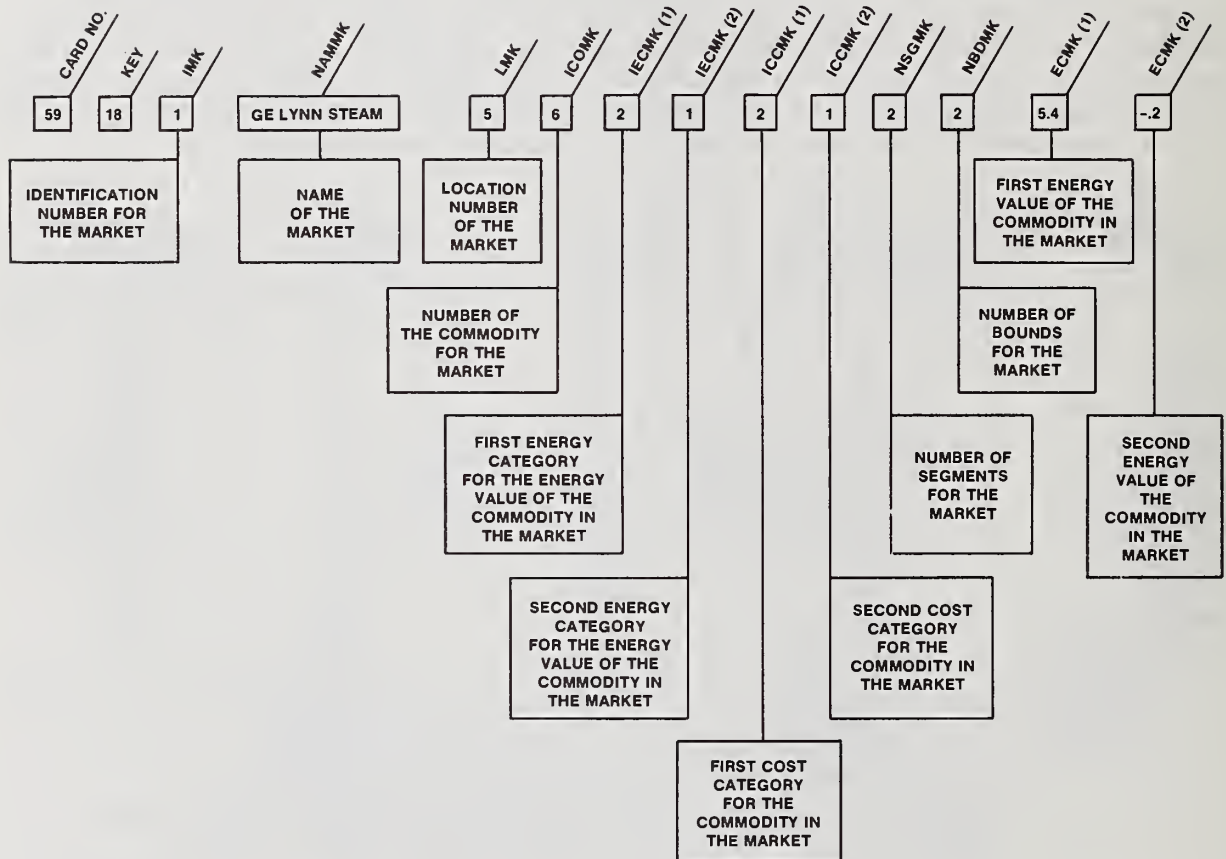
Exhibit 3.33   Case Study File:   Market Data (1)

Part B:   Interpretation

Markets are specified by commodity and location.   Markets may be either
limited or unlimited, and fixed price or declining price.   A declining price
market is represented by piecewise linear approximation with up to five linear
segments per market.   An unlimited fixed price market may be recorded here
explicitly, or represented implicitly by a net revenue on the SIPROC cards
(see exhibit 3.32).   Energy values of the commodity in the market are also
entered on this card.   For the two energy categories, the value is assumed to
be constant with respect to the marketed quantity, in contrast to the revenue,
which may decline with respect to the marketed quantity in up to five
segments.   No cards of this type should be entered if NMK was coded as 0 on
the control card (see exhibit 3.15).   A limited market has NBDMK = NSGMK.   An
unlimited market has NBDMK = MSGMK-1.   A fixed price market has NSGMK = 1.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 18 | 18 |
| IMK | I2 | 5 | 1 | NMK |
| NAMMK | 5A4 | 8 | -- | --- |
| LMK | I3 | 29 | 1 | LSTLO |
| ICOMK | I2 | 34 | 1 | NCO |
| IECMK(1) | I2 | 38 | 0 | NEC |
| IECMK(2) | I2 | 42 | 0 | NEC |
| ICCMK(1) | I2 | 46 | 1 | NCC |
| ICCMK(2) | I2 | 50 | 1 | NCC |
| NSGMK | I1 | 53 | 1 | 5 |
| NBDMK | I1 | 54 | NSGMK-1 | NSGMK |
| ECMK(1) | F10.5 | 55 | -- | --- |
| ECMK(2) | F10.5 | 65 | -- | --- |

Exhibit 3.34   Case Study File:  Market Data (2)

Part A:   Variable Definitions and Sequencing
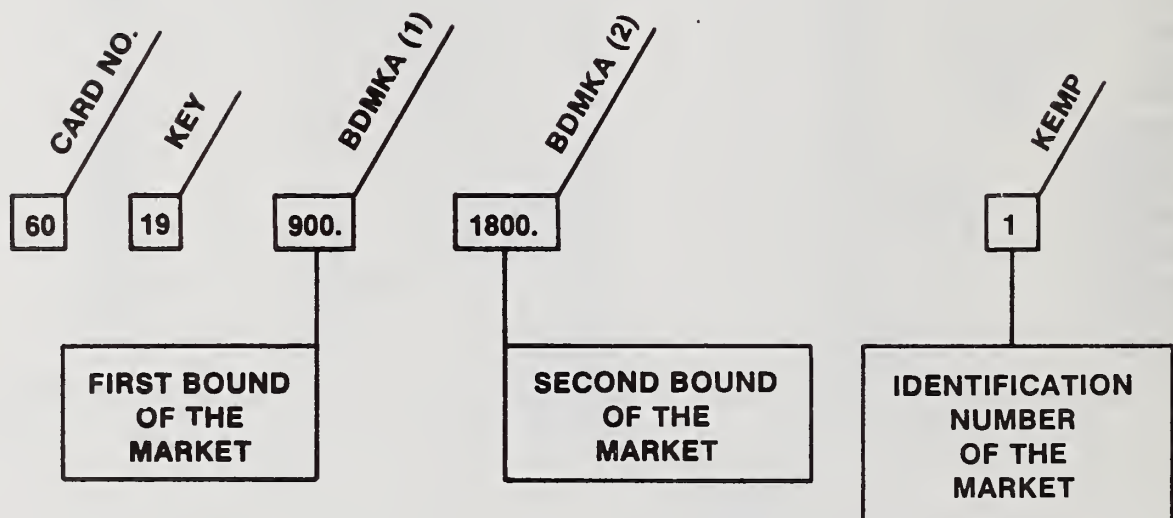
Exhibit 3.34  Case Study File:  Market Data (2)

Part B:  Interpretation

This card allows the user to trace a declining price market structure setting
up to five cumulative bounds above which the revenue per unit is reduced.
This card must be entered even if the market is unlimited.  In such a case,
the only entries are KEY and KEMP; they serve as placeholders.  No cards of
this type should be entered if NMK was coded as 0 on the control card.  Enter
a number of BDMKA(K) equal to NBDMK on the first market data card.  BDMKA(K)
for values of K greater than NBDMK will be read but not used.  Enter the
BDMKA(K) in cumulative units of the commodity.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 19 | 19 |
| BDMKA(1) | F7.2 | 3 | | |
| BDMKA(2) | F7.2 | 10 | | |
| BDMKA(3) | F7.2 | 17 | a | |
| BDMKA(4) | FY.2 | 24 | | |
| BDMKA(5) | F7.2 | 31 | | |
| KEMP | I2 | 75 | 1 | NMK |

a BDMKA(K) ≥ BDMKA(K-1) + 0.0001 K>1.

Exhibit 3.35  Case Study File:  Market Data (3)

Part A:  Variable Definitions and Sequencing

| CARD NO. | KEY | CFMKA (1) | CFMKA (2) | CFMKB (1) | CFMKB (2) | KEMP |
|----------|-----|-----------|-----------|-----------|-----------|------|
| 61 | 20 | 3.0 | 2.0 | 0. | 0. | 1 |

| FIRST REVENUE COEFFICIENT FOR THE COMMODITY IN THE MARKET WITHIN THE FIRST BOUND | FIRST REVENUE COEFFICIENT FOR THE COMMODITY IN THE MARKET WITHIN THE SECOND BOUND | SECOND REVENUE COEFFICIENT FOR THE COMMODITY IN THE MARKET WITHIN THE FIRST BOUND | SECOND REVENUE COEFFICIENT FOR THE COMMODITY IN THE MARKET WITHIN THE SECOND BOUND | IDENTIFICATION NUMBER OF THE MARKET |
|---|---|---|---|---|

Exhibit 3.35   Case Study File:   Market Data (3)

Part B:   Interpretation

The two sets of segments CFMKA and CFMKB allow for revenue sharing
arrangements.  The user should enter NSGMK market revenue coefficients for
each set.  For a single segment market, enter the pro rated price in CFMKA(1)
and CFMKB(1), respectively.  The sum of the two values must equal the price
per commodity unit.  For a multi-segment market, enter the marginal revenue
per segment (i.e., the slope of the total revenue function along that
segment).  Note that the price in the market is equal to the average revenue
(i.e, total revenue divided by the quantity sold).  The successive units must
be a decreasing function of the interval number.  The units of revenue are
assumed to be thousands of dollars per commodity unit.  No cards of this type
should be entered if NMK was coded as 0 on the control card.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---------------|------------------------|--------------|---------------|---------------|
| KEY           | I2                     | 1            | 20            | 20            |
| CFMKA(1)      | F7.3                   | 3            | 0.0           | ---           |
| CFMKA(2)      | F7.3                   | 10           | a             | ---           |
| CFMKA(3)      | F7.3                   | 17           | a             | ---           |
| CFMKA(4)      | F7.3                   | 24           | a             | ---           |
| CFMKA(5)      | F7.3                   | 31           | a             | ---           |
| CFMKB(1)      | F7.3                   | 38           | 0.0           | ---           |
| CFMKB(2)      | F7.3                   | 45           | b             | ---           |
| CFMKB(3)      | F7.3                   | 52           | b             | ---           |
| CFMKB(4)      | F7.3                   | 59           | b             | ---           |
| CFMKB(5)      | F7.3                   | 66           | b             | ---           |
| KEMP          | I2                     | 75           | 1             | NMK           |

a   $CFMKA(K) \leqslant CFMKA(K-1)$ $K>1$.
b   $CFMKB(K) \leqslant CFMKB(K-1)$ $K>1$.

Exhibit 3.36  Case Study File:  Cost Summation Data

Part A:  Variable Definitions and Sequencing
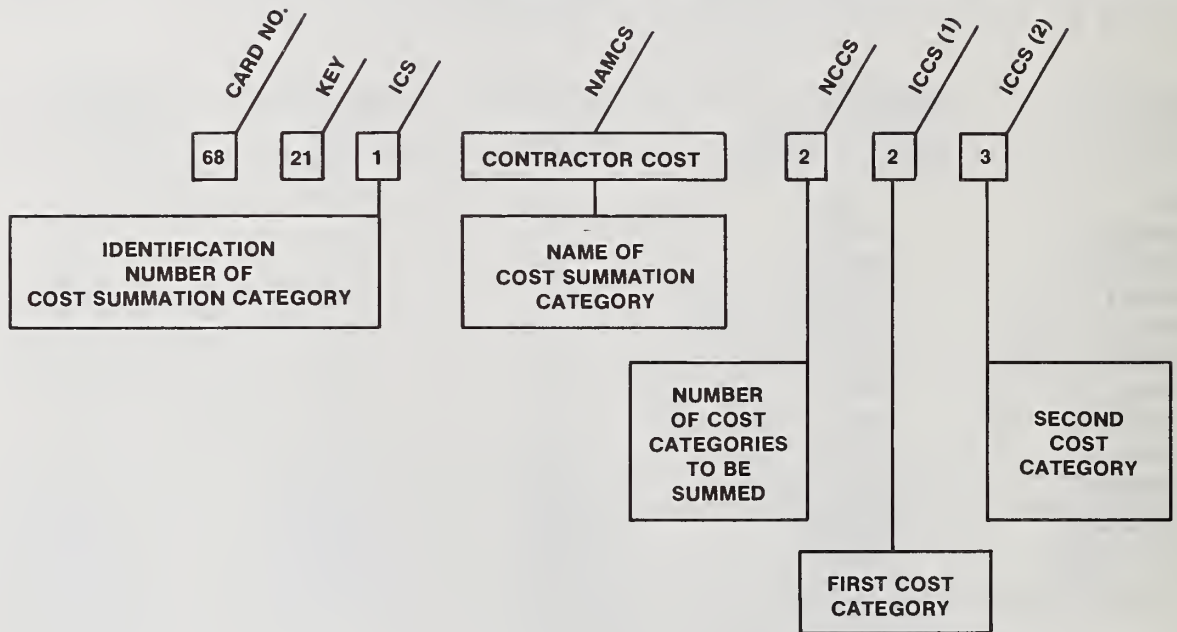
Exhibit 3.36  Case Study File:  Cost Summation Data

Part B:  Interpretation

This card permits the user to aggregate data from two or more cost categories
for purposes of reporting costs.  There are NCS such cards.  No cards of this
type should be entered if NCS was coded as 0 on the control card. Cost
summation categories may be used to make explicit what portion of the total
costs of the plan are being borne by the municipality, by a contractor
providing services to the municipality, or represent cash flows into or out of
the region.  A cost category may be listed in more than one cost summation
category without causing double-counting in the system costs.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 21 | 21 |
| ICS | I2 | 5 | 1 | NCS |
| NAMCS | 5A4 | 8 | -- | --- |
| NCCS | I2 | 28 | 1 | 10 |
| ICCS(1) | I2 | 32 | 1 | NCC |
| ICCS(2) | I2 | 36 | a | NCC |
| ICCS(3) | I2 | 40 | a | NCC |
| ICCS(4) | I2 | 44 | a | NCC |
| ICCS(5) | I2 | 48 | a | NCC |
| ICCS(6) | I2 | 52 | a | NCC |
| ICCS(7) | I2 | 56 | a | NCC |
| ICCS(8) | I2 | 60 | a | NCC |
| ICCS(9) | I2 | 64 | a | NCC |
| ICCS(10) | I2 | 68 | a | NCC |

[a]For K>NCCS no value should be entered; otherwise the minimum value is 1.

Exhibit 3.37   Case Study File:   Transportation Data (1)

Part A:   Variable Definition and Sequencing



**SOURCE TO SITE LINK**

CARD NO. | KEY | ITTYP | ITRCO | ITRSM
69 | 22 | 1 | 1 | 1

**TYPE OF TRANSPORTATION LINKAGE**

**SOURCE NUMBER**

**DESTINATION SITE NUMBER**
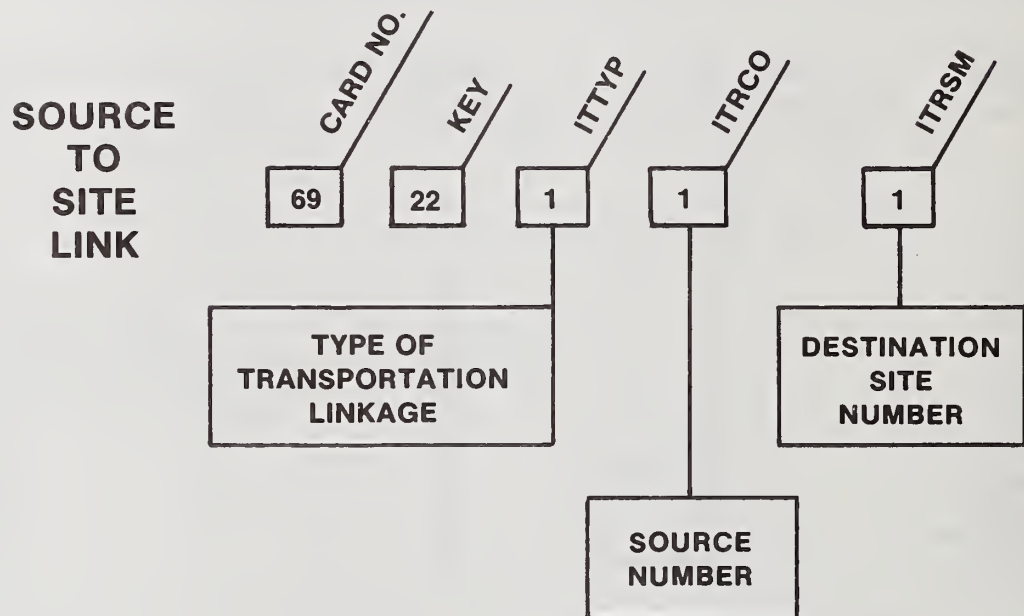
Exhibit 3.37   Case Study File:   Transportation Data (1)

Part B:   Interpretation

This is the first of three types of transportation linkage cards.  A value of ITTYP equal to 1 defines this as a source-to-site linkage.  For each source, the user offers one linkage to each site which can serve as an offload.  The origin is specified by the source number coded into ITRCO; the destination is specified by the site number coded into ITRSM.  The locations associated with the origin-destination pair are used to read the two distance files (see section 3.3).  There must be at least one ITTYP 1 card per source, and at least one ITTYP 1 or 2 card offloading per site.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---------------|------------------------|--------------|---------------|---------------|
| KEY | I2 | 1 | 22 | 22 |
| ITTYP | I1 | 4 | 1 | 1 |
| ITRCO | I2 | 7 | 1 | NSU |
| ITROG[a] | I3 | 10 | -- | --- |
| ITRSM | I2 | 15 | 1 | NSI |

a   Input value is irrelevant.

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Exhibit 3.38   Case Study File:   Transportation Data (2)

Part A:   Variable Definition and Sequencing
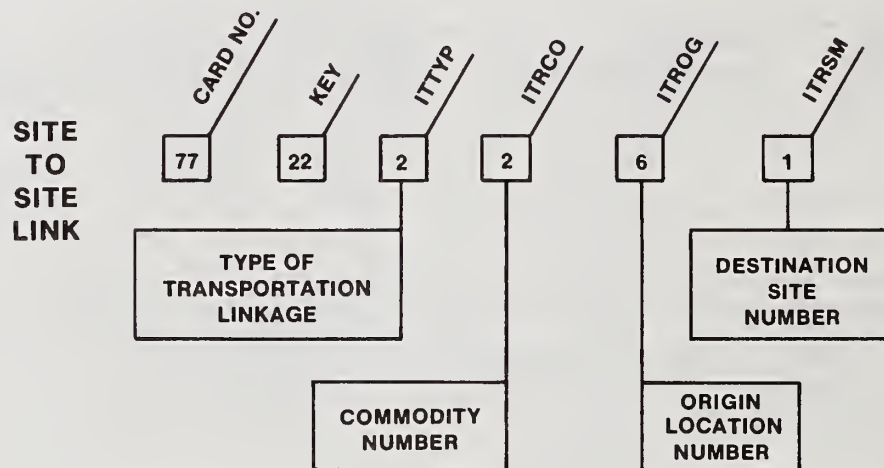
Exhibit 3.38   Case Study File:   Transportation Data (2)

Part B:   Interpretation

This is the second of the three types of transportation linkage cards.   A
value of ITTYP equal to 2 difines this as a site-to-site linkage.   The
commodity number is entered as ITRCO; the origin location number is entered as
ITROG, and the destination site number is entered as ITRSM.   There must be at
least one ITTYP 2 or 3 card entered per commodity/origin location combination.
There must be at least one ITTYP 1 or 2 card per site as destination.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---------------|------------------------|--------------|---------------|---------------|
| KEY   | I2 | 1  | 22 | 22    |
| ITTYP | I1 | 4  | 2  | 2     |
| ITRCO | I2 | 7  | 1  | NCO   |
| ITROG | I3 | 10 | 1  | LSTLO |
| ITRSM | I2 | 15 | 1  | NSI   |

Exhibit 3.39  Case Study File:  Transportation Data (3)

Part A:  Variable Definition and Sequencing
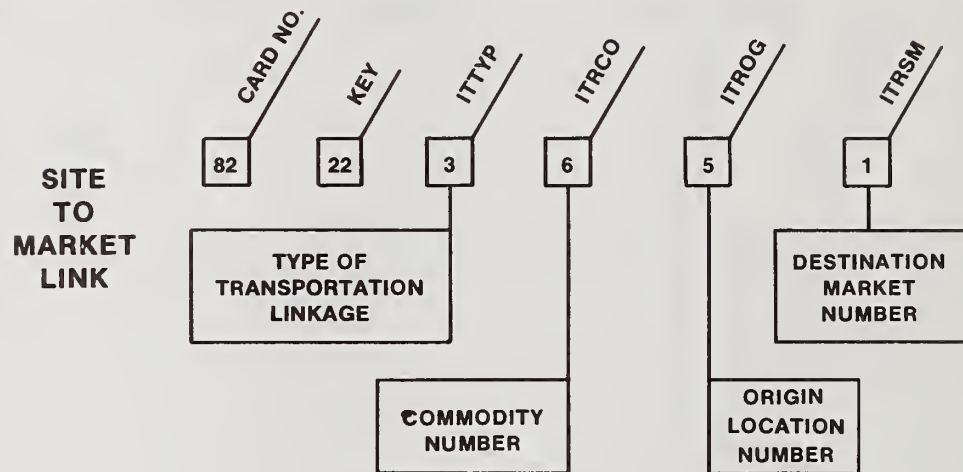


SITE TO MARKET LINK

Exhibit 3.39   Case Study File:   Transportation Data (3)

Part B:   Interpretation

This is the third of the three types of transportation linkage cards.   A value
of ITTYP equal to 3 defines this as a site-to-market linkage.   There must be
at least one input link to each market as destination.   There must be at least
one ITTYP 2 or 3 card per commodity/origin location combination.   Enter
commodity as ITRCO.   Enter origin location number as ITROG; enter destination
market number as ITRSM. If NMK was coded as 0 on card 1 then no type 3 cards
should be entered.[a] All other interpretations are the same as for site-to-site
shipments.

| Variable Name | Variable Specification | First Column | Minimum Value | Maximum Value |
|---|---|---|---|---|
| KEY | I2 | 1 | 22 | 22 |
| ITTYP | I1 | 4 | 3 | 3 |
| ITRCO | I2 | 7 | 1 | NCO |
| ITROG | I3 | 10 | 1 | LSTLO |
| ITRSM | I2 | 15 | 1 | NMK |

[a]The end of the transportation file is marked by a single card with
KEY = 23, and no other entry.   (See card number 86 in exhibit 3.14.)

## 3.3  PACKER AND VAN DISTANCE FILES

Each source of waste generation, transfer or processing site, disposal site, and market is identified by a three-digit location code.[1]  Two point-to-point distance files are input in either a triangular or square matrix format, one for packers and one for vans.  The files establish a measure of distance between each pair of three-digit location codes in miles, minutes, or cost.  These distance files are used by RRPLAN to calculate haul costs for various kinds of transportation activities.  The packer distance file is read on unit 7 whereas the van distance file is read on unit 8.  Each file must be fully sorted by major record and within a major record by minor record.  In a triangular file, the major record is the higher numbered location and the minor record is the lower numbered location.  In a square file, the major record is the destination location number and the minor record is the origin location number.  Setting the control variable ISQR to zero indicates that triangular distance files are to be input whereas a value of one indicates that square files are to be input.

Three different kinds of expansion are performed on the transportation file by RRPLAN; they are:  (1) location expansion, (2) source separation expansion; and (3) haul cost expansion.  The file itself, as entered on card type 22, is skeletal.  In the first expansion, RRPLAN extracts location numbers from the source, site, and market cards and adds them to the transportation file for sources and for destination sites and markets.  In the second expansion, the category 1 transportation portion of the transportation file (source-to-site shipments) is expanded to provide categories 4, 5, 6, 8, 9, and 11 through 15 in accordance with the source separation options entered as run controls (KMIX, KSEPO, NTRIG) on card 3 and as source controls (IMIXSU, ISEPSU, ITRIGS) on card type 11.[2]  As mentioned earlier, the run controls dominate the source controls.  In the third expansion, haul costs are calculated for each entry in the expanded transportation file.  This step uses the distance files for packers and for vans, and the haul cost multipliers, CCOCC(1), CCOCC(2), CCOEC(1), and CCOEC(2), entered on the commodity category cards.

If the distances in the files are recorded in miles, the haul cost multipliers should be dollars per ton-mile appropriate to the commodity.  If the distances are in minutes, the haul cost multipliers should be dollars per ton-minute to the commodity.  If the distances are in costs, said costs should be in the form of cost per ton over the distance between the two locations for the haul

---

[1] No location numbers are required for markets associated with implicit revenues (as declared on a SIPROC card).

[2] The activities corresponding to the expanded transportation file were described in section 2.2 and presented in summary form in table 2.2.

of MSW, by packer for the packer file and by van for the van file. In that case, the haul cost (CCOCC(1) + CCOCC(2)) should be 1.0 for commodity number 1 (haul of MSW in a packer) and for commodity number 2 (haul of MSW in a van). Other haul costs should be the ratio of the haul cost for that commodity to the haul cost of MSW. The denominator is haul cost of MSW in a van for all other commodities except number 4 which is source separation residue hauled in a packer. Energy requirements for haul are respectively per mile, per minute, and per dollar of MSW haul cost.

Turnaround times pose a number of difficulties which require some attention when constructing the case study and distance files so as to avoid double counting. Standard turnaround times are entered in CSPA (card 3), CSPB (card 3), and in CSLO(1) and CSLO(2) (card type 16). Non-standard turnaround times are entered in CSLO(1) and CSLO(2) for processes other than truck transfer stations and in the packer distance file. Both issues will be discussed in this section, although particular emphasis will be placed how each issue is related to the two distance files.

The standard turnaround time for unloading a packer should be included in the total cost of collection, CSPA, in the form of a cost per ton. The correct cost is the cost per minute for the packer, with its crew, multiplied by the number of minutes of standard time for unloading, divided by the average load of the packer in tons. The standard time, for both packer and van, is the time for unloading at a transfer station. Since the unit of measure of source-separation alternatives is (thousand) tons of preseparated MSW, there is a saving in turnaround cost in that the packer, now actually carrying source-separation residue, carries a larger payload if measured in equivalent preseparated MSW. The saving is (1 - PCRES) multiplied by the standard turnaround cost per ton, where PCRES is the percent of source separation residue by weight (card 3). This saving is subtracted from the incremental cost of source separation to obtain CSPB for entry on card 3.

The cost per ton of standard turnaround time for loading a van at the transfer station and unloading it at a selected offload (selected by the user to be the standard) should be added to the slope costs, CSLO(1) and CLSO(2), for each linear segment for each truck transfer process. The cost may be added to either CSLO(1) or CSLO(2), or split between the two. To add the cost to both would double-count it. Note again that the cost should be entered for each linear segment for each truck transfer process.

Non-standard turnaround costs should be added to CSLO(1) or CSLO(2) for each segment of the associated process (i.e., any process except a truck transfer station). The costs to be added include the total turnaround cost for loading all outputs in dollars per input of the process plus either of the following:

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(i)    if MSW-receiving, the actual turnaround cost per ton of MSW for unloading a van <u>minus</u> the standard turnaround cost for unloading a van; or

(ii)   if not MSW-receiving, the actual turnaround cost per unit of the input commodity for unloading a van (in thousands of dollars per input unit).

The van distance files have been kept clean of turnaround cost since these files are the basis for costing the haul of many different commodities. In order to keep the van files clean, an adjustment was made in the slopes of non-transfer processes to cover non-standard turnaround costs for vans. The form of the turnaround cost added to the slopes controls the form of the turnaround cost for packers, which is entered into the packer distance file.

The following turnaround cost should be added to entries in the packer distance file in the case where the standard turnaround cost does not apply to either packer or van or both:

The incremental packer offload turnaround cost (actual minus standard), minus the incremental van offload cost (actual minus standard), all divided by a unit translation factor.[1]

If the file is in a triangular format and the packer distance file adjustment is to be made for an offload, it should be entered for the corresponding location number as either origin or destination in the file because each location pair appears once in the file.

If the user wishes to differentiate a non-standard turnaround time adjustment for two or more site-process combinations, or a source and a site, at the same location, two or more location numbers may be entered into the packer distance file to represent the same real location. The sites and sources may then be keyed to the two location numbers. The non-standard turnaround cost is probably most significant for both packers and vans for offload at a landfill.

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[1]The unit translation factor is 1. if the units of the distance file are costs per ton (i.e., the turnaround cost is already commensurate with the costs in the distance file); the unit translation factor is cost per minute or cost per mile if the units of the distance file are minutes or miles, in order to convert the turnaround cost into equivalent minutes or miles. Note that the packer distance file will not need to be modified at all if both packers and vans use standard turnaround times since in that case the cost goes to zero in the above formula.

The triangular format distance files are arranged so that the entry for each
pair of points appears only once. This is accomplished by <u>arbitrarily</u>
defining the lower location number as the origin and the higher destination
number as the destination. Exhibits 3.40 and 3.41 are examples of triangular
distance files for packers and vans, respectively. Note that all entries are
in dollars per ton. The distance tables shown in the exhibits are examples of
complete linkage between each destination and all origins with lower location
numbers. Although complete linkages will not cause any error if the said
linkage was not declared on one of the type 22 transportation data cards, for
regions with a large number of locations the files may become unwieldly. The
general organization of the files is described in table 3.1.

<p style="text-align:center">Table 3.2  Structure of the Packer and Van Distance Files</p>

| Card Type | Variable Specification | First Column | Purpose |
|---|---|---|---|
| First | 20A4 | 1 | Title[a] |
| Second[b] | | | |
| Third[b] | | | |
| Destination (1)[c] | I1 | 1 | Flag[d] |
| Destination (1) | I3 | 3 | Destination Location No. |
| Destination (2)[d] | I3 | 2 | First origin |
| Destination (2) | F6.2 | 6 | First distance |
| Destination (2) | I3 | 14 | Second origin |
| Destination (2) | F6.2 | 18 | Second distance |
| Destination (2) | I3 | 26 | Third origin |
| Destination (2) | F6.2 | 30 | Third distance |
| Destination (2) | I3 | 38 | Fourth origin |
| Destination (2) | F6.2 | 42 | Fourth distance |
| Destination (2) | I3 | 50 | Fifth origin |
| Destination (2) | F6.2 | 54 | Fifth distance |
| Destination (3) | I1 | 1 | Flag[e] |

[a]Enter up to 80 alphanumeric characters to identify the distance file;
identification should include whether packer or van, and the name of the
region.

[b]No entries are to be made on these cards.

[c]Enter a block of cards for each destination, with the destination, blocks
ordered by destination location numer. Each destination block has one first
card (Destination(1)), one or more middle cards (Destination(2)), and one
last card (Destination (3)). The Destination (2) cards should be used to
enter origin/distance pairs, five pairs per card, in order of origin
location number, leaving no gaps. The last pair in each destination block
should be the diagonal element, origin equals destination, with a value of
0.

[d]The first entry must be coded as 1.

[e]The entry must be coded as 2.

Exhibit 3.40  Typical Distance File for Packers

```
 1        DISTANCE FILE FOR PACKERS IN DOLLARS PER TON
 2
 3
 4        1    1
 5            1 0.
 6        2
 7        1    2
 8            1 2.          2 0.
 9        2
10        1    3
11            1 1.5         2 1.4        3 0.
12        2
13        1    4
14            1 1.5         2 3.         3 3.5        4 0.
15        2
16        1    5
17            1 1.          2 2.5        3 2.0        4 1.        5 0.
18        2
19        1    6
20            1 30.         2 32.        3 31.        4 29.       5 30.
21            6 0.
22        2
23        1    7
24            1 15.         2 16.        3 14.        4 18.       5 16.
25            6 33.         7 0.
26        2
27        1    8
28            1 50.         2 51.        3 49.        4 50.       5 50.
29            6 38.         7 60.        8 0.
30        2
31        1    9
32            1 30.         2 32.        3 31.        4 29.       5 30.
33            6 0.          7 33.        8 38.        9 0.
34        2
```

Exhibit 3.41  Typical Distance File for Vans

```
 1          DISTANCE FILE FOR VANS IN DOLLARS PER TON
 2
 3
 4          1    1
 5             1 0.
 6          2
 7          1    2
 8             1 .6          2 0.
 9          2
10          1    3
11             1 .5          2 .45         3 0.
12          2
13          1    4
14             1 .5          2 1.          3 1.1         4 0.
15          2
16          1    5
17             1 .3          2 .8          3 .6          4 .3          5 0.
18          2
19          1    6
20             1 10.         2 11.         3 10.5        4 9.5         5 10.
21             6 0.
22          2
23          1    7
24             1 5.          2 5.4         3 5.          4 6.          5 5.5
25             6 11.         7 0.
26          2
27          1    8
28             1 16.         2 16.2        3 15.8        4 16.         5 16.
29             6 13.         7 20.         8 0.
30          2
31          1    9
32             1 10.         2 11.         3 10.         4 9.8         5 10.
33             6 0.          7 11.         8 13.         9 0.
34          2
```

Declaring transportation linkages requires careful handling by the user. A fully linked region would allow the model great freedom in finding the best solution, but it might be costly in problem size (due to greater computational effort). On the other hand, if there is too little linkage, the user may inadvertently predetermine the solution. At the extreme of minimum linkage, the solution coming out of the run will be in essence what the user entered. Minimum linkage, together with the use of one SIPROC per site, is the technique needed to enter a specified solution for evaluation (LOPT = 4). Similarly, minimum linkage for one or more sources is the technique needed for "locking in". The user should however avoid predetermining the solution through too-little linkage in an optimizing run.

# 4. THE RRPLAN OUTPUT AND ITS INTERPRETATION

The model's output reports can be classified into three basic categories. These outputs present a detailed summary of all inputs from the three data files, a complete characterization of each component of the preferred regional plan, and an in-depth analysis of all commodity flows and their associated cost implications. All output reports described in this chapter will be based on the example developed in chapter 3. Although this example is simple with regard to the size of the region, almost all options available to the user have been incorporated into it. The associated output is therefore sufficiently comprehensive to serve as a guide to interpreting the model's output in a general situation.

The description given in the chapter will go through each of the output reports on an item-by-item basis. Emphasis will be placed on relating each output to the relevant portions of the three data files. It is important for users to recognize that some interpretation and qualification is necessary when analyzing the preferred regional plan. The description presented in this chapter will attempt to address these issues for the example at hand. Readers should treat this as illustrative but not limit the interpretation of their own studies to the topics discussed in this chapter. In order to provide guidance for analyzing the solutions produced by the model in a general setting, the next chapter will establish criteria based on experience in model building and consultation among user groups for setting up and critiquing the model's results.

It is also important to point out that if the user were to run the case study described in the previous chapter, the paging would differ from that presented in this chapter. This is due to the fact that several output reports were sufficiently short that they could be presented on the same page. Therefore, in order to conserve on space, two or more output reports from the case example may have been combined into a single exhibit. It is important to note that the <u>order</u> in which <u>all</u> reports are presented in the exhibits is exactly the same as they are output. Since it is the logical sequence of the output and not the paging which is important for interpretation, it is anticipated that users who first test their knowledge of the model by running the case example will have no difficulty in making the crosswalk between the example presented in this chapter and their own case study.

## 4.1 INPUT SUMMARY

The seven exhibits presented in this section serve to characterize the problem as it was sent to the optimizer. In some cases, they reflect modification to the input data made by the model in order to maintain a satisfactory accounting system[1] as well as modifications to the transportation activities associated with the source separation options.

---

[1] Recall that no energy categories are required in order to use the model. The internal accounting system will however, create an artificial category if none is entered in order to handle certain variables in a consistent manner (e.g., the BTU content of MSW, paper and source separation residue).

Exhibit 4.1 summarizes the inputs read on KEYs 1 through 7. These data correspond to inputs coded onto cards 1 through 8 of the ACASE file (see exhibit 3.14). The first part of the output consists of the descriptive title, TEST CASE, based on the input read from card 2 of the ACASE file. The controls for the optimizer (LPHASE, NFORC, KOPT) are then output followed by the key economic variables. In this example, the analysis extends from 1983 until 2002 and uses an inflation rate of 6 percent and a discount rate of 10 percent. The objective of the analysis is to minimize the discounted cost of the regional plan over the 20 year study period.

The next block of information beginning with NUMBER OF COST CATEGORIES and ending with NUMBER OF COST SUMMATION CATEGORIES, establishes the counts for those inputs read on KEYs 8 through 21. The numbers are used internally as endpoints for do loops where each set of data is read in. The large block of information appearing beneath the title SOURCE DATA corresponds to the inputs read from cards 3 through 8 in the ACASE file. Outputs based on card 3 (read KEY 3) data present information on the composition of the waste stream by weight, the BTU values of source separation products, market information on cans and glass, collection costs, run controls governing source separation options, and cost allocation formulas for source separation residue and paper (both as processed waste and for potential capacity requirements when diverted into the waste stream due to the trigger price system). Information from card 4 (read KEY 4) on net energy (both in collection and source separation) and energy-to-cost ratios for paper, glass and cans is then output. Data on energy factors (read KEY 5) follow; they show the BTU content of MSW, an energy category for BTU differentiation, the energy value in the market for paper, glass and cans and the forcing override controls specified by the user.

The remainder of the information on the output report deals with the paper price distribution. Information which specifies the number, size of the intervals in the paper price distribution as well as the minimum price based on data read on KEY 7 is first output. Data from cards 6, 7 and 8 in the ACASE file are then used to compute the average price of paper and, for each trigger price, how much paper is burned and what the average price of paper marketed is expected to be. Notice that as the trigger price is raised, more paper is burned and that the average price of the paper marketed rises. This result is directly related to the shape of the paper price distribution. Since increasing the trigger price forces more paper to be diverted back into the waste stream for burning[1], the paper which is left must therefore be marketed at a price which is, on the average, higher than those associated with lower trigger prices.

---

[1]This is true by definition of the trigger price as that price below which the paper will be burned for its BTU value and above which it will be sold for its fiber content.

Exhibit 4.1   Input Summary of Program Controls and General Information

R R P L A N
A MODEL FOR REGIONAL RESOURCE RECOVERY PLANNING
WITH LIMITED AND DECLINING PRICE MARKETS,
WITH USER-DEFINED COST CATEGORIES AND ENERGY CATEGORIES

TEST CASE

LAST PHASE = 3   NUMBER OF FORCES = 1   OUTPUT OPTION (KOPT) = 3
NUMBER OF YEARS IN RUN = 20      FIRST YEAR = 1983
DISCOUNT RATE = 10.00 PERCENT PER YEAR.      GENERAL INFLATION RATE =   6.00 PERCENT PER YEAR.


OPTIMIZING MODE: MINIMIZE DISCOUNTED COST

NUMBER OF COST CATEGORIES   4      NUMBER OF ENERGY CATEGORIES:  2      NUMBER OF COMMODITIES:  8
NUMBER OF SOURCES:  4      NUMBER OF SITES:  4      NUMBER OF LANDFILLS:  2
NUMBER OF PROCESSES:  5      NUMBER OF SITE-PROCESSES:  5      NUMBER OF MARKETS:  3
NUMBER OF COST SUMMARIZATION CATEGORIES:  1


SOURCE DATA
PCT PAPER BY WEIGHT:  23.20      PCT GLASS BY WEIGHT:  11.80
PCT CANS BY WEIGHT:  8.00      PCT RESIDUE BY WEIGHT:  57.00
MILLION BTUS PER TON OF RESIDUE:  5.000      MILLION BTUS PER TON OF PAPER:  6.000
PRICE OF GLASS AT MARKET, $/TON:  25.49      PRICE OF CANS AT MARKET,$/TON:  15.00
COST CATEGORIES - PAPER:  1      GLASS:  1      CANS:  1
TOTAL COST OF COLLECTION - CATEGORY:  1      COST IN $/TON MSW: 20.000
INCREMENTAL COST OF SOURCE SEPARATION - CATEGORY:  1      COST IN $/PRESEPARATED TON:  2.000
KMIX = 1      KSEPO = 1      INPAP = 1      NUMBER OF TRIGGERS = 3
RPRPAP =  .800      ALLO =  .600      RPRRES =  .900
TOTAL NET ENERGY OF COLLECTION - CATEGORY:  1      REQ:      .800
INCREMENTAL NET ENERGY OF SEPARATE COLLECTION PER PRESEPARATED TON - CATEGORY:  1      REQ:      .100
ENERGY TO COST RATIOS FOR HAUL TO MARKET - PAPER:      .25000      GLASS:      .20000      CANS:      .15000
MBTUS FOR MSW:      5.20000      EN CAT FOR BTU DIFFERENCE:  2
ENERGY VALUES IN THE MARKET
PAPER:      20.00000  EN CAT:  1      GLASS:      2.00000  EN CAT:  1      CANS:      2.00000  EN CAT:  1
FORCING CONTROLS - IFDRV: 1      FDRIV:  10.00      IVDRV: 1      VDRIV:-999.00
NUMBER OF INTERVALS:      5      SIZE OF INTERVAL:  5.000      BOTTOM OF FIRST INTERVAL:  12.00
AVERAGE PRICE OF PAPER:  24.50

TRIGGER NO. 1 IS: 15.00   PERCENT OF BURN IS:  6.7
AVERAGE PRICE OF PAPER SOLD IS:      25.29

TRIGGER NO. 2 IS: 20.00   PERCENT OF BURN IS: 24.4
AVERAGE PRICE OF PAPER SOLD IS:      27.03

TRIGGER NO. 3 IS: 25.00   PERCENT OF BURN IS: 53.3
AVERAGE PRICE OF PAPER SOLD IS:      29.69

Exhibit 4.2 summarizes the inputs read on KEYs 8, 9 and 10. These data correspond to inputs coded onto cards 9 through 22 in the ACASE file. Note that all entries on the exhibit are individually numbered. Whenever the appropriate category is to be referenced within the program, it is that number which is used.

The first four lines of output correspond to the four cost categories; these input data were read from lines 9 through 12 of the ACASE file. Each cost category is printed out on a single line in sequence along with its descriptive name. The IDCC column indicates if the respective category is an operating (0) or a capital (1) cost. Since the objective of this run is to minimize discounted costs, all weights are shown equal to 1.[1] The next column gives the differential rate of inflation. The values may be positive, negative or zero; they are used for both operating and capital costs. The remaining four columns of the cost category output are used only for capital costs. The zero values recorded under municipal and contractor operating costs are thus merely placeholders. Data on useful life, the years to capitalize the loan, the interest rate of the loan and the life remaining for existing capital occupy the last four columns. The NREM, years remaining for existing capital, is used to schedule the replacement of all capital items in use at the beginning of the study period.

Data on the two energy categories are then output, followed by the data on the eight commodity categories (line numbers 15 through 22 of the ACASE file). As mentioned earlier, the first five commodities are fixed. Each commodity category has two haul cost and two energy multipliers. The multipliers are applied against the packer (APKR) and van (AVAN) distance files to get the cost of handling the commodity and its associated net energy demand. The integers listed beneath the four columns labeled CAT refer to the two cost and two energy categories. For example, the haul cost of MSW in a packer is allocated against municipal operating cost, whereas the cost of transporting incinerated ferrous is allocated against contractor operating cost.

Exhibit 4.3 summarizes the inputs read on KEYs 11, 12 and 13. These data correspond to inputs coded onto cards 23 through 32 in the ACASE file. Information on the four sources (read KEY 11) is printed out in two parts. The first part gives the source number and name followed by a location number. As mentioned earlier, once all worksheets have been filled out, it will be necessary to assign a location number to each source, site, landfill and market. It is this number which appears under the column labeled LOC; it is also used as a reference point in computing distances for hauling wastes to a site for processing. The rate of waste generation in thousands of tons per year (KTPY) appears in the next column. The last seven columns of the output

---

[1] Recall that cost weights are only required for optimizing modes 3 and 4. In all other cases, the weights needed to calculate the value of the objective function are automatically set within the MAIN program.

Exhibit 4.2  Input Summary for Cost, Energy and Commodity Category Data

COST CATEGORIES

| NO. | NAME | IDCC | WEIGHT | DIFLAT | LIFU | LIFC | INT RATE | NREM |
|-----|------|------|--------|--------|------|------|----------|------|
| 1 | MUNICIPAL COST | 0 | 1.000 | 2.000 | 0 | 0 | .000 | 0 |
| 2 | CONTRACTOR OP COST | 0 | 1.000 | -3.000 | 0 | 0 | .000 | 0 |
| 3 | CONTRACTOR CAP COST | 1 | 1.000 | 1.000 | 20 | 15 | 9.000 | 0 |
| 4 | SITE PREP COST | 1 | 1.000 | .000 | 50 | 15 | 9.000 | 0 |

ENERGY CATEGORIES

| NO. | NAME | WEIGHT |
|-----|------|--------|
| 1 | FUEL INPUT, MBTU | -1.000 |
| 2 | STEAM OUTPUT, MBTU | -1.000 |

COMMODITY CATEGORIES
WITH HAUL COST MULTIPLIERS AGAINST DISTANCE TABLES

| NO | NAME | 1ST COST | CAT | 2ND COST | CAT | 1ST ENERGY | CAT | 2ND ENERGY | CAT |
|----|------|----------|-----|----------|-----|------------|-----|------------|-----|
| 1 | MSW IN PKR, KTON | 1.000 | 1 | .000 | 1 | .200 | 1 | .000 | 1 |
| 2 | MSW IN VAN, KTON | 1.000 | 1 | .000 | 1 | .250 | 1 | .000 | 1 |
| 3 | S-S PAPER, KTON | .700 | 1 | .000 | 1 | .150 | 1 | .000 | 1 |
| 4 | S-S RES IN PKR, KTON | 1.000 | 1 | .000 | 1 | .200 | 1 | .000 | 1 |
| 5 | S-S RES IN VAN, KTON | 1.000 | 1 | .000 | 1 | .200 | 1 | .000 | 1 |
| 6 | STEAM, MLBS | 1.000 | 2 | .000 | 2 | 1.000 | 2 | .000 | 2 |
| 7 | PROC RESIDUE, KTON | .800 | 2 | .000 | 2 | .200 | 1 | .000 | 1 |
| 8 | INCIN FERROUS, KTON | .700 | 2 | .000 | 2 | .100 | 1 | .000 | 1 |

Exhibit 4.3  Input Summary for Source, Site and Landfill Data

SOURCES

| NO. | NAME | LOC | TONS, KTPY | MIX | SEP | TRIG 1 | 2 | 3 | 4 | 5 |
|-----|------|-----|-----------|-----|-----|--------|---|---|---|---|
| 1 | LYNN | 1 | 340.000 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 2 | MARBLEHEAD | 2 | 7.000 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3 | SALEM | 3 | 120.000 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 4 | REVERE | 4 | 40.000 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

SOURCES,CONTINUED    COST AND ENERGY FACTORS FOR HAUL OF SOURCE-SEPARATED RECOVERABLES TO MARKET

| NO. | COST CAT | ENERGY CAT | COST - PAPER | GLASS | CANS |
|-----|----------|------------|--------------|-------|------|
| 1 | 1 | 1 | 2.00 | 1.50 | 1.20 |
| 2 | 1 | 1 | 2.20 | 1.70 | 1.40 |
| 3 | 1 | 1 | 2.10 | 1.60 | 1.30 |
| 4 | 1 | 1 | 1.90 | 1.40 | 1.10 |

SITES

| NO. | NAME | LOC | INCO | ICAP | ILAND | NO PROC | SITE PREP COST | CAT | SITE PREP EN | CAT |
|-----|------|-----|------|------|-------|---------|----------------|-----|--------------|-----|
| 1 | SAUGUS PROC | 5 | 2 | 1 | 0 | 1 | 1000.000 | 4 | 250.00000 | 1 |
| 2 | WORCESTER PROC | 6 | 2 | 0 | 0 | 2 | 1000.000 | 4 | 250.00000 | 1 |
| 3 | AMESBURY LANDFILL | 7 | 7 | 0 | 1 | 1 | 200.000 | 4 | 50.00000 | 1 |
| 4 | SAUGUS SECONDARY PR | 5 | 7 | 0 | 1 | 1 | 400.000 | 4 | 100.00000 | 1 |

LANDFILLS

| NO. | NAME | LOC | LAND AVAILABLE |
|-----|------|-----|----------------|
| 1 | AMESBURY LANDFILL | 7 | 99800.000 |
| 2 | SAUGUS LANDFILL | 5 | 84000.000 |

show the source controls for the separation options.  Recall that the source controls are dominated by the values of the run controls (KMIX, KSEPO, NTRIG). In this case, Marblehead is the only source which will consider shipping mixed MSW.  All sources are listed as considering unconditional source separation, and Lynn and Salem are listed as considering conditional source separation with three possible trigger prices.  Each source also had a series of factors input for calculating the costs of hauling source separated recoverables to the market.  These figures, along with their respective cost and energy allocations, are presented under the title of SOURCES, CONTINUED.

The next piece of information output is concerned with the data on the four sites.  These input data were read from line numbers 27 through 30 of the ACASE file.  Note that each site is numbered sequentially.  Examining the location numbers, however, reveals that two sites are co-located (the Saugus processor and the Saugus secondary processor).  The first two sites receive MSW whereas the last two receive process residue (see the values recorded under the INCO column).  Two sites are required at Saugus because each site is coded as receiving a single commodity.[1]  The ICAP and ILAND columns show which sites are capacitated (ICAP = 1) and which have landfill available (ILAND = 1).  The number of processes offered at the site is recorded under the column heading NO PROC.  The last four columns show site preparation costs in thousands of dollars, its respective <u>cost</u> category number, the net energy required in site preparation, and its respective <u>energy</u> category number.  The last bit of information is concerned with data on landfills; these data were recorded on cards 31 and 32.  The two landfills are listed in sequence and named.  The location number of the landfill and the land available in acre feet occupy the last two columns.

The output report shown as exhibit 4.4 summarizes the inputs read on KEYs 14, 15, 16 and 17.  These data correspond to inputs coded onto cards 33 through 58 in the ACASE file.  Information on each process is output in sequence followed by the site-process combination data.

The first line of output for <u>each</u> process shows the process number and name, the incoming commodity number, an indication if the process is new or existing, the number of outputs, the number of linear segments, whether the process is land using or not, the acre feet of land required per unit (e.g., kilo ton) of input and the respective cost and energy categories.  For those processes which produce outputs, the next line of output lists the commodity number and how many commodity units are produced per unit of input to the process.  For example, the new water wall incinerator described under

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[1]Recall that MSW receiving sites and only such sites can receive more than one commodity; they can receive any of the first five commodities.

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Exhibit 4.4  Input Summary for Process and Site-Process Combination Data

PROCESS INPUTS

| NO. | NAME | INCOP | IEXIS | NCOF | NSEG | ILACOF | USLA | COST CAT: 1ST | 2NO | EN CAT: 1ST | 2ND |
|-----|------|-------|-------|------|------|--------|------|---------------|-----|-------------|-----|
| 1 | TRANS STA | 2 | 0 | 1 | 3 | 0 | .00000 | 2 | 3 | 1 | 1 |

OUTPUT COEFFICIENTS: COMMOOITY      COEFFICIENT
                          2          1.00000

```
SEG 1 INTERCEPTS: 1ST COST    20.00  2NO COST     20.00  1ST EN     .80  2ND EN      .00
SEG 1     SLOPES: 1ST COST  1.800000 2NO COST  1.800000  1ST EN .500000  2ND EN .000000
SEG 2 INTERCEPTS: 1ST COST    40.00  2NO COST     35.00  1ST EN     .70  2ND EN      .00
SEG 2     SLOPES: 1ST COST  .500000  2NO COST  .610000   1ST EN .400000  2ND EN .000000
SEG 3 INTERCEPTS: 1ST COST    60.00  2NO COST     55.00  1ST EN     .60  2NO EN      .00
SEG 3     SLOPES: 1ST COST  .260000  2NO COST  .240000   1ST EN .300000  2ND EN .000000
```

| NO. | NAME | INCOP | IEXIS | NCOF | NSEG | ILACOF | USLA | COST CAT: 1ST | 2ND | EN CAT: 1ST | 2NO |
|-----|------|-------|-------|------|------|--------|------|---------------|-----|-------------|-----|
| 2 | WATER-WALL INCIN | 2 | 1 | 3 | 1 | 0 | .00000 | 2 | 3 | 1 | 1 |

OUTPUT COEFFICIENTS: COMMOOITY      COEFFICIENT
                          6          5.48000
                          7           .15000
                          8           .07000

```
SEG 1 INTERCEPTS: 1ST COST   300.00  2ND COST       .00  1ST EN   70.00  2ND EN      .00
SEG 1     SLOPES: 1ST COST 7.300000  2NO COST  .000000   1ST EN 2.000000 2NO EN .000000
```

| NO. | NAME | INCOP | IEXIS | NCOF | NSEG | ILACOF | USLA | COST CAT: 1ST | 2NO | EN CAT: 1ST | 2ND |
|-----|------|-------|-------|------|------|--------|------|---------------|-----|-------------|-----|
| 3 | WATER-WALL INCIN | 2 | 0 | 3 | 2 | 0 | .00000 | 2 | 3 | 1 | 1 |

OUTPUT COEFFICIENTS: COMMOOITY      COEFFICIENT
                          6          5.48000
                          7           .15000
                          8           .07000

```
SEG 1 INTERCEPTS: 1ST COST   300.00  2NO COST    224.16  1ST EN   80.00  2NO EN      .00
SEG 1     SLOPES: 1ST COST 7.300000  2NO COST  7.000000  1ST EN 2.000000 2ND EN .000000
SEG 2 INTERCEPTS: 1ST COST  1000.00  2ND COST   1096.64  1ST EN  170.00  2NO EN      .00
SEG 2     SLOPES: 1ST COST 5.000000  2ND COST  4.236000  1ST EN 1.500000 2NO EN .000000
```

| NO. | NAME | INCOP | IEXIS | NCOF | NSEG | ILACOF | USLA | COST CAT: 1ST | 2NO | EN CAT: 1ST | 2NO |
|-----|------|-------|-------|------|------|--------|------|---------------|-----|-------------|-----|
| 4 | LANDFILL | 7 | 0 | 0 | 3 | 1 | 1.65300 | 2 | 3 | 1 | 1 |

```
SEG 1 INTERCEPTS: 1ST COST    40.00  2NO COST     40.00  1ST EN    1.60  2NO EN      .00
SEG 1     SLOPES: 1ST COST 3.600000  2ND COST  3.600000  1ST EN 1.000000 2ND EN .000000
SEG 2 INTERCEPTS: 1ST COST    80.00  2NO COST     70.00  1ST EN    1.40  2NO EN      .00
SEG 2     SLOPES: 1ST COST 1.000000  2ND COST  1.220000  1ST EN .800000  2NO EN .000000
SEG 3 INTERCEPTS: 1ST COST   120.00  2NO COST    110.00  1ST EN    1.20  2NO EN      .00
SEG 3     SLOPES: 1ST COST  .520000  2NO COST  .480000   1ST EN .600000  2NO EN .000000
```

| NO. | NAME | INCOP | IEXIS | NCOF | NSEG | ILACOF | USLA | COST CAT: 1ST | 2NO | EN CAT: 1ST | 2ND |
|-----|------|-------|-------|------|------|--------|------|---------------|-----|-------------|-----|
| 5 | SECONDARY PROC | 7 | 0 | 0 | 2 | 1 | .82000 | 2 | 3 | 1 | 1 |

```
SEG 1 INTERCEPTS: 1ST COST    40.00  2NO COST     40.00  1ST EN    1.60  2NO EN      .00
SEG 1     SLOPES: 1ST COST 2.000000  2NO COST  2.000000  1ST EN 1.000000 2NO EN .000000
SEG 2 INTERCEPTS: 1ST COST    80.00  2NO COST     70.00  1ST EN    1.40  2NO EN      .00
SEG 2     SLOPES: 1ST COST 1.000000  2NO COST  1.000000  1ST EN .800000  2NO EN .000000
```

SIPROCS

| SITE | PROCESS | CAPACITY IN KTPY | NET REVENUE | SEGMENTS: 1 2 3 | EN VAL OF REVENUE | REVENUE COST CAT | EN CAT |
|------|---------|------------------|-------------|-----------------|-------------------|------------------|--------|
| 1 | 2 | 360.000 | 1.000 | 1 0 0 | .20000 | 2 | 1 |
| 2 | 1 | .000 | .000 | 1 1 1 | .00000 | 2 | 1 |
| 2 | 3 | .000 | 1.000 | 1 1 0 | .30000 | 2 | 1 |
| 3 | 4 | .000 | .000 | 0 1 1 | .00000 | 2 | 1 |
| 4 | 5 | .000 | 3.000 | 1 0 0 | 1.00000 | 2 | 1 |

process number 3 produces 5.48 million pounds of steam, 0.15 kilotons of process residue, and 0.07 kilotons of incinerated ferrous per kiloton of MSW input.

The next block of data shows, for each linear segment, the values of the intercepts and slopes for each cost and energy category. For example, process 3 experiences economies of scale in both operation and capital costs, as shown by the increasing values of the intercept terms and decreasing values of the slopes. Recall that the intercepts correspond to the fixed charges whereas the slopes correspond to variable costs. Thus, as plant size is increased, the cost per ton of MSW declines (i.e., it is less expensive on a per ton basis to build and process a 1000 ton per day plant than to have two 500 ton per day plants). In this case, the costs opposite the label 1ST COST correspond to contractor operating costs and those opposite 2ND COST to contractor capital costs. Only one energy category (FUEL INPUT) is used for all five processes. The output presented in exhibit 4.4 corresponds to the following line numbers in the ACASE file for each process: (1) 33 through 37; (2) 38 through 40; (3) 41 through 44; (4) 45 through 49; and (5) 50 through 53.

The site-process (SIPROC) output follows closely the data on the upper portion of the exhibit. The site number and process number are given first. For example, a landfill operation (process number 4) is located at site number 3. Only the first site, Saugus, is capacitated, having a rated capacity of 360 KTPY. The next column gives the implicit revenues associated with the site-process combination. Thus for every ton of MSW processed at the existing water wall incinerator located at Saugus, $1 of revenue is produced. The next three columns show which linear segments are to be offered. Notice that it is not necessary to offer all segments. For example, if landfill operations are to take place at site 3, they are expected to exceed the level defined by the cutoff point between the first and second segment of the process. The last three columns show the energy value of the net revenue and to which cost and energy category the net revenue accrues.

Exhibit 4.5 summarizes the inputs read on KEYs 18, 19, 20 and 21. These data correspond to inputs coded onto cards 59 through 68 of the ACASE file. Data on each of the three markets are first output. The first line of each market output shows the market number, its name and location, which commodity category the market receives, and to which cost and energy categories revenues are to the allocated. For example, the GE facility at Lynn is located next to the Saugus processor from which it receives steam. The next two lines of output deal with how revenues are to be shared among the two parties listed under 1ST REV and 2ND REV on the first line of the market report. For example, GE pays[1] the contractor (cost category number 2) $3,000 per million

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[1]These figures are illustrative and not meant to be indicative of any contractual arrangements which may be in effect at the site.

pounds for the first 900 million pounds of steam and $2,000 per million pounds for the next 900 million pounds of steam; the municipality receives no revenues from the sale at either level of market activity. Note that the market has two segments and two bounds (900 and 1800 million pounds of steam). The output presented in exhibit 4.5 corresponds to the following line numbers in the ACASE file for each market: (1) 59 through 61; (2) 62 through 64; and (3) 65 through 67.

The last line of output is concerned with the cost summation categories. In this case, the single cost summation category groups contractor operating and contractor capital cost into a single category designated as contractor cost.

Exhibits 4.6 and 4.7 summarize the inputs read on KEY 22. These data correspond to inputs coded onto cards 69 through 85 in the ACASE file. Each of the 15 transportation categories are output in sequence.[1] The first transportation category was input on cards 69 through 76 and corresponds to the source-to-site shipments of solid waste prior to expansion. The columns show the category number, the source number, the source location number, the site number, the site location number, and the distance for packers and vans, respectively. No values are entered into the distance columns because the information printed out is not used by the model in its current form but is expanded. The degree of expansion is dependent on the values coded into the run controls and the source controls.

The next two blocks of output correspond to category 2 transportation, site-to-site, and category 3 transportation, site-to-market; these data were read from cards 77 through 81 and 82 through 85, respectively. Each of these outputs show the category number, the number and name of the commodity shipped, the site from which the shipment originates, the destination site or market, its location, and the distance measure for vans. Note that packers are not used for site-to-site and site-to-market shipments of wastes and recoverables; the distance for packers are thus not shown.

The remaining outputs on exhibits 4.6 and 4.7 correspond to source-to-site shipments after expansion.[2] Transportation category 4 and 5 represent unconditional MSW and unconditional source separation, respectively. Recall from the output on exhibit 4.3 that only Marblehead considered the shipment of mixed MSW. All communities considered unconditional source separation however, as reflected in the output for transportation category 5. Note that packer costs are approximately three times those of vans on a per ton basis.

---

[1]Transportation categories 7 and 10 are not used.

[2]If a local paper market exists in the region, then category 9 transportation is defined as shipments of paper from the source to the local paper market.

Exhibit 4.5  Input Summary for Market and Cost Summation Category Data

MARKETS

| NO. | NAME | LOC | COMMOD | CATEGORIES-1ST REV | 2ND REV | 1ST EN | 2ND EN | 1ST EN CDEF | 2ND EN COEF |
|-----|------|-----|--------|--------------------|---------|--------|--------|-------------|-------------|
| 1 | GE LYNN STEAM | 5 | 6 | 2 | 1 | 2 | 1 | 5.40000 | -.20000 |

| 1ST REVENUE-COEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | NO SEG | NO BOUNDS |
|------------------|-------|------|-------|------|-------|------|-------|------|-------|--------|-----------|
| 3.000 | 900.00 | 2.00D | 1800.00 | .000 | .00 | .000 | .00 | .0D0 | .00 | 2 | 2 |

| 2ND REVENUE-COEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | CDEF | BOUND | NO SEG | NO BOUNDS |
|------------------|-------|------|-------|------|-------|------|-------|------|-------|--------|-----------|
| .000 | 900.00 | .0D0 | 1800.00 | .000 | .00 | .000 | .00 | .000 | .00 | 2 | 2 |

| NO. | NAME | LOC | COMMOD | CATEGORIES-1ST REV | 2ND REV | 1ST EN | 2ND EN | 1ST EN COEF | 2ND EN COEF |
|-----|------|-----|--------|--------------------|---------|--------|--------|-------------|-------------|
| 2 | NEW YORK FERROUS | B | 8 | 2 | 1 | 1 | 1 | .20000 | -.20000 |

| 1ST REVENUE-COEF | BOUND | CDEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | NO SEG | NO BOUNDS |
|------------------|-------|------|-------|------|-------|------|-------|------|-------|--------|-----------|
| 11.860 | .00 | .000 | .00 | .000 | .00 | .000 | .00 | .000 | .00 | 1 | 0 |

| 2ND REVENUE-COEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | NO SEG | NO BOUNDS |
|------------------|-------|------|-------|------|-------|------|-------|------|-------|--------|-----------|
| .000 | .00 | .000 | .00 | .000 | .00 | .000 | .00 | .000 | .D0 | 1 | 0 |

| NO. | NAME | LOC | COMMOD | CATEGORIES-1ST REV | 2ND REV | 1ST EN | 2ND EN | 1ST EN COEF | 2ND EN COEF |
|-----|------|-----|--------|--------------------|---------|--------|--------|-------------|-------------|
| 3 | WORCESTER STEAM | 9 | 6 | 2 | 1 | 2 | 1 | 5.40000 | -.2D000 |

| 1ST REVENUE-COEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | NO SEG | NO BOUNDS |
|------------------|-------|------|-------|------|-------|------|-------|------|-------|--------|-----------|
| B.000 | 2000.00 | 6.000 | 4000.00 | .000 | .00 | .000 | .00 | .0D0 | .D0 | 2 | 2 |

| 2ND REVENUE-COEF | BOUND | CDEF | BOUND | COEF | BOUND | COEF | BOUND | COEF | BOUND | NO SEG | NO BOUNDS |
|------------------|-------|------|-------|------|-------|------|-------|------|-------|--------|-----------|
| .000 | 2000.00 | .000 | 4000.00 | .000 | .00 | .000 | .00 | .000 | .00 | 2 | 2 |

COST SUMMATION CATEGORIES

| NO. | NAME | NO COST CAT | CATEGORIES |
|-----|------|-------------|------------|
| 1 | CONTRACTOR COST | 2 | 2  3  0  0  0  0  0  0  0  0 |

Exhibit 4.6  Transportation Activities Considered by the Model:
Site-to-Site, Site-to-Market, and Source-to-Site
(Excluding Conditional Source Separation)


TRANSPORTATION ACTIVITIES
TOTAL NUMBER OF TRANSPORTATION ACTIVITIES IS  39 INCLUDING CATEGORIES 1 THROUGH 15

TRANSPORTATION ACTIVITY LISTING:

CATEGORY 1 TRANSPORTATION: SOURCE ORIGIN BEFORE EXPANSION IN THOUSAND TONS PER YEAR

| CATEGORY | SOURCE | ORIGIN LOC | OEST SITE | OEST LOC | DIST PKR | DIST VAN |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 5 | .00 | .00 |
| 1 | 1 | 1 | 2 | 6 | .00 | .00 |
| 1 | 2 | 2 | 1 | 5 | .00 | .00 |
| 1 | 2 | 2 | 2 | 6 | .00 | .00 |
| 1 | 3 | 3 | 1 | 5 | .00 | .00 |
| 1 | 3 | 3 | 2 | 6 | .00 | .00 |
| 1 | 4 | 4 | 1 | 5 | .00 | .00 |
| 1 | 4 | 4 | 2 | 6 | .00 | .00 |


CATEGORY 2 TRANSPORTATION: SITE TO SITE IN THOUSAND COMMODITY UNITS PER YEAR

| CATEGORY | COMMODITY | ORIG LOC | OEST SITE | OEST LOC | DIST PKR | DIST VAN |
|---|---|---|---|---|---|---|
| 2 | 2 | 6 | 1 | 5 | .00 | 10.00 |
| 2 | 7 | 5 | 3 | 7 | .00 | 5.50 |
| 2 | 7 | 5 | 4 | 5 | .00 | .00 |
| 2 | 7 | 6 | 3 | 7 | .00 | 11.00 |
| 2 | 7 | 6 | 4 | 5 | .00 | 10.00 |

CATEGORY 3 TRANSPORTATION: SITE TO MARKET IN THOUSAND COMMODITY UNITS PER YEAR

| CATEGORY | COMMODITY | ORIG LOC | OEST MKT | DEST LOC | DIST PKR | OIST VAN |
|---|---|---|---|---|---|---|
| 3 | 6 | 5 | 1 | 5 | .00 | .00 |
| 3 | 8 | 5 | 2 | 8 | .00 | 16.00 |
| 3 | 6 | 6 | 3 | 9 | .00 | .00 |
| 3 | 8 | 6 | 2 | 8 | .00 | 13.00 |


CATEGORY 4 TRANSPORTATION: SOURCE ORIGIN AFTER EXPANSION; UNSEPARATEO MSW (MIXED SOLIO WASTE) IN THOUSAND TONS PER YEAR

| CATEGORY | SOURCE | ORIG LOC | OEST SITE | OEST LOC | OIST PKR | OIST VAN |
|---|---|---|---|---|---|---|
| 4 | 2 | 2 | 1 | 5 | 2.50 | .80 |
| 4 | 2 | 2 | 2 | 6 | 32.00 | 11.00 |


CATEGORY 5 TRANSPORTATION: SOURCE ORIGIN AFTER EXPANSION; UNCONOITIONAL SOURCE SEPARATION
WITH NATIONAL PAPER MARKET. IN THOUSAND PRESEPARATED TONS PER YEAR

| CATEGORY | SOURCE | ORIG LOC | OEST SITE | DEST LOC | DIST PKR | DIST VAN |
|---|---|---|---|---|---|---|
| 5 | 1 | 1 | 1 | 5 | 1.00 | .30 |
| 5 | 1 | 1 | 2 | 6 | 30.00 | 10.00 |
| 5 | 2 | 2 | 1 | 5 | 2.50 | .80 |
| 5 | 2 | 2 | 2 | 6 | 32.00 | 11.00 |
| 5 | 3 | 3 | 1 | 5 | 2.00 | .60 |
| 5 | 3 | 3 | 2 | 6 | 31.00 | 10.50 |
| 5 | 4 | 4 | 1 | 5 | 1.00 | .30 |
| 5 | 4 | 4 | 2 | 6 | 29.00 | 9.50 |

Exhibit 4.7   Transportation Activities Considered by the Model:
Conditional Source Separation Options

CATEGORIES 11 - 15 TRANSPORTATION: SOURCE ORIGIN AFTER EXPANSION;
CONDITIONAL SOURCE SEPARATION FOR TRIGGER EQUAL TO CATEGORY NUMBER MINUS 10;
IN THOUSAND PRESEPARATED TONS PER YEAR

| CATEGORY | SOURCE | ORIG LOC | DEST SITE | DEST LOC | DIST PKR | DIST VAN |
|----------|--------|----------|-----------|----------|----------|----------|
| 11 | 1 | 1 | 1 | 5 | 1.00 | .30 |
| 11 | 1 | 1 | 2 | 6 | 30.00 | 10.00 |
| 11 | 3 | 3 | 1 | 5 | 2.00 | .60 |
| 11 | 3 | 3 | 2 | 6 | 31.00 | 10.50 |

CATEGORIES 11 - 15 TRANSPORTATION: SOURCE ORIGIN AFTER EXPANSION;
CONDITIONAL SOURCE SEPARATION FOR TRIGGER EQUAL TO CATEGORY NUMBER MINUS 10;
IN THOUSAND PRESEPARATED TONS PER YEAR

| CATEGORY | SOURCE | ORIG LOC | DEST SITE | DEST LOC | DIST PKR | DIST VAN |
|----------|--------|----------|-----------|----------|----------|----------|
| 12 | 1 | 1 | 1 | 5 | 1.00 | .30 |
| 12 | 1 | 1 | 2 | 6 | 30.00 | 10.00 |
| 12 | 3 | 3 | 1 | 5 | 2.00 | .60 |
| 12 | 3 | 3 | 2 | 6 | 31.00 | 10.50 |

CATEGORIES 11 - 15 TRANSPORTATION: SOURCE ORIGIN AFTER EXPANSION;
CONDITIONAL SOURCE SEPARATION FOR TRIGGER EQUAL TO CATEGORY NUMBER MINUS 10;
IN THOUSAND PRESEPARATED TONS PER YEAR

| CATEGORY | SOURCE | ORIG LOC | DEST SITE | DEST LOC | DIST PKR | DIST VAN |
|----------|--------|----------|-----------|----------|----------|----------|
| 13 | 1 | 1 | 1 | 5 | 1.00 | .30 |
| 13 | 1 | 1 | 2 | 6 | 30.00 | 10.00 |
| 13 | 3 | 3 | 1 | 5 | 2.00 | .60 |
| 13 | 3 | 3 | 2 | 6 | 31.00 | 10.50 |

This underscores the rationale behind the consideration of a dedicated transfer station for each source. Transportation categories 11 through 13 outputs are shown in exhibit 4.7. There is one such conditional source separation category for each trigger price offered. Note that only Lynn and Salem are considering conditional source sepration (see exhibit 4.3).

4.2  ANALYSIS OF THE REGIONAL PLAN

The outputs presented in the previous section serve to define the problem as it is sent to the optimizer. From this information a preferred regional plan will be selected. The outputs discussed in this section answer the three major questions associated with the preferred plan. First, how should wastes and recoverables be routed among sources, sites and markets? Second, which processes should be carried out, where should they be located, and how should the facility be sized? Third, which commodities should be marketed, where should they be marketed, and in what quantities?

The first of the six exhibits shown in this section consists of a capsule summary of the preferred regional plan. The first block of entries serves merely to define the study; it is identical to the top portion of exhibit 4.1. The information on the solution is contained under the heading THE PHASE 3 SOLUTION. For this case, a value of $62.5 million was revealed as optimal. The subsequent output reports will analyze the preferred plan in detail. The last two rows of the output show the size of the A matrix as sent to the optimizer. In this case, the A matrix contained 30 rows (constraints) and 54 columns (activities). Of the 1620 entries in the A matrix only 153 were non-zero.

The transportation activities in the solution are shown in exhibit 4.9. In reviewing the output, it may be useful to first reexamine exhibits 4.6 and 4.7. In these exhibits data on 31 transportation activities were presented (the 8 activities associated with transportation category 1 have been excluded since they are not a part of the optimization problem). Exhibit 4.9 contains only seven transportation activities however, which shows how the preferred routing dominates the complete linkage offered. The source-to-site shipments are summarized under the expanded transportation categories (5 through 11). They will be discussed after the activities associated with transportation categories 2 and 3 have been summarized.

Site-to-site shipments are summarized under category 2 transportation activities. For the case at hand, all wastes originate from the Saugus processor and are sent to the Saugus secondary processor. The only commodity shipped is process residue, which produces a net revenue of $3 per ton (see the SIPROC entry on exhibit 4.4). The model shows an activity of approximately 45 KTPY. The residue from the secondary processor is then landfilled (see the values coded beneath ILACOF and USLA for process 5 in exhibit 4.4).

Exhibit 4.8   Abbreviated Form of the Solution

S U M M A R Y   O F   R R P L A N   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      =  30
NUMBER OF COLUMNS   =  84
NUMBER OF NON-ZERO ELEMENTS OF THE (A) MATRIX =  153
THE ACTUAL SIZE OF THE (A) MATRIX IS  306 ELEMENTS

R R P L A N
A MODEL FOR REGIONAL RESOURCE RECOVERY PLANNING
WITH LIMITED AND DECLINING PRICE MARKETS,
WITH USER-DEFINED COST CATEGORIES AND ENERGY CATEGORIES

TEST CASE

LAST PHASE = 3   NUMBER OF FORCES = 1   OUTPUT OPTION (KOPT) = 3
NUMBER OF YEARS IN RUN = 20     FIRST YEAR = 1983
DISCOUNT RATE = 10.00 PERCENT PER YEAR.    GENERAL INFLATION RATE =   6.00 PERCENT PER YEAR.

OPTIMIZING MODE: MINIMIZE DISCOUNTED COST

THE PHASE 3 SOLUTION
SOLUTION VALUE IS:    62545.766602
NUMBER OF ROWS IS: 30     NUMBER OF COLUMNS IS:  54
NUMBER OF NON-ZERO COEFFICIENTS IS:   153

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Exhibit 4.9  Transportation Activities in the Solution

TRANSPORTATION ACTIVITIES IN THE SOLUTION

CATEGORY 2 TRANSPORTATION ACTIVITIES: SITE TO SITE
ACTIVITY LEVELS IN COMMODITY UNITS PER YEAR

| CAT | ORIGIN LOCATION | DESTINATION SITE | LOC | COMMODITY | ACTIVITY LEVEL |
|-----|-----------------|------------------|-----|-----------|----------------|
| 2 | 5 | 4 SAUGUS SECONDARY PR | 5 | 7 PROC RESIDUE, KTON | 44.6486 |

CATEGORY 3 TRANSPORTATION ACTIVITIES: SITE TO MARKET
ACTIVITY LEVELS IN COMMODITY UNITS PER YEAR

| CAT | ORIGIN LOCATION | DESTINATION MARKET | LOC | COMMODITY | ACTIVITY LEVEL |
|-----|-----------------|--------------------|-----|-----------|----------------|
| 3 | 5 | 1 GE LYNN STEAM | 5 | 6 STEAM, MLBS | 1631.1592 |
| 3 | 5 | 2 NEW YORK FERROUS | 8 | 8 INCIN FERROUS, KTON | 20.8361 |

CATEGORY 5 TRANSPORTATION ACTIVITIES: SOURCE TO SITE
UNCONDITIONAL SOURCE SEPARATION WITH NATIONAL PAPER MARKET
ACTIVITY LEVELS IN THOUSAND TONS OF PRESEPARATED MSW PER YEAR

| CAT | ORIGIN SOURCE | LOC | DESTINATION SITE | LOC | COMMODITY | ACTIVITY LEVEL | TRAN STA SE |
|-----|---------------|-----|------------------|-----|-----------|----------------|-------------|
| 5 | 2 MARBLEHEAD | 2 | 1 SAUGUS PROC | 5 | 4 S-S RES IN PKR, KTON | 7.0000 | |
| 5 | 4 REVERE | 4 | 1 SAUGUS PROC | 5 | 4 S-S RES IN PKR, KTON | 40.0000 | |

CATEGORIES 11 THROUGH 15 TRANSPORTATION ACTIVITIES:
CONDITIONAL SOURCE SEPARATION SUBJECT TO TRIGGER PRICE; TRIGGER PRICE = CAT - 10
ACTIVITY LEVELS IN THOUSAND TONS OF PRESEPARATED MSW PER YEAR

| CAT | ORIGIN SOURCE | LOC | DESTINATION SITE | LOC | COMMODITY | ACTIVITY LEVEL | TRAN STA SE |
|-----|---------------|-----|------------------|-----|-----------|----------------|-------------|
| 11 | 1 LYNN | 1 | 1 SAUGUS PROC | 5 | 5 S-S RES IN VAN, KTON | 340.0000 | |
| 11 | 3 SALEM | 3 | 1 SAUGUS PROC | 5 | 5 S-S RES IN VAN, KTON | 120.0000 | |

Shipments of recoverables are summarized under trnasportation category 3 activities. Two commodities are shipped to two different markets. On the first line, a shipment of 1630 million pounds of steam per year from the Saugus processor to the GE plant at Lynn is indicated. (Explicit revenues from the sale are summarized on exhibit 4.11.) The second line of the output indicates that approximately 20 KTPY of incinerated ferrous is shipped from the Saugus processor to scrap dealers in New York City.

Transportation category 5 shows that Marblehead and Revere should practice unconditional source separation and ship the source separation residue to the Saugus processor. Since these communities are fairly small, the use of a dedicated transfer station was not found to be cost effective, as indicated by the zero entry under TRAN STA SEG.

Lynn and Salem, on the other hand, should practice conditional source separation and ship the source separation residue and whatever paper is to be burned to the Saugus processor. The solution produced by the model shows that selecting the lowest trigger price, a value of $15 per ton, will have the most favorable effect on the cost of the plan. Thus some paper will be burned in order to generate greater revenues from steam sales. Since Lynn and Salem produce much larger amounts of MSW than the two other communities, the use of dedicated transfer stations was found to be cost-effective. The one in Lynn operates within the third linear segment of the cost function; the one in Salem operates within the second linear segment.[1] Note that Saugus is the offload point for all source-to-site shipments.

Exhibit 4.10 summarizes the processing activities appearing in the solution. The first two activities deal with the processing of source separation residue and source separated paper when processed as waste. Since all four sources were separating their wastes, the activity level is equal to the product of the total annual waste stream of 507 KTPY and the portion of the waste stream which corresponds to source separation residue (57%). A value of approximately 289 KTPY results. Processing of source separated paper is somewhat more complex since it is based on the trigger price system. The amount of source separated paper processed as waste is in this case equal to the product of 0.232 (the proportion of paper in the waste stream by weight) by 0.067 (the burn rate for the first trigger price) by 460 (the amount of MSW generated by Lynn and Salem combined in KTPY). The figure shown on the output is slightly over 7 KTPY.

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[1] In order to calculate the costs of the transfer stations, it would be necessary to use the process cost information shown on exhibit 4.4. Once the appropriate segment number has been identified, as in exhibit 4.9, the operating and capital costs can be easily calculated. For this example, the operating costs of the station would be equal to the 1ST COST INTERCEPT plus the product of the SLOPE and equivalent tonnage (see exhibit 4.14 in section 4.3). The capital costs of the station would be calculated in the same manner.

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Exhibit 4.10  Processing Activities in the Solution

PROCESS ACTIVITY LEVELS

PASS-THROUGH PROCESSING OF SOURCE SEPARATION RESIDUE
SITE                      ACTIVITY LEVELS IN THOUSAND TONS OF RESIDUE PER YEAR
 1 SAUGUS PROC                   288.9901

PASS-THROUGH PROCESSING OF SOURCE-SEPARATED PAPER
SITE                      ACTIVITY LEVELS IN THOUSAND TONS OF PAPER PER YEAR
 1 SAUGUS PROC                     7.1148

PROCESSING ACTIVITIES IN COMMODITY UNITS INPUT PER YEAR
SITE                  PROCESS              LOC  SEG  INPUT COMMODITY              ACTIVITY LEVEL        CAP  PCT CAP
 1 SAUGUS PROC         2 WATER-WALL INCIN    5    1   2 MSW IN VAN, KTON             297.6568    360.000   82.68
 4 SAUGUS SECONDARY PR 5 SECONDARY PROC      5    1   7 PROC RESIDUE, KTON            44.6487


DEDICATED TRANSFER STATIONS: TONNAGE IN THOUSAND TONS PER YEAR
SOURCE                LOC   SEG   UNSEPARATED TONS   SOURCE SEP RESIDUE TONS   TOTAL TONS
 1 LYNN                 1     3           .00                    193.80          193.80
 3 SALEM                3     2           .00                     68.40           68.40

LANDFILL ACTIVITIES MEASURED IN ACRE-FEET
LANDFILL            LOC   LAND REQUIRED   LAND AVAILABLE   PERCENT USED   LAND REMAINING
AMESBURY LANDFILL    7          .0000      99800.0000             .00       99800.0000
SAUGUS LANDFILL      5       732.2389      84000.0000             .87       83267.7617

The next block of information on the output, shows the annual processing activities for the water wall incinerator at Saugus and the secondary processor. The water wall incinerator operates on the first segment[1] and receives MSW as its input. Since the process receives a mixture of source separation residue and source separated paper, the activity level shown deviates slightly from the sum of the two activities discussed previously. This is due to a distinction between "real" tons and "equivalent" tons. Real tons are equal to the <u>weight</u> of the wastes processed. Equivalent tons translate real tonnage into a number which reflects the <u>cost</u> of processing. Since the costs of processing source separation residue and paper differ, it is necessary to reduce them to an equivalent amount. This point will become more clear when exhibit 4.14 is examined in section 4.3. Using equivalent tons as the processing measure, the final entry shows that the plant operates at approximately 83 per cent of its rated capacity (360 KTPY). As indicated on the previous output, the secondary processor receives the residue from the water wall incinerator. The 44 KTPY processing activity resulting from the shipment is shown on this output (all wastes arriving at a site must be processed).

The next block of information is an explicit summary of dedicated transfer station activity. The output identifies not only the sources where such stations are located but also the linear segment on which the process should operate. Shipments of both MSW and source separation residue are given along with the total tonnage from all sources processed.

The final output on exhibit 4.10 shows the landfill activity. All landfills are summarized, even if it is not cost-effective to include them in the plan. The landfill located at Saugus is used to dispose of those elements which cannot be reclaimed from the process residue. For the case at hand, 732 acre feet of the landfill's capacity are required over the 20 year study period. This corresponds to less than 1 percent of the total land available at the site.

The market activities in the solution are summarized in exhibit 4.11. The output is divided into three parts. The first part deals with market activities of explicit commodities (i.e., commodities defined by the user, see exhibit 4.2). The second part deals with marketing of source separation recoverables. The third part deals with implicit revenues which are created whenever processing takes place (see exhibit 4.4 where such revenues are defined for each SIPROC).

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[1]There is only one segment for this process (see exhibit 4.4 process number 2).

Marketing activities of explicit commodities are summarized in two ways. The first summary table shows the market number, name, location, and segment within which sales are taking place. Information on the commodity sold includes the volume of sales in commodity units per year, the cumulative sales (by segment), and, if appropriate, the market limit and the percent of the limit for cumulative sales. Each market segment in the solution occupies a line of output. The second summary table provides information on revenues. These are gross revenue figures so that haul costs must be deducted to get net revenues. As for the previous table, the market number and name, commodity number and name and market segment number are listed. The revenue summary includes the average revenue[1] in thousands of dollars per year, the cumulative revenue, the discounted revenue[2], and the cumulative discounted revenue. For example, the GE Lynn plant is sold steam in two blocks. The first 900 million pounds of steam produce a gross revenue of slightly over $2 million, whereas the next shipment of approximately 730 million pounds produces an additional gross revenue of $1.1 million. Cumulative sales are therefore 1630 million pounds of steam for a gross revenue of approximately $3.1 million.

Marketing activities of source separation recoverables are summarized in a similar fashion. First, the total sales of glass, cans and paper in KTPY are presented. The gross revenue (both undiscounted and discounted) associated with each recoverable are then output. The last piece of information shows the net revenues associated with any SIPROCs in the solution. This output lists the site number and name, the process number and name, the input commodity number and name, the revenue per unit of input (e.g., KTPY) declared on the SIPROC card, and the average undiscounted and discounted revenue per year.

Exhibit 4.12 summarizes revenue by market type. This summary is useful because the output data on explicit commodity sales and sales of source separation recoverables represented gross rather than net revenues. Exhibit 4.12 consists of two parts. The first part summarizes gross revenues, haul

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[1]The average revenue calculation is based on a multiplier which incorporates the differential inflation rate for the respective cost category but to which no discount rate is applied.

[2]The discounted revenue calculation is based on a multiplier which incorporates both the differential inflation rate for the respective cost category and the discount rate to reflect the time value of money.

Exhibit 4.11  Marketing Activities in the Solution

MARKETING ACTIVITIES OF EXPLICIT COMMODITIES MEASURED IN THOUSAND COMMODITY UNITS PER YEAR

| MARKET | COMMODITY | LOC | SEG | ACTIVITY LEVEL | CUMULATIVE SALES | MARKET LIMIT | PCT OF LIMIT |
|---|---|---|---|---|---|---|---|
| 1 GE LYNN STEAM | 6 STEAM. MLBS | 5 | 1 | 900.0000 | 900.0000 | 1800.0000 | 50.0000 |
| 1 GE LYNN STEAM | 6 STEAM. MLBS | 5 | 2 | 731.1593 | 1631.1593 | 1800.0000 | 90.6200 |
| 2 NEW YORK FERROUS | 8 INCIN FERROUS. KTON | 8 | 1 | 20.8363 | 20.8363 | | |

MARKET REVENUES OF EXPLICIT COMMODITIES IN THOUSAND DOLLARS PER AVERAGE YEAR

| MARKET | COMMODITY | SEG | REVENUE | CUM REVENUE | DISC REVENUE | CUM DISC REVENUE |
|---|---|---|---|---|---|---|
| 1 GE LYNN STEAM | 6 STEAM. MLBS | 1 | 2053. | 2053. | 1050. | 1050. |
| 1 GE LYNN STEAM | 6 STEAM. MLBS | 2 | 1112. | 3165. | 569. | 1619. |
| 2 NEW YORK FERROUS | 8 INCIN FERROUS. KTON | 1 | 188. | 188. | 96. | 96. |

SALES OF GLASS IN MARKET IN THOUSAND TONS PER YEAR:     59.82600

SALES OF CANS IN MARKET IN THOUSAND TONS PER YEAR:     40.56000

SALES OF PAPER IN MARKET IN THOUSAND TONS PER YEAR:     110.50933     (NATIONAL MARKET)

REVENUES OF SOURCE SEPARATION RECOVERABLES (EXCEPT LOCAL PAPER MARKET) IN THOUSAND DOLLARS PER AVERAGE YEAR

| | TOTAL REVENUE | TOTAL DISCOUNTED REVENUE |
|---|---|---|
| GLASS: | 1853. | 817. |
| CANS: | 739. | 326. |
| PAPER: | 3384. | 1492. |

IMPLICIT REVENUES NET OF COST OF HAUL TO MARKET, IN THOUSAND DOLLARS PER AVERAGE YEAR

| SITE | PROCESS | INPUT COMMODITY | REV IN $/TON | REV/AV YR | DISC REV/AV YR |
|---|---|---|---|---|---|
| 1 SAUGUS PROC | 2 WATER-WALL INCIN | 2 MSW IN VAN, KTON | 1.00 | 226. | 116. |
| 4 SAUGUS SECONDARY PR | 5 SECONDARY PROC | 7 PROC RESIDUE, KTON | 3.00 | 102. | 52. |

costs and net revenue by market type[1], summing them to get a total net average undiscounted revenue figure. The second part is identical to the first except that all figures are discounted. All entries in both sections are in thousands of dollars per average year.

The analytical summary of the output is presented as exhibit 4.13. The output reports shown as exhibits 4.9 through 4.12 were designed to lay out specific attributes and illustrate the mechanics of implementing the plan. This output report is designed to show how the preferred regional plan looks in a more general setting. The output is divided into four parts. The first part consists of a lifetime summary by key factor. These factors include summaries over the study period and per year for: tonnage; undiscounted and discounted costs; and net energy. Figures on the cost per ton (which incorporate all cash flows positive and negative) and the net energy per ton are also output.

The differential effects of the plan on the various segments of the community are laid out under the heading COST CATEGORY SUMMARY. Data on each cost category are summarized on a line of output. Costs are labeled as operating or capital. Four column headings to the right show whether the cost is: (1) LIFETIME COST; (2) COST PER YEAR; (3) LIFETIME DISCOUNTED COST; or (4) DISCOUNTED COST PER YEAR. All costs are in thousands of dollars. In the printout some costs may be positive (disbursements) and some negative (net revenues). For example, contractor operating cost is shown as −1207. This means that on the average the operation of the Saugus plant produces $1.2 million dollars of revenue annually net not only of haul cost but also of operating costs.[2] Note that lifetime costs are equal to the product of the annual costs and the length of the study period.

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[1]The three market types are: explicit commodity; source separation recoverables; and implicit markets. Revenues from implicit markets are already net of haul, so only one line of output is necessary. The reader should note the distinction between market type as used above and market structure as used in section 2.2. All sales and haul costs within a particular market type are aggregated in the printout.

[2]Operating costs (in thousands of dollars) or the plant can be calculated by noting that total revenue for the plant are 3681 (3353 + 328). Since the cost per year was listed as −1207, this would imply that annual operating costs are 2474 (3681 −1207).

Exhibit 4.12   Revenue Summary by Market Type


REVENUE SUMMARY IN THOUSAND DOLLARS PER AVERAGE YEAR, UNDISCOUNTED

      3353.   MARKET VALUE OF EXPLICIT COMMODITIES
       355.   HAUL COST TO MARKET
      2998.   NET REVENUE OF EXPLICIT COMMODITIES

      5976.   MARKET VALUE OF SOURCE SEPARATION RECOVERABLES
       441.   HAUL COST TO MARKET
      5535.   NET REVENUE OF SOURCE SEPARATION RECOVERABLES

       328.   IMPLICIT REVENUES NET OF HAUL COST TO MARKET

      8861.   TOTAL REVENUE PER AVERAGE YEAR


REVENUE SUMMARY IN THOUSAND DOLLARS PER AVERAGE YEAR, DISCOUNTED

      1715.   MARKET VALUE OF EXPLICIT COMMODITIES
       182.   HAUL COST TO MARKET
      1533.   NET REVENUE OF EXPLICIT COMMODITIES

      2635.   MARKET VALUE OF SOURCE SEPARATION RECOVERABLES
       195.   HAUL COST TO MARKET
      2440.   NET REVENUE OF SOURCE SEPARATION RECOVERABLES

       168.   IMPLICIT REVENUES NET OF HAUL COST TO MARKET

      4141.   TOTAL REVENUE PER AVERAGE YEAR

Exhibit 4.13  Analytical Summary of the Solution

ANALYTICAL SUMMARY

LIFETIME SUMMARIES FOR 20 YEARS
```
  10140.0000  TOTAL TONS (THOUSANDS)
144861.7598  TOTAL COST (THOUSAND DOLLARS)
 62545.7310  TOTAL DISCOUNTED COST (THOUSAND DOLLARS)
185929.4258  TOTAL NET ENERGY
    507.0000  TOTAL TONS PER YEAR (THOUSANDS)
   7243.0880  TOTAL COST PER YEAR (THOUSAND DOLLARS)
   3127.2865  TOTAL DISCOUNTED COST PER YEAR (THOUSAND DOLLARS)
   9296.4712  TOTAL NET ENERGY PER YEAR
     14.2862  COST PER TON
      6.1682  DISCOUNTED COST PER TON
     18.3362  NET ENERGY PER TON
```

COST CATEGORY SUMMARY      ALL COSTS IN THOUSAND DOLLARS

| COST CATEGORY | CAP CODE | LIFETIME COST | COST PER YEAR | LIFETIME DISCOUNTED COST | DISCOUNTED COST PER YEAR |
|---|---|---|---|---|---|
| 1 MUNICIPAL COST | 0 | 166822.2969 | 8341.1147 | 73553.5703 | 3677.6785 |
| 2 CONTRACTOR OP COST | 0 | -24141.3691 | -1207.0685 | -12347.1553 | -617.3578 |
| 3 CONTRACTOR CAP COST | 1 | 392.7768 | 19.6388 | 241.2161 | 12.0608 |
| 4 SITE PREP COST | 1 | 1788.0580 | 89.4029 | 1098.1003 | 54.9050 |

COST SUMMATIONS      ALL COSTS IN THOUSAND DOLLARS

| COST SUMMATION CATEGORY | LIFETIME COST | COST PER YEAR | LIFETIME DISCOUNTED COST | DISCOUNTED COST PER YEAR |
|---|---|---|---|---|
| 1 CONTRACTOR COST | -23748.5925 | -1187.4296 | -12105.9392 | -605.2970 |

ENERGY CATEGORY SUMMARY

| CATEGORY | LIFETIME NET ENERGY | NET ENERGY PER YEAR |
|---|---|---|
| 1 FUEL INPUT, MBTU | 21884.10889 | 1094.20544 |
| 2 STEAM OUTPUT, MBTU | 164045.31836 | 8202.26587 |

The cost summation categories are printed out next. In this case, they show the total cost to the contractor for operation of the Saugus plant. As before, a negative value implies that the plant can operate at a profit. Cost summation categories are a convenient way for aggregating costs so that it becomes clear who benefits and who bears the burden of the program. The final piece of information is entitled ENERGY CATEGORY SUMMARY. This output lists the energy category number and name along with the lifetime net energy and the net energy per year. In this output, a negative value implies a net input of energy is required.

4.3 POST-OPTIMALITY ANALYSIS

The outputs presented in this section constitute a post-optimality analysis of the preferred regional plan. The term post-optimality is used above because the analysis which generates the output reports shown as exhibits 4.14 through 4.20 is done after the solution returns from the optimizer. Such an analysis permits the user to trace through some of the implications associated with the siting, marketing and routing details of the solution presented in the previous section. There are three types of post-optimality analysis described in this section. They focus on splits, routing requests, and cost analyses, respectively. It was mentioned earlier that because of site capacity constraints, landfill constraints, and market limits, transportation and site-process splits can occur. Exhibit 4.14 summarizes the post-optimality analysis of the three types of splits. The first block of data on exhibit 4.14 is concerned with source tonnage splits. These splits occur because sources may be split among offload sites; even if this is not true, some tonnage may go to source separation recoverables markets. By examining the upper portion of the exhibit, it can be seen that four lines of output are required for each source. For example, Lynn ships glass, cans and paper to the recoverables market and source separation residue plus a small fraction of paper to the Saugus processor. The fourth line shows that all 340 KTPY are allocated.[1] The remaining columns in the output help to define the difference between real tonnage and percentages and equivalent tonnage and percentages. The real ton column is equal to the product of the real percent and the source tonnage recorded under ALLOC TNS. For example, 11.80 percent of Lynn's solid waste is glass sent to the market; this corresponds to the 40.12 KTPY figure recorded under REAL TNS. Equivalent tons are used as inputs to processes and reflect the real cost of processing the solid waste stream. The values of the equivalent tonnage are based on the values of RPRPAP, ALLO, and RPRRES, input by the user and shown in exhibit 4.1. In this case, for Lynn, the 23.2 percent of the waste stream accounted for by paper was split; 21.65 percent went to the national paper market and 1.55 percent went to the Saugus processor to be burned. The 57 percent of the waste stream corresponding to

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[1]Full preseparation tonnage is allocated to the offload site of the residue.

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SOURCE TONNAGE SPLITS
LINK COSTS FOR SITE OFFLOADS INCLUDE ALLOCATED REVENUES AND HAUL COSTS OF GLASS, CAN, AND NATIONAL PAPER MARKETS.
ALL TONS IN THOUSAND TONS PER YEAR.
ALL COSTS IN UNDISCOUNTED COST PER TON, AVERAGED OVER YRS OF RUN.
ALLOC TNS AND ALLOC PCT ARE PRESEPARATED 000 TONS AND PCT, ALL ·ALLOCATED TO OFFLOAD OF RESIDUE (USED FOR LINK COSTS).
REAL TNS AND REAL PCT ARE 000 TONS AND PCT AS DELIVERED TO SITES AND MARKETS.
EQUV TNS AND EQUV PCT ARE 000 TONS AND PCT IN EQUIV MSW (EQUIV IN PROCESSING COST) (USED FOR OFFLOAD COSTS).

| SOURCE | OFFLOAD | ALLOC TNS | ALLOC PCT | REAL TNS | REAL PCT | EQUV TNS | EQUV PCT | LINK COS |
|--------|---------|-----------|-----------|----------|----------|----------|----------|----------|
| 1 LYNN | GLASS MARKET | | | 40.12 | 11.80 | | | |
| 1 LYNN | CANS MARKET | | | 27.20 | 8.00 | | | |
| 1 LYNN | PAPER MARKET | | | 73.62 | 21.65 | | | |
| 1 LYNN | 1 SAUGUS PROC | 340.00 | 100.00 | 199.06 | 58.55 | 202.19 | 59.47 | 16.51 |
| 2 MARBLEHEAD | GLASS MARKET | | | .83 | 11.80 | | | |
| 2 MARBLEHEAD | CANS MARKET | | | .56 | 8.00 | | | |
| 2 MARBLEHEAD | PAPER MARKET | | | 1.62 | 23.20 | | | |
| 2 MARBLEHEAD | 1 SAUGUS PROC | 7.00 | 100.00 | 3.99 | 57.00 | 3.59 | 51.30 | 19.17 |
| 3 SALEM | GLASS MARKET | | | 14.16 | 11.80 | | | |
| 3 SALEM | CANS MARKET | | | 9.60 | 8.00 | | | |
| 3 SALEM | PAPER MARKET | | | 25.98 | 21.65 | | | |
| 3 SALEM | 1 SAUGUS PROC | 120.00 | 100.00 | 70.26 | 58.55 | 71.36 | 59.47 | 17.23 |
| 4 REVERE | GLASS MARKET | | | 4.72 | 11.80 | | | |
| 4 REVERE | CANS MARKET | | | 3.20 | 8.00 | | | |
| 4 REVERE | PAPER MARKET | | | 9.28 | 23.20 | | | |
| 4 REVERE | 1 SAUGUS PROC | 40.00 | 100.00 | 22.80 | 57.00 | 20.52 | 51.30 | 16.94 |

SITE/SIPROC SPLITS; TONNAGE IN THOUSAND TONS OR COMMODITY UNITS PER YEAR

| SITE | COMMODITY | PROCESS | TONNAGE | PCT OF SITE TONNAGE |
|------|-----------|---------|---------|---------------------|
| 1 SAUGUS PROC | 2 MSW IN VAN, KTON | 2 WATER-WALL INCIN | 297.7 | 100.00 |
| 4 SAUGUS SECONDARY PR | 7 PROC RESIDUE, KTON | 5 SECONDARY PROC | 44.6 | 100.00 |

LOCATION-COMMODITY SPLITS:
COST PER TON IS UNDISCOUNTED, AVERAGED OVER YRS OF RUN..
ACT IS ACTIVITY LEVEL IN THOUSAND TONS OR COMMODITY UNITS PER YEAR.

| LOC | COMMODITY | OFFLOAD: SITE | MKT | NAME | ACT | PCT LOC-COMM TNS | LINK COST/TON |
|-----|-----------|---------------|-----|------|-----|------------------|---------------|
| 5 | 7 PROC RESIDUE, KTON | 4 | 0 | SAUGUS SECONDARY PR | 44.6 | 100.00 | .00 |
| 5 | 6 STEAM, ML8S | 0 | 1 | GE LYNN STEAM | 1631.2 | 100.00 | .00 |
| 5 | 8 INCIN FERROUS, KTON | 0 | 2 | NEW YORK FERROUS | 20.8 | 100.00 | 17.03 |

source separation residue was sent to Saugus. Since ALLO is defined as the allocation of paper processing cost of actual paper processed as waste versus potential paper processed as waste when the trigger price system is used (as for Lynn and Salem), the computation of equivalent tonnage becomes more complex because potential processing costs must be accounted for. From exhibit 4.1 it can be seen that the appropriate values are: RPRPAP, 0.8; ALLO, 0.6; RPRRES, 0.9. The equivalent tonnage of residue is thus 0.9 times 0.57 times 340 or 174.42. The equivalent tonnage of paper actually processed as waste is 0.8 times 0.0155 times 340 or 4.22. The equivalent tonnage of paper potentially processable as waste is 0.8 times 0.2155 times 0.4 (i.e., 1-ALLO) times 340 or 23.56. The total equivalent tonnage is therefore 202.2; the associated equivalent percentage is 59.47. The link cost is defined as the cost per ton of collection, source separation and haul to the offload site minus net revenues due to the sale of source separation recoverables in the market. The link cost for Lynn is $16.51 per ton.

The SITE/SIPROC splits are then output. Sites may be split among the processes offered due to constraints at other sites or at the market. The printout provides information on the site, the commodity, the process, the tonnage and the percent of the site tonnage. The two sites which were in the solution did not experience splits as can be seen by the entry of 100.0 under the heading, PCT OF SITE TONNAGE. Each site is shown as a single line of output.

Location-commodity splits are then output. A location from which a process output commodity is shipped may be split among offload sites and markets. The printout provides information on the origin location number, the commodity, the destination site or market, the activity level, the percent of location-commodity tons, and the link cost per ton. The shipments from the Saugus processor did not experience splits, as can be seen by the entry of 100.0 under the heading PCT LOC-COMM TNS. Each location commodity is shown as a single line of output.

Exhibit 4.15 summarizes each of the four site routing requests. For a single site at a level, the procedure will trace routing through the SITE/SIPROC splits, through the output coefficients of each process, and through the location-commodity splits, to a series of sites and markets. At each point in the routing, the activity level as a ratio of the activity level at the subject site is maintained. The end-point sites are assigned a continuation number for the next level, and the continuation factor (ratio of activity level at the end-point of the level to subject site activity level) is recorded to be used at the start of the next level for that site. There is no corresponding continuation for markets.

Exhibit 4.15   Analysis of Site Routings for the Four Sites Considered
             by the Model

SITE ROUTING REQUEST

SUBJECT SITE:   1 SAUGUS PROC              INPUT COMMOD:   2  MSW IN VAN, KTON      LOC   5   ACT LEVEL:    297.657
                PROCESS                    PCT OF SITE   CONT ACT LEV   CONT FACTOR
                2 WATER-WALL INCIN            100.00        297.7      1.0000000
                   COEFFICIENTS:
                   COMMODITY                      COEFFICIENT   CONT ACT LEV   CONT FACTOR
                    6 STEAM, MLBS                  5.480000        1631.2       5.4799999
                       LOCATION-COMMODITY SPLIT
                       PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                      CONTIN NO
                           100.00         1631.2      5.4799999                  O   1 GE LYNN STEAM
                   COMMODITY                      COEFFICIENT   CONT ACT LEV   CONT FACTOR
                    7 PROC RESIDUE, KTON           .150000          44.6        .1500000
                       LOCATION-COMMODITY SPLIT
                       PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                      CONTIN NO
                           100.00          44.6        .1500000               4   O SAUGUS SECONDARY PR                 1
                   COMMODITY                      COEFFICIENT   CONT ACT LEV   CONT FACTOR
                    8 INCIN FERROUS, KTON          .070000          20.8        .0700000
                       LOCATION-COMMODITY SPLIT
                       PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                      CONTIN NO
                           100.00          20.8        .0700000                  O   2 NEW YORK FERROUS


LEVEL NUMBER: 2
CONTIN NO 1   SITE            INPUT COMMODITY            LOC   CONTINUATION ACT LEV   CONTINUATION FACTOR
              4 SAUGUS SECONDARY PR   7 PROC RESIDUE, KTON    5              44.6                   .1500000
              PROCESS                PCT OF SITE   CONT ACT LEV   CONT FACTOR
              5 SECONDARY PROC          100.00         44.6        .1500000




SITE ROUTING REQUEST

SUBJECT SITE:   2 WORCESTER PROC          INPUT COMMOD:   2  MSW IN VAN, KTON       LOC   6   ACT LEVEL:     .000
SUBJECT SITE IS NOT IN THE SOLUTION




SITE ROUTING REQUEST

SUBJECT SITE:   3 AMESBURY LANDFILL       INPUT COMMOD:   7  PROC RESIDUE, KTON     LOC   7   ACT LEVEL:     .000
SUBJECT SITE IS NOT IN THE SOLUTION




SITE ROUTING REQUEST

SUBJECT SITE:   4 SAUGUS SECONDARY PR     INPUT COMMOD:   7  PROC RESIDUE, KTON   LOC   5   ACT LEVEL:    44.649
                PROCESS                    PCT OF SITE   CONT ACT LEV   CONT FACTOR
                5 SECONDARY PROC              100.00         44.6      1.0000000

All sites at one level will be analyzed before any sites at the next continuation level. Thus the list of continuation sites will be generated in order of the sites from which they were generated at the preceding level. A single site may well appear more than once at a single level; but if so, the site at each appearance would be assigned a different continuation number, and would probably also show a different continuation factor.

For a subject site, the following is reported: subject site number and name; input commodity number and name; location; activity level. For a continuation site, the following is reported: level number; continuation number; site number and name; commodity number and name; location; continuation activity level; continuation factor. For each process at the site, the following is reported: process number and name; percent of site; continuation activity level; continuation factor. All coefficients for a process are analyzed before the next process is analyzed. For each coefficient, the following is reported: commodity number and name; coefficient; continuation activity level; continuation factor. All location-commodity splits for a coefficient are analyzed before the next coefficient is analyzed. For each location-commodity split, the following is reported: percent of location-commodity; continuation activity level; continuation factor; offload site or market number and name; continuation number.

Exhibits 4.16 through 4.19 are source routing requests. For a source (first level only) the procedure will trace routing and continuation factors only to the first offload, using the equivalent percents of the source splits. Since all four exhibits are very similar, only the first which deals with Lynn will be discussed in any detail. Once at the site, the offload tonnage from the source, measured as the process CONT ACT LEV on the output, will be traced through the process(es). For example, 202.2 MSW equivalent tons arrive at Saugus from Lynn at level 1. Processing this waste at level 2 produces: (a) 1108 million pounds of steam per year for sale to the GE plant at Lynn; (b) 30.3 KTPY of process residue sent to site 4 (Saugus secondary processor) with a continuation to level 3; (c) 14.2 KTPY of incinerated ferrous for delivery to New York City scrap dealers. At level 3, the Saugus secondary processor either disposes of the wastes or markets recoverables from it through the implicit market (revenue) defined on the SIPROC card; there is no continuation to level 4.

Exhibit 4.20 consists of a source cost analysis and a site cost analysis. The two sets of results are somewhat interdependent, so it will be necessary to move from one block of data to the other. The source cost analysis shows for each source, its name location and tonnage, the offload point, the allocation percentage, the link cost, the equivalent percentage, the offload cost and the total source cost per ton. All terms but the last two were discussed as a part of the output report shown as exhibit 4.14. The two new terms, offload cost and total source cost per ton are closely related to the tipping fee calculation summarized under the site cost analysis. The two crucial factors

Exhibit 4.16  Analysis of Source Routings for Lynn, Massachusetts

SOURCE ROUTING REQUESTS
TONNAGE AND PERCENTS SHOWN IN TWO FORMS:
PRESEPARATED TONS: KTPY WITH SEPARATED TONNAGE ALLOCATED TO CORRESPONDING RESIDUE OFFLOAD
OFFLOAD TONNAGE: KTPY IN EQUIVALENT MSW (EQUIVALENCE IN PROCESSING COST) OF MSW, RES, AND PAPER ARRIVING AT SITE
FIRST MEASURE IS USED TO GENERATE LINK COSTS:
SECOND MEASURE IS USED TO GENERATE OFFLOAD COST.
ALL PERCENTAGES ARE PERCENTAGES OF TOTAL SOURCE TONS BEFORE SEPARATION.


    SOURCE ROUTING REQUEST

    SOURCE:  1 LYNN               LOCATION   1   SOURCE TONS (KTPY):   340.000

      OFFLOAD: SITE MKT NAME              PRESEP TONS  PRESEP PCT  OFFLOAD TONS  OFFLOAD PCT  CONTIN NO
               1    0 SAUGUS PROC              340.0      100.00        202.2        59.47          1


LEVEL NUMBER: 2
CONTIN NO 1  SITE                    INPUT COMMODITY           LOC  CONTINUATION ACT LEV  CONTINUATION FACTOR
             1 SAUGUS PROC           2 MSW IN VAN, KTON         5                202.2            .5946640
               PROCESS               PCT OF SITE  CONT ACT LEV  CONT FACTOR
               2 WATER-WALL INCIN       100.00       202.2      .5946640
                 COEFFICIENTS:
                 COMMODITY           COEFFICIENT  CONT ACT LEV  CONT FACTOR
                 6 STEAM, MLBS         5.480000     1108.0      3.2587585
                   LOCATION-COMMODITY SPLIT
                   PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                    CONTIN
                       100.00         1108.0      3.2587585             O   1 GE LYNN STEAM
                 COMMODITY           COEFFICIENT  CONT ACT LEV  CONT FACTOR
                 7 PROC RESIDUE, KTON   .150000       30.3      .0891996
                   LOCATION-COMMODITY SPLIT
                   PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                    CONTIN
                       100.00          30.3       .0891996             4   O SAUGUS SECONDARY PR
                 COMMODITY           COEFFICIENT  CONT ACT LEV  CONT FACTOR
                 8 INCIN FERROUS, KTON  .070000       14.2      .0416265
                   LOCATION-COMMODITY SPLIT
                   PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                    CONTIN
                       100.00          14.2       .0416265             O   2 NEW YORK FERROUS


    LEVEL NUMBER: 3
    CONTIN NO 1  SITE                 INPUT COMMODITY          LOC  CONTINUATION ACT LEV  CONTINUATION FACTOR
                 4 SAUGUS SECONDARY PR  7 PROC RESIDUE  KTON    5                30.3             .0891996
                   PROCESS             PCT OF SITE  CONT ACT LEV  CONT FACTOR
                   5 SECONDARY PROC       100.00       30.3      .0891996

Exhibit 4.17  Analysis of Source Routings for Marblehead, Massachusetts

SOURCE:  2 MARBLEHEAD          LOCATION   2  SOURCE TONS (KTPY):     7.000

OFFLOAD: SITE MKT NAME              PRESEP TONS  PRESEP PCT  OFFLOAD TONS  OFFLOAD PCT  CONTIN NO
         1    O SAUGUS PROC              7.0       100.00         3.6        51.30           1




LEVEL NUMBER: 2
CONTIN NO 1  SITE                    INPUT COMMODITY          LOC  CONTINUATION ACT LEV  CONTINUATION FACTOR
         1 SAUGUS PROC               2 MSW IN VAN, KTON        5                3.6              .5130000
           PROCESS                   PCT OF SITE  CONT ACT LEV  CONT FACTOR
           2 WATER-WALL INCIN           100.00        3.6        .5130000
           COEFFICIENTS:
           COMMODITY                 COEFFICIENT  CONT ACT LEV  CONT FACTOR
           6 STEAM, MLBS               5.480000       19.7      2.8112399
               LOCATION-COMMODITY SPLIT
               PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                  CONTIN NO
                   100.00          19.7      2.8112399             O  1 GE LYNN STEAM
           COMMODITY                 COEFFICIENT  CONT ACT LEV  CONT FACTOR
           7 PROC RESIDUE. KTON         .150000        .5        .0769500
               LOCATION-COMMODITY SPLIT
               PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                  CONTIN NO
                   100.00           .5        .0769500           4  O SAUGUS SECONDARY PR            1
           COMMODITY                 COEFFICIENT  CONT ACT LEV  CONT FACTOR
           8 INCIN FERROUS. KTON        .070000        .3        .0359100
               LOCATION-COMMODITY SPLIT
               PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME                  CONTIN NO
                   100.00           .3        .0359100           O  2 NEW YORK FERROUS




LEVEL NUMBER: 3
CONTIN NO 1  SITE                    INPUT COMMODITY          LOC  CONTINUATION ACT LEV  CONTINUATION FACTOR
         4 SAUGUS SECONDARY PR       7 PROC RESIDUE  KTON      5                 .5              .0769500
           PROCESS                   PCT OF SITE  CONT ACT LEV  CONT FACTOR
           5 SECONDARY PROC             100.00         .5        .0769500

Exhibit 4.18  Analysis of Source Routings for Salem, Massachusetts

SOURCE ROUTING REQUEST

SOURCE:  3 SALEM                    LOCATION   3  SOURCE TONS (KTPY):    120.000

| OFFLOAD: SITE MKT NAME | PRESEP TONS | PRESEP PCT. | OFFLOAD TONS | OFFLOAD PCT | CONTIN NO |
|---|---|---|---|---|---|
| 1  0  SAUGUS PROC | 120.0 | 100.00 | 71.4 | 59.47 | 1 |

LEVEL NUMBER: 2
CONTIN NO 1  SITE                        INPUT COMMODITY           LOC   CONTINUATION ACT LEV   CONTINUATION FACTOR
             1 SAUGUS PROC                2 MSW IN VAN, KTON         5                71.4                .5946640
             PROCESS                     PCT OF SITE   CONT ACT LEV   CONT FACTOR
             2 WATER-WALL INCIN           100.00         71.4         .5946640
             COEFFICIENTS:
             COMMODITY                    COEFFICIENT   CONT ACT LEV   CONT FACTOR
             6 STEAM, MLBS                 5.480000       391.1         3.2587585
                 LOCATION-COMMODITY SPLIT
                 PCT OF LOC-COMM   CONT ACT LEV   CONT FACTOR   OFFLOAD: SITE MKT NAME                   CONTIN NO
                     100.00           391.1         3.2587585           0   1 GE LYNN STEAM
             COMMODITY                    COEFFICIENT   CONT ACT LEV   CONT FACTOR
             7 PROC RESIDUE, KTON          .150000        10.7          .0891996
                 LOCATION-COMMODITY SPLIT
                 PCT OF LOC-COMM   CONT ACT LEV   CONT FACTOR   OFFLOAD: SITE MKT NAME                   CONTIN NO
                     100.00           10.7          .0891996           4   0 SAUGUS SECONDARY PR           1
             COMMODITY                    COEFFICIENT   CONT ACT LEV   CONT FACTOR
             8 INCIN FERROUS, KTON         .070000        5.0           .0416265
                 LOCATION-COMMODITY SPLIT
                 PCT OF LOC-COMM   CONT ACT LEV   CONT FACTOR   OFFLOAD: SITE MKT NAME                   CONTIN NO
                     100.00           5.0           .0416265           0   2 NEW YORK FERROUS

LEVEL NUMBER: 3
CONTIN NO 1  SITE                        INPUT COMMODITY           LOC   CONTINUATION ACT LEV   CONTINUATION FACTOR
             4 SAUGUS SECONDARY PR        7 PROC RESIDUE, KTON       5                10.7                .0891996
             PROCESS                     PCT OF SITE   CONT ACT LEV   CONT FACTOR
             5 SECONDARY PROC             100.00         10.7          .0891996

Exhibit 4.19   Analysis of Source Routings for Revere, Massachusetts


SOURCE ROUTING REQUEST

SOURCE:  4 REVERE                LOCATION   4  SOURCE TONS (KTPY):    40.000

OFFLOAD: SITE MKT NAME                    PRESEP TONS  PRESEP PCT  OFFLOAD TONS  OFFLOAD PCT  CONTIN NO
         1    0 SAUGUS PROC                   40.0      100.00         20.5        51.30          1




LEVEL NUMBER: 2
CONTIN NO 1  SITE                    INPUT COMMODITY         LOC  CONTINUATION ACT LEV  CONTINUATION FACTOR
         1 SAUGUS PROC              2 MSW IN VAN, KTON        5             20.5               .5130000
           PROCESS                  PCT OF SITE  CONT ACT LEV  CONT FACTOR
           2 WATER-WALL INCIN          100.00       20.5       .5130000
             COEFFICIENTS:
             COMMODITY                 COEFFICIENT  CONT ACT LEV  CONT FACTOR
             6 STEAM, MLBS               5.480000       112.4     2.8112398
                LOCATION-COMMODITY SPLIT
                PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME              CONTIN NO
                    100.00          112.4       2.8112398              0    1 GE LYNN STEAM
             COMMODITY                 COEFFICIENT  CONT ACT LEV  CONT FACTOR
             7 PROC RESIDUE, KTON        .150000        3.1       .0769500
                LOCATION-COMMODITY SPLIT
                PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME              CONTIN NO
                    100.00           3.1        .0769500              4    0 SAUGUS SECONDARY PR       1
             COMMODITY                 COEFFICIENT  CONT ACT LEV  CONT FACTOR
             8 INCIN FERROUS, KTON       .070000        1.4       .0359100
                LOCATION-COMMODITY SPLIT
                PCT OF LOC-COMM  CONT ACT LEV  CONT FACTOR  OFFLOAD: SITE MKT NAME              CONTIN NO
                    100.00           1.4        .0359100              0    2 NEW YORK FERROUS




    LEVEL NUMBER: 3
    CONTIN NO 1  SITE                  INPUT COMMODITY         LOC  CONTINUATION ACT LEV  CONTINUATION FACTOR
             4 SAUGUS SECONDARY PR    7 PROC RESIDUE  KTON      5             3.1               .0769500
               PROCESS                PCT OF SITE  CONT ACT LEV  CONT FACTOR
               5 SECONDARY PROC          100.00       3.1       .0769500




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which influence the tipping fee are on-site cost and net off-site cost.
On-site costs are those operating and capital costs incurred because of
processing activity. They are measured through the two cost categories
declared on the process cards as well as any site prepration costs declared on
the site card and matched to the process on the SIPROC card. Net off-site
costs, on the other hand, include implicit revenues and the implications of
all outputs of the process. The sum of these two costs is equal to the
tipping fee. The offload cost for the source may now be calculated by
multiplying the tipping fee by the equivalent percentage. The total source
cost per ton is then defined as the sum of the link cost and the offload cost.
The total source cost per ton may also be used to show the relationship
between source costs and the undiscounted cost per ton given as part of the
analytical summary (see exhibit 4.13). If the proportion that each source
contributes to the overall waste stream is designated as $P_i$, where i is equal
to 1 for Lynn, 2 for Marblehead, 3 for Salem and 4 for Revere, and the total
source cost as recorded on exhibit 4.20 is designated as $C_i$, then the sum of
the $P_i C_i$ products is equal to approximately \$14.25 per ton.

Exhibit 4.20   Source Cost and Site Cost Analysis

SOURCE COST ANALYSIS
ALL COSTS ARE UNDISCOUNTEO COST PER ORIGINAL PRESEPARATEO SOURCE TON, AVERAGEO OVER THE YEARS OF THE MOOEL RUN.
LINK CDSTS INCLUOE REVENUES AND HAUL COSTS OF GLASS, CAN, AND NATIONAL PAPER MARKETS ALLOCATEO TO OFFLOAO OF RESIDUE.
ALLOC PCT IS TONNAGE AS PCT OF SOURCE TDNNAGE, WITH SEPARABLES, AS ABOVE, ALLOCATEO TO OFFLOAO OF RESIOUE.
EQUIV PCT IS TONNAGE AS PCT OF SOURCE TONNAGE IN EQUIVALENT MSW, WITH EQUIVALENCE IN PROCESSING COST.

SOURCE:  1 LYNN                    LOCATION:   1    TOTAL SOURCE TONS:    340.00
OFFLOAO                     ALLOC PCT   LINK CDST   EQUIV PCT   OFFLOAD COST
 1 SAUGUS PROC                 100.OO      16.51       59.47       -2.56

TOTAL SOURCE COST PER TON:  13.95

SOURCE:  2 MARBLEHEAD               LOCATION:   2    TOTAL SOURCE TONS:      7.00
OFFLOAD                     ALLOC PCT   LINK COST   EQUIV PCT   OFFLDAO COST
 1 SAUGUS PROC                 100.DD      19.17       51.30       -2.21

TOTAL SOURCE COST PER TON:  16.97

SOURCE:  3 SALEM                    LOCATION:   3    TOTAL SOURCE TDNS:    120.00
OFFLOAD                     ALLOC PCT   LINK CDST   EQUIV PCT   OFFLDAO CDST
 1 SAUGUS PROC                 100.00      17.23       59.47       -2.56

TOTAL SOURCE COST PER TON:  14.67

SOURCE:  4 REVERE                   LOCATION:   4    TOTAL SOURCE TONS:     40.00
OFFLOAO                     ALLOC PCT   LINK COST   EQUIV PCT   OFFLOAO COST
 1 SAUGUS PROC                 100.OD      16.94       51.30       -2.21

TOTAL SOURCE COST PER TON:  14.73

SITE COST ANALYSIS
ACT IS ACTIVITY LEVEL IN THOUSANO TONS OR COMMOO UNITS PER YEAR.
ALL COSTS IN UNOISCOUNTEO COST PER SITE TON OR COMMOO UNIT AVERAGED OVER YRS OF RUN.

SITE:  1 SAUGUS PROC           LOCATION:   5    ACT:    297.66    FULL SITE COST (TIPPING FEE):  -4.30
PROCESS                   ACT   PCT OF SITE  ON-SITE COST   NET OFF-SITE COST   TOTAL COST
 2 WATER-WALL INCIN       297.66     100.DO       6.53            -10.83          -4.30

SITE:  4 SAUGUS SECONDARY PR   LOCATION:   5    ACT:     44.65    FULL SITE COST (TIPPING FEE):    .68
PROCESS                   ACT   PCT OF SITE  ON-SITE COST   NET OFF-SITE COST   TOTAL COST
 5 SECDNOARY PROC          44.65     100.00       2.96             -2.28            .68

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5. GUIDANCE ON USING RRPLAN

The purpose of this chapter is to provide guidance for making intelligent use of the model. The previous chapters dealt with the technical underpinnings of the model and the mechanics of setting up and interpreting a case study. This chapter goes beyond these basic issues by attempting to answer three major questions associated with model use. First, what are the objectives of the analysis? Second, what level of detail is appropriate for the case at hand? Third, how should the study be structured? The first two questions and a number of related issues are the subject of section 5.1. The last question is the subject of section 5.2.

5.1  SETTING UP A TEST RUN

Once all data have been collected and prior to an analysis with the model, a series of important questions must be answered. The answers to these questions affect not only the mechanics of the optimization, through the setting of run controls, but also the strategy for performing the technical-economic analysis of competing alternatives.

As an initial step, the user must carefully define the objectives of the study and attempt to relate them to the data recorded on the worksheets. Some typical objectives which senior management might wish to analyze involve: (a) comparisons of recovery technologies with the status quo; (b) defining a strategy for shifting the costs of the program so that a more equitable outcome is produced; (c) finding the most economical location for siting competing alternatives; (d) development of a plan for upgrading existing facilities or scheduling the construction of new facilities.

In performing any of the analyses mentioned above, it is essential that sufficient detail be incorporated into the three data files so the model can make meaningful tradeoffs. For example, a baseline run using a minimum of linkage can be used to establish the costs of the current program. Candidate sites, processes and markets can then be defined for analysis of the recovery technology run. A series of "what-if" questions can be addressed by changing the values of certain inputs and rerunning the model. These results can then be compared against the status quo to determine if the overall costs of processing the region's solid waste has declined. Similarly, RRPLAN can provide a detailed cost accounting summary which could lead to changes in tipping fees, a reallocation of vehicles among sources or sites, or point to areas where a contract for the sale of recoverables would be beneficial.

The focus will now shift to when and how to use a particular combination of options so that the relationship to objectives, like those stated above, becomes more clear. If the model is to be used effectively, it is crucial that the values of 12 variables be set correctly. These 12 variables are: (1) LPHASE; (2) NFORC; (3) KOVER; (4) KOPT; (5) LOPT; (6) KSUPP; (7) KMIX; (8) KSEPO; (9) NTRIG; (10) RPRPAP; (11) ALLO; AND (12) RPRRES. Each variable will be defined and systematically analyzed in the discussion which follows.

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The first six appear on the run control card (always the first card in the case study file). They govern the type and nature of all calculations performed. The last six appear on the third card of the case study file. Although they were discussed earlier, they are of sufficient importance to be reexamined in this section.

The six run controls govern forcing (LPHASE, NFORC, KOVER), the output from the optimizer (KOPT, KSUPP) and the mode of operation (LOPT). The forcing controls are independent of the two other sets of controls. The forcing mode is entered through the settings of three inputs, all on the control card. The purpose of each variable is as follows: (1) LPHASE tells the optimizer which of the four phases discussed in section 2.2 is the last one; (2) NFORC specifies the column forcing mode (i.e., single or double column forcing); and (3) KOVER sets the control for site and site-process forcing and serves as an override for the limitation on problem size when double column forcing is used.

For no force at all, set LPHASE to 3 and KOVER to 00 (NFORC is irrelevant, but set to 1). For single column forcing, set LPHASE to 4, set KOVER to 00, and set NFORC to 1. For double column forcing, set LPHASE to 4, set KOVER to 00, and set NFORC to 2. In this case, a maximum matrix size of 50 rows and 100 columns is imposed to control the high computing costs of the double column force. To override the matrix size and return to the general maximum matrix size of 90 by 360, set KOVER to 99. Due to its effect on computational expenses, the use of the override is not recommended.

For site forcing, set KOVER to 01; for site-process forcing, set KOVER to 02.[1] A KOVER of 01 or 02 will cause LPHASE to be reset to 3, and hence it will override any other control on forcing. An LPHASE less than 3 or greater than 4 will be reset to 3. A KOVER greater than 02, including a 99 after the matrix size is overridden, will be reset to 00. If all of the above controls are left blank, the run will default to the no-force case.

The optimization reports are controlled by two inputs on the run control card: KOPT and KSUPP. The alternative settings of KOPT will be considered below. A KSUPP of 0 will suppress reports on the search for an initial feasible solution. The optimizer is called once except in site and site-process forcing, in which it is called iteratively. Reports are generated only for the first call.

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[1] For either site forcing or site-process forcing, controls are provided on card number 5 for overriding the values of variable and fixed costs used for "urging in". These controls are: (1) IFDRV, the control for the fixed cost driver; (2) IVDRV, the control for the variable cost driver; (3) FDRIV, the value of the fixed cost driver; and (4) VDRIV, the value of the variable cost driver. The built-in values may be applied by leaving these controls blank.

If KSUPP is 0, all reports on the search for an initial feasible solution
will be suppressed, and if there is no negative activity level in the initial
basis, there will also be no report. If KSUPP is greater than 0, and if
there is at least one negative activity level in the initial basis, the
following will be reported:

The basis in column number and the activity levels.
The new column and the old column in index form.
The basis in column index and the activity levels.

The column index is the sequential number of the column; the column number is
the same before expansion, but artificials are numbered 2000 plus the row
number, and slacks are numbered 3000 plus the row number.[1] The old column is
the one with the largest negative activity level (it will always be a slack)
and the new column corresponds to activity NZ which is always the last column
before expansion, and which relieves all constraints.

If KOPT is 2 or 3, a summary of the optimization is then issued, showing:

Number of rows, number of columns (after expansion of the matrix for
slacks and artificials), number of non-zero coefficients in the matrix
(after expansion), and the actual size of the matrix in elements.

If KOPT is 1, the matrix is shown in detail (after expansion) as follows:

(i)     The last phase and that the method of steepest descent will be
        used.

(ii)    Number of rows; for each:
            Row number, type (0 is equation; 1 is less-than-or-equal
            constraint), right-hand side.

(iii)   Number of columns, for each:
            Column index, column number, variable cost, fixed cost.

(iv)    Number of non-zero coefficients; for each:
            Coefficient index, row number, column number, coefficient.

---

[1]There is one artificial variable for every equality constraint and one slack
variable for every less than or equal to constraint. These variables are
introduced at the start of the search for an optimal solution in order to
provide an identity basis. An excellent introductory text for those readers
who wish more information on this subject is: S. I. Gass, Linear
Programming: Methods and Applications, Fourth Edition, (New York:
McGraw-Hill Book Company, 1975).

If KOPT is 1, the following will be reported after the solution:

The user-supplied initial basis in column number form (this is actually the initial <u>feasible</u> basis);
Phase 3 and 4 solutions (as appropriate) in column number and activity level.

If activity NZ is found to be in the solution at the end of optimization, there is indeed no feasible solution -- that fact is reported and the run is stopped. If a scenario evaluation is being conducted, activity NZ will have been replaced with activity NZX, which also relieves all constraints at lower cost, so that the run will proceed to the back end of RRPLAN for interpretation and analysis of the solution.

As mentioned earlier, the model has five basic modes of operation. Each mode serves to define the type of objective which is to be minimized or maximized. The first two modes of operation minimize the <u>total</u> cost of the regional plan over a specified planning period. If both the timing and magnitude of cash flows are important, then the <u>discounted</u> costs of the regional plan should be minimized. This may be accomplished by setting LOPT to a value of 0. If only the magnitude of cash flows is important then <u>undiscounted</u> costs should be minimized. This may be accomplished by setting LOPT to a value 1. It is important to note that the choice of discounted rather than undiscounted costs and vice versa may cause both the costs of the plan and the physical flows within the system to differ. The third mode of operation seeks to maximize the <u>net energy</u> (energy produced (saved) from (due to) resource recovery activities minus all other energy inputs) of the regional plan. Such an objective function might be useful in comparing various waste-to-energy programs. The model will maximize net energy if LOPT is set to a value of 2. The fourth mode of operation seeks to minimize a <u>linear form</u> (weighted sum) of program cost and net energy. This approach might prove useful in comparing mixtures of traditional and waste-to-energy programs if some form of matching formula for funds was in effect. This may be accomplished by setting LOPT to a value of 3. LOPT = 3 is also useful if the user wants to require other than equal weighting for cost and energy categories. The final mode of operation focuses on the topic of <u>scenario evaluation</u>. For example, a region may have a proposed plan which needs to be evaluated from the viewpoint of technical and economic feasibility. Typical questions addressed under this mode of operation would include the following. Are all facilities able to process the indicated waste stream without exceeding their rated capacity, or that of plants down the line which they feed into? Can resources be reallocated so that overall costs are reduced? The model will check the feasibility of a prespecified plan if LOPT is set to a value of 4.

The next three variables (KMIX, KSEPO, NTRIG) affect not only the objective being analyzed but also the size of the matrix. Therefore, in first attempting to solve an actual case study, it would be wise to minimize the size of the problem. This can be done by setting KMIX equal to 1 and KSEPO and NTRIG equal to 0. In this case, mixed MSW will always be sent to the candidate sites for processing. Thus, the A matrix would not include any rows or columns which would be associated with conditional or unconditional source separation. All of the source control values (IMIXSU, ISEPSU, ITRIGS(K)) may be coded onto the cards read on KEY 11, but since they are dominated by the

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run controls, they will be inoperative. Consequently, once this simplified example has been run, the source separation options can be explored by "turning on" the values of KSEPO and NTRIG.

The values of the last three variables (RPRPAP, ALLO, RPRRES) have a significant impact on processing costs due to the distinction between real tonnage and equivalent tonnage. RPRPAP and RPRRES are only used if either form of source separation (i.e., conditional or unconditional) is offered in the run. ALLO is only used if the trigger price system (i.e. conditional source separation) is offered in the run.

There are several practical considerations which govern the amount of detail desirable for a given case study. These considerations affect primarily the designation of cost, energy and commodity categories. First, all topics should be ranked according to their importance to the decision maker. This implies that greater effort should be made to obtain more precise information on selected "high visibility" items, rather than spending an inordinate amount of time on relatively unimportant data. Ideally, all data would be of a comparable degree of accuracy. Second, geographical considerations should be made explicit. If a region has several metropolitan areas and several rural areas, the data base should be constructed in such a manner that undue emphasis is not placed on one area at the expense of the other. For example, metropolitan areas may have the greatest impact on processing costs whereas rural areas may have the greatest impact on transportation costs. Thus both are capable of influencing siting decisions. Third, as stated in section 3.3, care must be exercised in linking up sources with sites and sites with other sites and markets. If the model is not given an opportunity to choose among competing linkages, the model will do little more than print back the case input. Finally, processing and marketing activities must be analyzed in an objective manner. For example, if problem size is of importance and a market for an output is unlimited, then all market activities for that commodity can be modeled through an implicit revenue declared on the SIPROC card. If the market has a declining price, then such an approach would be advisable only if processing activity was sufficiently small that the marketing was likely to be carried out in the first segment.

The last topic serves to underscore the claim that the single greatest constraint on detail is the size of the problem which the model can solve. Since RRPLAN can not solve any problem with more than 90 rows (constraints) or 360 columns (activities), it is essential that users be able to accurately calculate the size of the problem before an attempt to solve it is made. Tables 5.1 and 5.2 provide step-by-step instructions for calculating the size of the problem. Table 5.1 contains the calculation for the row dimension; table 5.2 contains the calculation for the column dimension.

Table 5.1  Guidelines for Calculating the Number of Rows in the A Matrix

| Constraint Type | Allocate one row each: |
|---|---|
| Source balance equations | Source |
| Source paper balance equations | Source coded for unconditional source separation with a <u>local</u> paper market |
| Site input residue balance equations | Site capable of receiving source separation residue |
| Site input paper balance equations | Site capable of receiving source separated paper |
| Site input balance equations for MSW | Site receiving MSW |
| Site input balance equations for other commodities | Site receiving any non-MSW commodity |
| Site output balance equations | Location-commodity combination |
| Market input balance equations | Market |
| Site capacity constraints | Capacitated site |
| Land capacity constraints | Land using location |
| Market bounds | Market segment for which there is an upper bound |
| Constraint on artificial processing activities | Problem formulation[a] |

[a]The model builds in one column per site to take on a very small value (epsilon) without incurring a fixed cost.  Such columns are needed to balance epsilon values on the right hand sides of site input balance equations, which in turn retain these equations in use even if the sites are actually inactive.  Total inactivity of an equation could cause an inability to invert the basis during optimization.  These artificial processing activities are upper bounded with a single constraint which is always the last row in the matrix.

Table 5.2  Guidelines for Calculating the Number of Columns in the A Matrix

| Activity Type | Allocate one column for each: |
|---|---|
| Category 2 transportation | Site-to-site shipment declared on read KEY 22 |
| Category 3 transportation | Site-to-market shipment declared on read KEY 22 |
| Category 4 transportation | Source-to-site shipment of unseparated MSW[a] |
| Category 5 transportation | Source-to-site shipment of source separated MSW (National paper market)[b] |
| Category 6 transportation | Source-to-site shipment of source separated MSW (Local paper market)[c] |
| Category 8 transportation | Source-to-site shipment of preseparated paper (Local paper market)[c] |
| Category 9 transportation | Source-to-market shipment of preseparated paper (Local paper market)[c] |
| Category 11 transportation | Source-to-site shipment of source separated MSW (National paper market)[d] |
| Category 12 transportation | Source-to-site shipment of source separated MSW (National paper market)[d] |
| Category 13 transportation | Source-to-site shipment of source separated MSW (National paper market)[d] |
| Category 14 transportation | Source-to-site shipment of source separated MSW (National paper market)[d] |
| Category 15 transportation | Source-to-site shipment of source separated MSW (National paper market)[d] |
| Residue | Site at which source separation residue may arrive |
| Paper | Site at which source separated paper may arrive |
| Processing | Linear segment of a process at a given site |
| Artificial processing activities | Site[e] |
| NZ | Problem formulation[f] |
| NZX | Scenario evaluation[g] |

[a]Assumes KMIX = 1 on card 3 and IMIXSU = 1 for the source under consideration.
[b]Assumes KSEPO = 1 on card 3 and ISEPSU = 1 or 2 for the source under consideration.
[c]Assumes KSEPO = 2 on card 3 and ISEPSU = 1 or 2 for the source under consideration.
[d]Assumes KSEPO = 1 on card 3 and ITRIGS(K) = 1 for the source under consideration.
 The value of K is equal to the transportation category minus ten.
[e]See note a on table 5.1.
[f]Relieves infeasibilities associated with an advanced starting point.
[g]Relieves infeasibilities when performing a scenario evaluation.  Is not to be counted unless LOPT = 4.

The case example presented in chapter 3 will be used in order to illustrate how the sizing calculation would be performed in practice. Reference will be made to exhibit 3.14, the case study file for the example, in performing the calculation. Since there are four sources, there are four source balance equations which insures that each source's wastes enter into transportation. The value of KSEPO on card 3 was coded as 1, indicating a national paper market, so there are no source paper balance equations. Two of the four sites were coded as MSW receiving, which implies they can also receive source separation residue from those sources which consider unconditional or conditional source separation. Thus, there are two site input residue balance equations. The two MSW-receiving sites can also receive source separated paper from those sources which consider conditional source separation, so there are two site input paper balance equations. There are two site input balance equations for MSW for the two sites listed as MSW receiving. The two sites which receive process residue each have a site input balance equation for non-MSW commodities. Two of the four sites offer processes which produce output commodities. For example, the water wall incinerator at Saugus produces steam, incinerated ferrous and process residue. The two processes at the Worcester site produce MSW (through the transfer station) and steam, incinerated ferrous and process residue (through the water wall incinerator). This implies a need for seven site output balance equations. There are three market input balance equations, one for each market. The only site listed as capacitated (ICAP = 1 for the subject site read on KEY 12) was Saugus, so there is a single site capacity constraint. The two landfills each account for a land capacity constraint. Altogether the two markets for steam had four bounds (GE Lynn: 900 and 1800; Worcester: 2000 and 4000) which translates into four constraints. The final row, which is always included, is the constraint on artifical processing activities at each of the sites. The results of the row tabulations are summarized in table 5.3, where it can be seen that the A matrix defined by the data in the ACASE file contains 30 rows.

In performing the column calculation, it becomes necessary to recognize the relationship between the run control variables (KMIX, KSEPO, NTRIG), the source control variables (IMIXSU, ISEPSU, ITRIGS(K)) and the linkages defined on the transportation category 1 cards read on KEY 22. These controls govern the expansion of the transportation category 1 data. Turning to exhibit 3.14, it can be seen that there are five category 2 transportation activities (line numbers 77 through 81) and four category 3 transportation activities (line numbers 82 through 85), respectively. The data on each source was coded onto lines 23 through 26. A review of this data shows that only one source (Marblehead) considered the shipment of mixed MSW. Turning now to the transportation category 1 cards for Marblehead (line numbers 71 and 72), it can be seen that this source ships its waste to either Saugus or Worcester. This implies a need for two category 4 transportation activities. An analysis of the values coded into ISEPSU and ITRIGS(K) shows that Marblehead considered both unconditional MSW and source separation, Revere considered unconditional

Table 5.3  Calculating the Number of Rows in the A Matrix for the Example
Presented in Chapter 3

| Constraint Type | Quantity |
|---|---|
| Source balance equations | 4 |
| Source paper balance equations | 0 |
| Site input residue balance equations | 2 |
| Site input paper balance equations | 2 |
| Site input balance equations for MSW | 2 |
| Site input balance equations for other commodities | 2 |
| Site output balance equations | 7 |
| Market input balance equations | 3 |
| Site capacity constraints | 1 |
| Land capacity constraints | 2 |
| Market bounds | 4 |
| Constraint on artificial processing | 1 |
| TOTAL | 30 |

Table 5.4  Calculating the Number of Columns in the A Matrix for the
Example Presented in Chapter 3

| Activity type | Quantity |
|---|---|
| Category 2 transportation | 5 |
| Category 3 transportation | 4 |
| Category 4 transportation | 2 |
| Category 5 transportation | 8 |
| Category 6 transportation | 0 |
| Category 8 transportation | 0 |
| Category 9 transportation | 0 |
| Category 11 transportation | 4 |
| Category 12 transportation | 4 |
| Category 13 transportation | 4 |
| Category 14 transportation | 0 |
| Category 15 transportation | 0 |
| Residue | 2 |
| Paper | 2 |
| Processing | 9 |
| Marketing | 5 |
| Artificial processing | 4 |
| NZ | 1 |
| NZX | 0 |
| TOTAL | 54 |

source separation only, and Lynn and Salem considered both unconditional and conditional source separation. All sources are therefore candidates for category 5 transportation activities. Through reference to line numbers 69 through 76 in the ACASE file, it can be seen that there are two category 5 activities for each source, resulting in a total of eight. Since this is a national paper market (KSEPO = 1), there are no category 6, 8 or 9 transportation activities. The fact that there are three trigger prices (NTRIG = 3), implies that Lynn and Salem can each have transportation categories 11, 12 and 13. There are no transportation category 14 or 15 activities permitted in this run due to the setting of NTRIG. (To have a category 14 transportation activity NTRIG would have to be either 4 or 5; to have a category 15 transportation activity NTRIG would have to be 5.) Lines 69 and 70 and 73 and 74 show that each source can ship to two sites. This implies that each source has two activities for each transportation category (i.e., four for category 11, four for category 12, four for category 13). From the previous discussion we know that two sites are MSW receiving so they can also receive source separation residue and source separated paper. Thus there are two residue activities and two paper activities. The SIPROC cards (lines 54 through 58) provide all the information necessary to calculate the number of processing activities. The number of processing activities is simply the number of times a 1 appears in each of the ISPSEG(K) columns. Counting up these cases for the example indicates that nine activities are needed. The marketing activities may be calculated by summing the number of segments (i.e., the value of NSGMK declared on the first market card) across all markets. In this case, there are five marketing activities. Since there are four sites, there are four artificial processing activities used as a control on artifically low processing activities for each site. The A matrix also contains activity NZ as a means of relieving any infeasibilities associated with an advanced starting basis. There is no NZX activity in this example because LOPT is not equal to 4. The results of the column tabulation are summarized in table 5.4, where it can be seen that the A matrix defined by the data in the ACASE file contains 54 columns.

Since the model limits the size of the problem to 90 rows by 360 columns, it is obvious that much larger case studies than defined in the ACASE file can be easily solved. The formula outlined in tables 5.1 through 5.4 should permit users to determine the impact of problem size on their case study. More precisely, if the number of rows or columns is large and computational cost is of importance, trimming down the problem can now be done in an objective manner. First, it should be recognized that reducing the number of rows (constraints) will result in the greatest reduction in computational costs. Second, the three factors which have the greatest impact on the row dimension are: (1) the number of sources; (2) the source separation options; and (3) the output commodities. Thus, any decision to combine sources or model a market via the implicit revenue figure on the SIPROC card may translate into a substantial savings in computer costs. Third, the source separation options

and the processing activities have the greatest impact on the column dimension. Thus, any decision to combine sources or preclude source separation should be column conserving as well as row conserving.

Whenever large amounts of data are collected, collated and input, it is almost inevitable that some errors in recording or entering the data will occur. In order to address these problems, RRPLAN has an elaborate system for edit-checking the values of key input variables. If an error is encountered, then a message is printed out to the user which should help to locate and correct the error. There are three basic types of error messages: (1) general errors; (2) linkage errors; and (3) process-related errors. General errors are the easiest to find and correct. They are associated with input values which are out of range, cards out of sequence, or sums of values that are out of tolerance. They are likely to be due to typographical errors (e.g., incorrect column alignment) or leaving out (or duplicating) a card. The diagnostics produced, the data output and remedies for such errors are summarized in table 5.5.

Linkage errors occur whenever the transportation network is incorrectly specified. These errors are more subtle than general errors. Hence these errors require greater care in locating and correcting. There are nine types of linkage errors, all but two of which produce output data as aids in troubleshooting. The two linkage errors which do not produce output data are: (1) more than 300 transportation activities; or (2) the lack of a market for source separated paper. The first error should not occur if attention is paid to the sizing issue outlined in tables 5.1 through 5.4. The second error can only occur when KSEPO is coded equal to 2 on the third card indicating a local paper market. In the event that the region is served by a local paper market, it will be necessary to define a market which receives source separated paper (commodity category number 3) as its input. Distances from all sources from which pre-separated paper could come should then be recorded in the two distance files. The seven other linkage errors all provide output which should enable the user to locate the file in which the problem is occurring (e.g., ACASE, APKR, or AVAN). The errors can then be located and corrected by following the prescriptions given in table 5.6. Once the error is corrected, the user should perform one additional check. If the error involved one of the cards read on KEY 22, then each of the two distance files should be examined to determine if the linkage defined in the case study file has a distance recorded in each of the distance files.

Process-related errors are due to inconsistencies between two groups of input cards (e.g., sites and processes). For example, if a site listed its input commodity as MSW and a process which received a non-MSW commodity was to be located at the site, an error would result. This is because each site is coded as receiving only one commodity. Methods for finding and correcting the errors are summarized in table 5.7

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Table 5.5   General Errors

| Diagnostic | Data output | Remedy |
|---|---|---|
| VALUE OUT OF RANGE | KEY, card number of sequence, value on card | Consult appendix A for proper range of values for the variable. The KEY and card number should be sufficient to identify on which card the error occurs. Check column alignment. |
| SEQUENCE ERROR | KEY as read, KEY as should be, card number of sequence | Check for missing cards in the previous block of cards. Check the settings on the loop controls given on the first card to see if any are either too low or too high. Check that cards within KEY are in sequence by identification number. |
| ERROR SUM OF FREQUENCIES | Value of sum | Locate negative frequencies as entered on the FREQ cards. All frequencies must be non negative. |
| TOTAL OF WEIGHTS | Value of sum[a] | Make sure all WTCC weights are positive and all WTEC weights are negative. |

[a]Used only if LOPT is equal to 3. Sum of cost weights minus sum of energy weights.

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Table 5.6  Linkage Errors

| Diagnostic | Data output | Remedy |
|---|---|---|
| MORE THAN 300 TRANS ENTRIES | None | Reduce problem size; use tables 5.1 through 5.4. |
| MAJOR RECORD FOR LOCATION CANNOT BE FOUND IN DISTANCE FILE | Location number, file number | Determine if a linkage to or from that location is needed and if so construct a distance table. Check if the destination(s) card shown on table 3.2 is missing. |
| LOCATION CANNOT BE FOUND IN DISTANCE FILE | Destination location<br>Origin location, file number | Determine if a linkage to or from that pair of locations is needed and if so provide an entry in the appropriate file(s). |
| NO MARKET FOR SOURCE SEPARATED PAPER[a] | None | Define a local paper market.[b] |
| TRANS CARD OUT OF SEQUENCE | Card number within those read on KEY 22 | Scan column 4 of the type 22 cards to see where the transportation category type, ITTYP, reverses itself (e.g., goes from 2 to 1). All 1's should proceed all 2's which should proceed all 3's. |
| SOURCE UNLINKED | Source number | Insert the source-to-site linkage card(s) within the ITTYP equal 1 cards read on KEY 22. |
| LOCATION COMMODITY IS NOT LINKED | Location number, commodity number | Check the card type 15s for a process with outputs that is matched to a site at the problem location. One of these output commodities is not being sent to another site or a market. |
| INPUT LINKAGE MISSING FOR SITE | Site number | Insert source-to-site or site-to-site linkage card(s) within either the ITTYP equal 1 or 2 cards read on KEY 22. |
| NO LINKAGE FOR MARKET | Market number | Insert the site-to-market linkage card(s) within the ITTYP equal three cards read on KEY 22. |

[a]Only applies when KSEPO is equal to 2 indicating a local paper market.

[b]The input to a local paper market must be commodity number three.

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Table 5.7  Process-Related Errors

| Diagnostic | Data output | Remedy |
|---|---|---|
| DUPLICATED LANDFILL | Location number | Define a new location number for one of the landfills or delete one landfill card at the location. |
| NO SIPROCS FOR SITE | Site number | Allocate one of the processes to this site. |
| MORE THAN ONE SIPROC FOR SITE WITH EXISTING PROCESS | Site number | Create a new site at the same location or delete extra processes at the site. |
| DUPLICATED SIPROC | Site number, process number | Check site number and process number for an error; one or the other must be changed. |
| NO VALID SEGMENTS ON SIPROC | SIPROC number | Check the values coded into the ISPSEG(K), K=1,2,3, on the SIPROC card against the card 14 value of NSEG for the process considered. |
| LANDFILL REQUIRED AT LOCATION BY SITE | Loction number, site number | Check the values coded into ILACOF on the first process card and ILAND on the site card. If a landfill is necessary, one should be created at the location. |
| INPUT COMMODITY MISMATCH, SIPROC | Input commodity for the site, input commodity for the process. | Either the input commodity for the site or for the process matched up to it on the SIPROC card must be changed. Both commodities must be the same in order for the match to be valid. |

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As an aid in building skills at troubleshooting, readers are encouraged to experiment with the example from chapter 3. A useful strategy might be as follows. First, run the model with all data as shown in chapter 3. Second, make several copies of each of the files for use in subsequent runs. Third, create an error in one of the files (e.g., delete a line, duplicate a line, change the column alignment on a card, exceed the maximum or minimum value, etc.). Fourth, run the model and examine the diagnostics. Fifth, determine what steps you would take to fix the problem based only on the information provided. Would these steps correct the problem? If the answer is no, then it will be necessary to study the relationship between the error you created and the diagnostics produced by the program to determine the source of the difficulty.

## 5.2  CONTROLLING THE STRUCTURE OF THE RUN

Once a baseline case has been established, it becomes necessary for the user to impose a structure on the overall study. The issues dealing with problem structure addressed in this section relate to: (a) the way linkages are specified in a scenario evaluation or for locking in certain sources, sites, or markets; (b) cost accounting for multicommodity SIPROCs or when more than three cost categories are required for a process; (c) modeling a process where decreasing returns to scale have set in; (d) the treatment of large or unusually complex problems; and (e) techniques for performing a sensitivity analysis.

In performing an analysis with lock ins, it is important to recognize that optimizing runs are based on settings of LOPT between 0 and 3. In all cases, the user should be generous with alternative linkages, sites, and processes to assure that the solution has not been predetermined.

The model will perform a scenario evaluation (check feasibility, generate costs and net energies implied by the plan by category and total, and resolve any alternatives given to it) by running the model with LOPT = 4. A scenario is a specified plan, input with alternatives eliminated, or at least seriously reduced, and coded LOPT = 4. If a processing or land capacity or market limit is exceeded, that fact will be noted, together with the percentage of capacity required for that element.

A scenario evaluation can be accomplished through a single run of the model. However, it is useful to compare a feasible specified plan against a model-generated preferred plan. This can be accomplished by running the same scenario in an optimizing mode, but with more alternative sites, processes, and linkages. For this purpose, LOPT = 0 (minimum discounted cost) is recommended as the most appropriate base for comparison.

Difficulties in cost accounting may result due either to multicommodity SIPROCs or when more than three cost categories are required for a process. The same technique may be used to address both problems; it will be illustrated through reference to the issue of cofiring sludge. It is possible to study MSW and sludge in the same run by providing no overlap of linkage. Thus, some source, process, and site numbers can represent MSW and others sludge.

If the cost of a process receiving a mix of MSW and sludge can be represented by a linear function of MSW and sludge inputs, it becomes possible to offer a site for cofiring MSW and sludge within a single optimizing run. The cofiring site requires the use of three sites, processes, and site-processes, all at the same location. One set is to receive MSW, one set is to receive sludge, and the third is to receive an artificial commodity generated by each of the other two. The user can represent the linear cost function, and the various recoverables generated, and energy impacts, through the cost and energy inputs of the three processes, and through the three sets of output coefficients.

In the more likely event that the cost and energy impacts are non-linear functions of the inputs of MSW and sludge, as for example if a fixed mix of the two is required, a different procedure is required. The user can lock in any source to a site by providing only one link from the source -- that to the site of the lock-in. By locking in one or more MSW sources and one or more sludge sources to a single cofiring site, the user can control the mix, and can put in a cost function appropriate to that mix. The remainder of the run can be optimized. By varying the "lock-in" across a sequence of runs, the user can determine the preferred solution among the cofiring plans tested, and can compare that to a solution with no cofiring at all. In this procedure, it is useful to the user that each case, representing a lock-in, is optimized except for the lock-in itself.

The case of non-linear cost/energy functions also illustrates one way to handle the problem of decreasing returns to scale. If decreasing returns to scale have set in, then the user can lock-in certain sources and sites to control the activity level at a SIPROC and input a cost function appropriate to that level. Such a cost function will most likely consist of a single segment with the fixed and variable cost components calibrated for the target activity level. New sources and/or sites can then be locked in or uncoupled in a sequence of runs to determine the preferred solution. As in the cofiring example, the remainder of the run should be optimized.

Another approach to the decreasing returns to scale case which can be fully otpimized is to define three levels of site-processes, initial, intermediate, and final, at the same location. The full normal increasing-returns-to-scale cost functions are entered for a single final-level site-process, uncapacitated, representing the total cost function up to the point of decreasing returns. Incoming transportation links arrive at a single initial-level site-process which is costless and uncapacitated. The initial-level site-process links to each intermediate-level site-process, which in turn links to the final-level site-process. The first intermediate-level site-process is costless, but is capacitated to the point of decreasing returns.

The second intermediate-level site-process has a slope cost equal to the difference between the slope cost after decreasing returns and the last-segment slope cost of the final-level site-process. If the cost after decreasing returns turns upward again, say at scale S, the cost curve can be followed by capacitating the second intermediate-level site-process by the difference between scale S and the point of decreasing returns, and by using a slope cost for the third intermediate site-process equal to the difference between the slope cost after scale S and the last-segment slope cost of the final site-process. As many intermediate-level site-processes may be added as are necessary to follow the cost curve.

The model is designed to study a large range of geography, on the one hand, and detail, on the other. Balancing these is the art of designing a good application. For large geography, gross detail runs, perhaps at state-level, source separation alternatives should be avoided, since they are expensive in matrix size. (A logical region size for a gross detail run would appear to be that defined by a standard metropolitan statistical area (SMSA), since it explicitly includes for economic transactions within the region.) Most of the available matrix size should be used to define sources, and most of the remainder to define sites. One linear segment, or two at most, should be entered on the SIPROC cards (KEY 17) since small scales are unlikely. The dedicated transfer station function will prove most useful for such large geography runs since the selection of a dedicated transfer station has no impact on the size of the matrix at all. Such runs are most useful for defining sub-regions which become candidates in turn for optimizatin using the model at a finer level of detail. In optimizing each sub-region, the geography of the sub-region should be extended so that there is an overlap zone at each regional interface. For these runs, source-separation options are useful, but the dedicated transfer station function becomes less useful, and may be locked out (set IXDED to 1 on the first card). Sources should be defined at a finer level of detail, and a full offering of linear segments on the SIPROC cards should be considered.

Sensitivity analysis is a widely used technique for answering many what-if type questions. If the analysis is done carefully, it may be possible to decompose the plan in such a way that statistical relationships can be estimated. Ideally, these relationships would show for a given change in one or more of the inputs how some variable of interest would be affected. Those readers who wish to attempt such an analysis of the output are encouraged to first carefully postulate from two to six input variables which are of interest and their likely ranges. Values from the range can then be selected in a coordinated manner to develop a basis for the subsequent statistical analysis. It is recommended that users familarize themselves with some elementary topics in the literature on the planning and analysis of comparative experiments prior to atempting such an endeavor.[1]

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[1] An excellent text on the subject is: W.G. Cochran and G.M. Cox, Experimental Designs, (New York: John Wiley and Sons, 1957).

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In most cases, two techniques for testing the sensitivity of the solution to changes in input values through comparison of two or three coordinated runs should be sufficient. First, by running a pair of cases, identical except for the input of interest, the user can measure the full cost and energy impacts of the change in the input of interest by calculating cost and energy differences between the runs. This procedure referred to as the optimization of an input assumes that the information is available in time to optimize to the setting of the input.

Second, running a case for a setting of an input the user may generate a straw-man optimal plan for that setting. Then, by using the scenario evaluation capability of the model (LOPT = 4) the user can measure the cost and energy impact of using the straw-man optimal plan in the face of a different setting of the input of interset. A third run, optimizing to the second setting of the input will provide a basis for the calculation of the cost of optimizing to the wrong setting of the input (cost and energy differences between the second and third runs). This procedure is referred to as the cross optimization of an input.

A what-if question is evaluated through a pair-wise comparison of runs, identical in all respects except for the input representing the what-if question. The cost and energy differences between the runs represent the full impacts of the change in the input, with each case being optimized. These differences are thus a full answer to the what-if question. The what-if question technique can be used to evaluate site issues, transportation issues, source separation issues, market issues, MSW supply, public versus private ownership, as well as planning over time. Each issue will be addressed briefly.

What if a key controversial site were not available? The model is run with and without the site. If the site is not used when offered in the first run, the second run need not be executed. The cost differences between the runs will measure how much it is worth to fight through the political difficulties of the site. By clarifying the economic value of using the site, the analysis might help resolve the political issue.

What if a route is not available for packers? The change in input is a longer distance in the packer distance file for one or more location pairs.

What if a source separation alternative were made available at one or more sources? A run can be performed with the alternative offered. If accepted at any source, a comparison run can be executed with the alternative deleted.

A pair of runs can be executed to test either alternative market values or alternative price distributions. Since these values are subject to great uncertainty, this is an issue which would lend itself well to the cross-optimization technique.

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Alternative assumptions on future MSW supply can be tested by either the optimization to input technique or the cross-optimization technique.

The public versus private ownership issue is represented by differentiated cost functions and by differentiated financial assumptions (interest rate for capitalization and years for capitalization). This is an example of a what-if question that requires the change of several inputs between the comparison pair.

RRPLAN's predecessor, WRAP, was designed with a dynamic mode through which it could generate optimal plans through time in up to four discrete time periods. That capability proved very costly in matrix size, however, so that it could be used only for extremely small sized problems (small in number of sources, sites, processes, linkages, etc.).

A different approach has been used in the design of RRPLAN which permits dynamic planning with no sacrifice of source, site, process, or linkage availability. A specific capability for treating existing plants was built into the costing model of RRPLAN through the use of a remaining life, which is input for each captial cost category. Through this capability RRPLAN can generate dynamic plans through an overlapping comparative static approach.

Each succeeding run would include among its inputs, as existing facilities, all site-processes generated in the previous run, with remaining lifetimes being the remaining life of the previous run minus the time interval between the first years of this and the previous run. Each run should use market prices and costs that are average expected estimates over the time interval from the first year of this run to the first year of the following run. Source tonnages should be the annual tonnage expected over that same interval, but the maximum rather than the average over the period, since it will be necessary to allow for growth of tonnage until the next planning period, signaled by the starting period of the following run. The time interval need not be constant among the various runs in the series. It would be useful to set the first year of a run to coincide with the end of life of a major processing facility.

In order to run the model for an overlapping set of time periods, it is necessary to be able to:

1. Step the first year of the run (IFIRST on card 01) forward through time.
2. Enter as existing sites:
      -all sites that were existing at the start of the set of runs
      -all sites selected in prior runs of the set
   providing such sites have not completed their useful lives.

<u>To step the first year of the run</u> forward to the first year of the current run:

1. Adjust all costs by multiplying by:

$$(1 + .01 DIFLAT(J))^{T-t}$$

where DIFLAT(J) is the differential inflation rate for cost category J,
   T is the first year of the current run, and
   t is the first year of the run set.

2. Enter year T as IFIRST.

3. Enter the number of years for this run as NYR on card 01.

<u>To enter existing sites</u>:

1. Code the process "existing" by setting IEXIS(I) to 1 for the Ith site read on KEY 14.

2. Code the number of processes assigned to the site to 01 (NPROSI(K) on the site card read on KEY 12). (An existing process <u>must</u> be the only process offered at its site.)

3. For capital cost categories corresponding to the site, enter as NREM(J), the years of life remaining for the corresponding capital item. The first estimate of NREM(J) is:

NREM(J) = LIFU(J) - (T -tb)

where LIFU(J) is the useful life of the cost category and tb is the year the plant was built.

If NREM(J) is negative we should assume that the capital will have been replaced at the end of its useful life, and add LIFU(J) to NREM(J) to simulate the years remaining in the second life cycle. This process may be repeated if NREM(J) is still negative.

The costs of overlapping stages cannot be combined in any meaningful way because of the double-counting of overlapped years. If the user wishes to obtain costs for the total period consistent with the decisions reached in the overlapped stages, the stages may be run again, except without overlap, as follows:

1. NYR should be the number of years to the next stage (i.e., no overlap).

2. The plan determined by the corresponding overlapped stage should be entered as a specified plan with LOPT = 4 and with alternatives removed.

3.  Cost and remaining life inputs should be entered as for the overlapped stage.

4.  After running the model for all stages, all discounted costs should be rediscounted to year t, the first year of the first stage:

$$C_t = C(1 + .01 DISCO)^{t-T}$$

where DISCO is the discount rate as a percent,
        C is the discounted cost output by the model, discounted to year T, and
        $C_t$ is the corresponding rediscounted cost, discounted to year t where T and t are as previously defined.

In this form, all lifetime discounted costs may be aggregated, by total and by cost category and cost summation category. Lifetime undiscounted costs may be aggregated without any corresponding adjustment.

5.  Costs per year and costs per ton should be interpreted as average costs per year and per ton over the years of the stage. This applies also for net energy.

6.  Lifetime energy may be aggregated following the rules of undiscounted cost.

In using RRPLAN, it is crucial that the results of each run are carefully critiqued. Each solution, or set of solutions, should be viewed critically; users should attempt to probe into their results, looking beyond the numbers for implications. At a minimum, the following three questions should be considered. Are the answers meaningful? Are all implicit objectives satisfied? Have new problems (or opportunities) been identified? If one carefully plans the analysis, he should both be able to identify areas where the biggest payoffs are likely to occur as well as gain intuition on what will happen if one of the basic assumptions changes.

APPENDIX A  GLOSSARY OF INPUT VARIABLES

This appendix is designed to give the model user an in-depth summary of all
input terms.  The description goes beyond that given in chapter 3 because
array dimensions are defined and, where applicable, references are made to the
effects caused by variable settings in other parts of the input deck.  The
glossary is arranged in alphabetical order by variable name.  In all but a few
cases, a mnemonic, which should help the user associate the variable with its
purpose, is given.  The key letters in the related name are capitalized and
underlined.  The specification declared in the FORMAT statement through which
the variable is read in is then given.  The read KEY, card type, and first
column on the card available for this variable follow immediately.  If the
variable has a range, the range is given.  Each variable is then cross
referenced to a worksheet and a specific question.  The variable is then
defined; and additional information is also noted at that time.

With regard to the worksheet-question responses in the glossary, there are
three cases which serve as exceptions.  The first relates to the location
number.  The question on the worksheet refers to the location as a street
address or intersection.  Once all worksheets have been filled out, each
address or intersection is assigned a number.  It is this number which is used
for all distance calculations.  If the term Note A is used, it is an
indication that the user must assign the location number and construct the
distance table from the data on the worksheets.  The second exception relates
to the end points of do loops.  This case is designated by Note B.  Variables
falling into this category correspond to counts on the number of times a
particular worksheet was filled out.  Each of the variables in this category
also serve to define an end point for a sequence of sources, sites, markets,
etc.  Therefore, when the worksheets are counted, they should also be assigned
a sequence number.  The third exception relates to run controls addressed in
chapter 5.  This case is designated by Note C.  Six other variables are also
grouped into this category.  They are:  the distance file format control, ISQR
(see section 3.3); the dedicated transfer station control, IXDED (see section
2.2); and the four fixed and variable cost drivers, IFDRV, IVDRV, FDRIV, VDRIV
(see section 5.1).

In the discussion which follows, it is sometimes necessary to refer to a
specific element within an array.  So that this may be done efficiently, a
labeling convention has been adopted and is used throughout the appendix.  If
the array is one-dimensional, the index is listed as K (i.e., ARRAY(K)).  If
the array is two-dimensional, the indices are J and K, respectively (i.e.,
ARRAY(J,K)).  If the array is three-dimensional, the indices are I, J and K,
respectively (i.e., ARRAY(I,J,K)).

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ALLO                     Mnemonic:  ALLOcation
                         Specification:  F4.3    Key: 3         First Column:  73
                         Minimum:  0.0         Maximum:   1.0
                         Worksheet:  I         Question:  9.c
                         Definition:  Allocation of paper processing cost to actual
                         paper processed as waste (ALLO) versus potential paper
                         processed as waste (1-ALLO).


AREAD(5)                 Specification:  F6.2
                         Worksheet:  Note A
                         Definition:  The Kth distance on the card read in either the
                         packer or van distance file.


ATRIG(5)                 Mnemonic:  Average TRIGger price
                         Specification: F5.2     Key: 6         First Column: 52
                         Minimum: ATRIG(K-1) + 0.0001(ATRIG(K)) K>1
                         Worksheet:  II         Question:  4.a
                         Definition:  Average price of paper sold in the market for
                         the Kth trigger price.


AVLA(30)                 Mnemonic:  AVailable LAnd
                         Specification: F10.3    Key: 13        First Column: 29
                         Minimum: 0.001
                         Worksheet:  VIII       Question:  3
                         Definition:  Land available at the Kth landfill.


BDMKA(5,30)              Mnemonic:  BounD MArKet
                         Specification:  F7.2    Key: 19        First Column: 3
                         Minimum: BDMKA(J-1,K) + 0.0001(BDMKA(J,K))
                         Worksheet:  XI         Question:  2.a
                         Definition:  Bound for the Jth segment of the Kth market.


BOTTOM                   Mnemonic: BOTTOM price
                         Specification: F5.2
                         Worksheet:  II         Question:  2.a
                         Definition:  Lower limit of first (lowest price) interval in
                         dollars per ton in the paper market price distribution.


BTMSW                    Mnemonic: BTu content of MSW
                         Specification: F10.5    Key: 5         First Column: 39
                         Minimum: 0.05
                         Worksheet:  I          Question:  5.a
                         Definition:  Millions of BTUs per ton of MSW.

BTPAP

Mnemonic: BTu content of PAPer
Specification: F6.3    Key: 3    First Column: 29
Minimum:  0.0
Worksheet:  I    Question:  5.b
Definition:  Millions of BTUs per ton of source separated
paper when processed as solid waste.

BTRES

Mnemonic: BTu content of source separation RESidue
Specification: F6.3    Key: 3    First Column: 23
Minimum:  0.0
Worksheet:  I    Question:  5.c
Definition:  Millions of BTUs per ton of source separation
residue.

BTRIG(5)

Mnemonic:  percent Burn by TRIGger price
Specification: F4.1    Key: 6    First Column: 32
Minimum:  BTRIG(K-1) + 0.0001(BTRIG(K))  K>1
Worksheet:  II    Question:  4.b
Definition:  Percent of source separated paper burned for
the Kth trigger price.

CAPSP(80)

Mnemonic:  CAPacity for a Site-Process
Specification: F9.3    Key: 17    First Column: 12
Minimum: 0.0001 if the site is coded as capacitated
Worksheet:  X    Question:  3
Definition:  Capacity the process at the site under
consideration assuming the process is the only one at that
site.

CCOCC(2,20)

Mnemonic:  haul Cost-COmmodity-Cost Category
Specification: F8.3    Key: 10    First Column: 30
Minimum: 0.00001 if J=1 Maximum:  1000.0
Worksheet:  V    Question:  2.
Definition:  The Jth haul cost factor for the Kth commodity
category (CCOCC(J,K)).

CCOEC(2,20)

Mnemonic:  haul Cost-COmmodity-Energy Category
Specification: F8.3    Key: 10    First Column: 50
Worksheet:  V    Question:  3
Definition:  The Jth haul cost factor for the Kth energy
commodity (CCOEC(J,K)).

CCPREP(50)

Mnemonic:  Constant Cost for Site PREParation
Specification: F10.3    Key: 12    First Column: 44
Worksheet:  VII    Question:  5.b
Definition:  Site preparation cost for the Kth site in
thousands of dollars.

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CEPREP(50)          Mnemonic:  Constant Energy for site PREParation
                    Specification:  F10.3    Key: 12          First Column:  56
                    Worksheet:  VII          Question:  5.d
                    Definition:  Site preparation energy requirement for the Kth
                    site in full energy units.

CFMKA(5,30)         Mnemonic:  CoeFficient MarKet A
                    Specification:  F7.3    Key: 20          First Column:  3
                    Minimum: 0.0             Maximum: CFMKA(J-1,K)
                    Worksheet:  XI           Question:  4.d
                    Definition:  Jth revenue coefficient for the Kth market
                    (slope of the total revenue function for the Jth segment)
                    for the first cost category.

CFMKB(5,30)         Mnemonic:  CoeFficient MarKet B
                    Specification:  F7.3    Key: 20          First Column:  38
                    Minimum: 0.0             Maximum: CFMKB(J-1,K)
                    Worksheet:  XI           Question:  4.d
                    Definition:  Jth revenue coefficient for the Kth market
                    (slope of the total revenue function for the Jth segment)
                    for the second cost category.

CHCA(60)            Mnemonic:  Cost for Hauling CAns
                    Specification:  F5.2    Key: 11          First Column:  64
                    Worksheet:  VI           Question:  6.e
                    Definition:  Cost per ton to haul cans from source K to the
                    market.

CHGL(60)            Mnemonic:  Cost for Hauling GLass
                    Specification:  F5.2    Key: 11          First Column:  59
                    Worksheet:  VI           Question:  6.d
                    Definition:  Cost per ton to haul glass from source K to the
                    market.

CHPA(60)            Mnemonic:  Cost for Hauling PAper
                    Specification:  F5.2    Key: 11          First Column:  54
                    Worksheet:  VI           Question:  6.c
                    Definition:  Cost per ton to haul paper from source K to the
                    market.

CINT(30,3,2)        Mnemonic:  Cost INTercept
                    Specification:  F9.2    Key: 16          First Column:  8
                    Worksheet:  IX           Question:  6.c
                    Definition:  Intercept (fixed charge) cost in thousands of
                    dollars for the Ith process, Jth segment, Kth cost type.

COF(7,30)          Mnemonic:  output COeFficient
                   Specification:  F8.5     Key: 15        First Column:  10
                   Worksheet:  IX          Question:  5
                   Definition:  The Jth output coefficient (output per unit of
                   incoming commodity) for the Kth process.

CSLO(30,3,2)       Mnemonic:  Cost SLOpe
                   Specification:  F9.6     Key: 16        First Column:  44
                   Worksheet:  IX          Question:  6.c
                   Definition:  Slope (variable cost in dollars per ton) for
                   the Ith process, Jth segment, Kth cost type.

CSPA               Mnemonic:  Cost SeParation A
                   Specification:  F5.3     Key: 3         First Column:  49
                   Minimum:  0.0            Maximum:  1000.0
                   Worksheet:  I           Question:  8.a
                   Definition:  Total cost of collection in dollars per ton of
                   unseparated MSW.

CSPB               Mnemonic:  Cost SeParation B
                   Specification:  F5.3     Key: 3         First Column:  56
                   Minimum:  0.0            Maximum:  1000.0
                   Worksheet:  I           Question:  8.b
                   Definition:  Incremental cost of source separation in
                   dollars per preseparated ton.

DIFLAT(50)         Mnemonic:  DIfferential inFLATion
                   Specification:  F5.3     Key: 8         First Column:  39
                   Worksheet:  III         Question:  4
                   Definition:  Differential annual inflation rate in percent
                   for the Kth cost category.

DISCO              Mnemonic:  DISCOunt rate
                   Specification:  F8.4     Key: 1         First Column:  19
                   Minimum:  0.0            Maximum:  50.0
                   Worksheet:  I           Question:  2
                   Definition:  Annual discount rate in percent.

ECANM              Mnemonic:  Energy value of CANs at the Market
                   Specification:  F10.5    Key: 5         First Column:  27
                   Worksheet:  I           Question:  10.c
                   Definition:  Energy value of cans per ton in the market when
                   delivered there.

ECMK(2,30)         Mnemonic:  Energy Coefficient MarKet
                   Specification:  F10.5    Key: 18        First Column:  55
                   Worksheet:  XI          Question:  5
                   Definition:  Jth energy market value per ton when marketed
                   in the Kth market.

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EGLAM                   Mnemonic:  Energy value of GLAss at the Market
                        Specification: F10.5    Key: 5        First Column: 15
                        Worksheet:  I           Question:   10.b
                        Definition:  Energy value of glass per ton in the market
                        when delivered there.

EINT(30,3,2)            Mnemonic:  Energy INTercept
                        Specification: F9.2     Key: 16       First Column: 26
                        Worksheet:  IX          Question:   7.b
                        Definition:  Intercept energy in full energy units for the
                        Ith process, Jth segment, Kth energy type.

EPAPM                   Mnemonic:  Energy value of PAPer at the Market
                        Specification: F10.5    Key: 5        First Column: 3
                        Worksheet:  I           Question:   10.a
                        Definition:  Energy value of paper per ton in the market
                        when delivered there.

EREVSP(80)              Mnemonic:  Energy REVenue Site-Process
                        Specification: F10.5    Key: 17       First Column: 41
                        Worksheet:  X           Question:   5.d
                        Definition:  Energy value of recoverables not entered into
                        the commodity file (implicit revenues) net of energy
                        requirement of haul to the market.  In the back end,
                        EREVSP(K) is redefined as the total implicit revenue per
                        average year for the Kth SIPROC in undiscounted cost.

ESLO(30,3,2)            Mnemonic:  Energy SLOpe
                        Specification: F9.6     Key: 16       First Column: 62
                        Worksheet:  IX          Question:   7.b
                        Definition:  Energy slope for the Ith process, Jth segment,
                        Kth energy type.

ESPA                    Mnemonic:  Energy SeParation A
                        Specification: F10.3    Key: 4        First Column: 6
                        Worksheet:  I           Question:   11.a
                        Definition:  Net energy requirement for collection of
                        unseparated waste per ton.

ESPB                    Mnemonic:  Energy SeParation B
                        Specification: F10.3    Key: 4        First Column: 18
                        Worksheet:  I           Question:   11.b
                        Definition:  Net incremental energy requirement for source
                        separation per ton of preseparated waste.

FDRIV                   Mnemonic:  Fixed and DRIVer
                        Specification: F5.2     Key: 5        First Column: 53
                        Worksheet:   Note C
                        Definition:  Fixed cost value used for driving into the
                        solution an activity not in the solution when either site or
                        site-process forcing is used.

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FLATO
Mnemonic:   inFLATiOn rate
Specification:  F8.4    Key: 1        First Column:   31
Minimum: 0.0           Maximum: 50.0
Worksheet:   I         Question:   3
Definition:  General annual inflation rate in percent.

FREQ(200)
Mnemonic:   FREQuency
Specification:  F5.3                 First Column:   1
Worksheet:   II        Question:   3
Definition:  The Kth frequency; frequency for the Kth
interval in the paper market price distribution function.

IBTU
Mnemonic:  Identity BTU
Specification: I2      Key: 5         First Column:   37
Worksheet:   I         Question:   13.d
Definition:  Energy category for BTU differentiation among
MSW, paper and source separation residue.

ICANM
Mnemonic:   Identity CANs Market
Specification: I2      Key: 5         First Column:   37
Worksheet:   I         Question:   13.c
Definition:  Energy category for cans in the market.

ICAP(50)
Mnemonic:   Identity CAPacity
Specification: I1      Key: 12        First Column:   37
Worksheet:   VII       Question:   6.a
Definition: Capacity code for the Kth site:  0 if the site
is uncapacitated; 1 if the site is capacitated.

ICC(50)
Mnemonic:  Identity Cost Category
Specification: I2      Key: 8         First Column:   5
Worksheet:   III       Question:   1.b
Definition:  Identification number of the Kth cost
category.

ICCCAN
Mnemonic:  Identity Cost Category CANs
Specification: I2      Key: 3         First Column:   47
Worksheet:   I         Question:   14.c
Definition:  Cost category number for cans in the market.

ICCGLA
Mnemonic:  Identity Cost Category GLAss
Specification: I2      Key: 3         First Column:   45
Worksheet:   I         Question:   14.b
Definition:  Cost category number for glass in the market.

ICCMK(2,30)
Mnemonic:  Identity Cost Category MarKet
Specification: I2      Key: 18        First Column:   46
Worksheet:   XI        Question:   4
Definition:  Jth cost (i.e., revenue) for the Kth market.

ICCPAP          Mnemonic:  Identity Cost Category PAPer
                Specification: I2        Key: 3          First Column:  67
                Worksheet:    I          Question:   14.a
                Definition:  Cost category number for national paper market.
                Not used for explicit paper markets under KSEPO = 2.

ICCS(10,10)     Mnemonic:  Identity Cost Category Summation
                Specification: I2        Key: 21         First Column:  32
                Worksheet:    XII        Question:   2
                Definition:  The identity of the Jth cost category in the
                Kth cost summation.

ICO(20)         Mnemonic:  Identity COmmodity
                Specification: I2        Key: 10         First Column:  5
                Worksheet:    V          Question:   1.b
                Definition:  Identification number for the Kth commodity.

ICOCC(2,20)     Mnemonic:  Identity COmmodity Cost Category
                Specification: I2        Key: 10         First Column:  28
                Worksheet:    V          Question:   2
                Definition:  Cost category for the Jth haul cost factor for
                the Kth commodity.

ICOEC(2,20)     Mnemonic:  Identity COmmodity Energy Category
                Specification: I2        Key: 10         First Column:  48
                Worksheet:    V          Question:   3
                Definition:  Energy category for the Jth energy level factor
                for the Kth commodity.

ICOF(7,30)      Mnemonic:  Identity COeFficient
                Specification: I2        Key: 15         First Column:  8
                Worksheet:    IX         Question:   5
                Definition:  The commodity category number for the Jth
                coefficient of the Kth process.

ICOMK(30)       Mnemonic:  Identity COmmodity MarKet
                Specification: I2        Key: 18         First Column:  34
                Worksheet:    XI         Question:   3
                Definition:  The commodity category number for the Kth
                market.

ICPR(30,2)      Mnemonic:  Identity Cost PRocess
                Specification: I2        Key: 14         First Column:  44
                Worksheet:    IX         Question:   6
                Definition:  The Kth cost category for the Jth process.

ICPREP(50)      Mnemonic:  Identity Cost site PREParation
                Specification: I2        Key: 12         First Column:  42
                Worksheet:    VII        Question:   5.a
                Definition:  The cost category number for the Kth site's
                preparation costs.

ICS(10)                  Mnemonic:  Identity Cost Summation
                         Specification: I2      Key: 21      First Column:  5
                         Worksheet:   XII        Question:  1.b
                         Definition:  Identification number of the Kth cost summation
                         category.

IDCC(50)                 Mnemonic:  IDentity code Capital Cost
                         Specification: I2      Key: 21      First Column:  5
                         Worksheet:   III        Question:  2
                         Definition:  Cost type code:  0 is operating cost; 1 is
                         capital cost.

IEC(20)                  Mnemonic:  Identity Energy Category
                         Specification: I2      Key: 9       First Column:  5
                         Worksheet:   IV         Question:  1.b
                         Definition:  The identification number of the Kth energy
                         category.

IECMK(2,30)              Mnemonic:  Identity Energy Category MarKet
                         Specification: I2      Key: 18      First Column:  38
                         Worksheet:   XI         Question:  5
                         Definition:  The identification number of the Jth energy
                         category for the Kth market.

IEPR(30,2)               Mnemonic:  Identity Energy PRocess
                         Specification: I2      Key: 14      First Column:  48
                         Worksheet:   IX         Question:  7
                         Definition:  The identification number of the Kth energy
                         category for the Jth process.

IEPREP(50)               Mnemonic:  Identity Energy PREParation
                         Specification: I2      Key: 12      First Column:  54
                         Worksheet:   VII        Question:  5.c
                         Definition:  The energy category number for the Kth site's
                         preparation energy.

IEXIS(30)                Mnemonic:  Identity EXIStence
                         Specification: I1      Key: 14      First Column:  31
                         Worksheet:   IX         Question:  3
                         Definition:  Existing process code:  0 is new; 1 is
                         existing.

IFDRV                    Mnemonic:  Identity Fixed cost DRiVer
                         Specification: I1      Key: 5       First Column:  52
                         Worksheet:   Note C
                         Definition:  Driver control for fixed costs.  If 0, fixed
                         costs will be set to zero to "urge in" an activity in site
                         and site-process forcing; if 1, FDR1V will be used as the
                         fixed cost to "urge in" during site and site-process
                         forcing.

IFIRST
Mnemonic:  Identity FIRST year
Specification: I4        Key: 1        First Column:   15
Worksheet:   I          Question:   1.a
Definition:  The identity of the first year in the run.

IGLAM
Mnemonic:  Identity GLAss Market
Specification: I2        Key: 5        First Column:   25
Worksheet:   I          Question:   13.b
Definition:  The energy category number for glass when
delivered to the market.

IHCSEP(60)
Mnemonic:  Identity Haul Cost SEParation
Specification: I2        Key: 11       First Column:   50
Worksheet:   VI         Question:   6.a
Definition:  The cost category number for haul of paper,
glass and cans to the market for the Kth source.

IHESEP(60)
Mnemonic:  Identity Haul Energy SEParation
Specification: I2        Key: 11       First Column:   52
Worksheet:   VI         Question:   6.b
Definition:  The energy category number for haul of paper,
glass and cans to the market for the Kth source.

ILACOF(30)
Mnemonic:  Identity code LAnd COeFficient
Specification: I1        Key: 14       First Column:   34
Worksheet:   IX         Question:   9
Definition:  Landfill coefficient code:  0 if process does
not use on-site landfill; 1 if it does.

ILAND(50)
Mnemonic:  Identity code LAND
Specification: I1        Key: 12       First Column:   38
Worksheet:   VII        Question:   6.b
Definition:  Landfill code:  0 if no landfill is available
at the Kth site; 1 if a landfill is available.

IMIXSU(60)
Mnemonic:  Identity MIXed msw SoUrce
Specification: I1        Key: 11       First Column:   43
Worksheet:   VI         Question:   5.a
Definition:  Code for MSW option (no source separation) at
source K:  if 0, option is not offered; if 1 option is.

IMK(30)
Mnemonic:  Identity MarKet
Specification: I2        Key: 18       First Column:   5
Worksheet:   XI         Question:   1.b
Definition:  Identification number of Kth market.

INCO(50)
Mnemonic:  INput COmmodity
Specification: I2        Key: 12       First Column:   34
Worksheet:   VII        Question:   4
Definition:  The commodity number of the input to the Kth
site.

INCOP(30)    Mnemonic: INput COmmodity Process
        Specification: I2  Key: 14  First Column: 29
        Worksheet: IX  Question: 2
        Definition: The commodity number of the input to the Kth
        process.

INPAP      Mnemonic: INput mode for PAPer
        Specification: I1  Key: 3  First Column: 66
        Worksheet: II  Question: 4
        Definition: Input mode for paper price distribution: if 0,
        input trigger prices, percents of burn, and average prices;
        if 1, input trigger prices and a paper market price
        distribution function.

IPAPM      Mnemonic: Identity PAPer Market
        Specification: I2  Key: 5  First Column: 13
        Worksheet: I  Question: 13.a
        Definition: The energy category for paper in the market.

IPR(30)     Mnemonic: Identity PRocess
        Specification: I2  Key: 14  First Column: 5
        Worksheet: IX  Question: 1.b
        Definition: The identification number of the Kth process.

IREAD(5)    Mnemonic: Identity READ
        Specification: I3
        Worksheet: Note A
        Definition: The Kth minor location number on a card.

IREVSP(80)   Mnemonic: Identity REVenue Site-Process
        Specification: I2  Key: 17  First Column: 36
        Worksheet: X  Question: 5.a
        Definition: The cost category number for accumulating
        implicit revenues associated with the Kth site-process
        combination.

ISEPSU(60)   Mnemonic: Identity SEParation SoUrce
        Specification: I1  Key: 11  First Column: 44
        Worksheet: VI  Question: 5.b
        Definition: Code for unconditional source separation at
        source K: if 0, option is not offered; if 1 or 2, national
        or local paper option as defined by KSEPO is offered.

ISI(50)     Mnemonic: Identity SIte
        Specification: I2  Key: 12  First Column: 5
        Worksheet: VII  Question: 1.b
        Definition: Identification number of the Kth site.

ISIREQ(50)          Mnemonic:  Identity SIte REQuest
                    Specification: I1      Key: 12      First Column:   3
                    Worksheet:   VII       Question:   2
                    Definition:  Site routing request code:  if 0, routing not
                    requested; if greater than zero, ISIREQ(K) levels of routing
                    are requested for site K, if site K is in the solution.

ISPA                Mnemonic:  Identity SeParation A
                    Specification: I2      Key: 3      First Column:   54
                    Worksheet:   I        Question:   14.d
                    Definition:  Cost category number for total cost of
                    collection, CSPA.

ISPB                Mnemonic:  Identity SeParation B
                    Specification: I1      Key: 3      First Column:   61
                    Worksheet:   I        Question:   14.e
                    Definition:  Cost category number for incremental cost of
                    source separation, CSPB.

ISPPR(80)           Mnemonic:  Identity Site-Process, PRocess
                    Specification: I2      Key: 17      First Column:   9
                    Worksheet:   X        Question:   2.b
                    Definition:  The process number of the Kth site-process
                    combination.

ISPSEG(80,3)        Mnemonic:  Identity Site-Process, SEGment
                    Specification: I1      Key: 17      First Column:   32
                    Worksheet:   X        Question:   4
                    Definition:  Kth linear segment code for the Jth site- or
                    process combination:  if 0, the segment is not offered; if
                    1, the segment is offered.

ISPSI(80)           Mnemonic:  Identity Site-Process, SIte
                    Specification: I2      Key: 17      First Column:   5
                    Worksheet:   X        Question:   1.b
                    Definition:  The site number of the Kth site-process
                    combination.

ISQR                Mnemonic:  Identity SQuaRe
                    Specification: I1      Key: 1      First Column:   27
                    Worksheet:   Note C
                    Definition:  Distance file format control:  if 0, model is
                    prepared for a triangular distance file; if 1, model is
                    prepared for a square distance file.  The file is read major
                    record, minor record, distance.  In a triangular file, the
                    major record is the higher numbered location and the minor
                    record is the lower numbered location.  In a square file,
                    the major record is the destination location number and the
                    minor record is the origin location number.

ISU(60)            Mnemonic:  Identity SoUrce
                   Specification: I2      Key: 11       First Column:   5
                   Worksheet:   VI        Question:   1.b
                   Definition:  The identification number of the Kth source.

ISUREQ(60)         Mnemonic:  Identity SoUrce REQuest
                   Specification: I1      Key: 11       First Column:   3
                   Worksheet:   VI        Question:   2
                   Definition:  Source routing request code:  if 0, routing is
                   not requested; if greater than zero, ISUREQ(K) levels of
                   routing are requested for source K, if source K is in the
                   solution.

ITRCO(600)         Mnemonic:  Identity TRansportation COmmodity
                   Specification: I2      Key: 22       First Column:   7
                   Worksheet:   XIII
                   Definition:  Transportation source/commodity code; Kth
                   transportation activity:  if source-origin, categories
                   1,4,5,6,8,9,11-15, source number; if site-origin, categories
                   2 and 3, commodity number.

ITRIGS(5,60)       Mnemonic:  Identity TRIGger Source
                   Specification: I1      Key: 11       First Column:   45
                   Worksheet:   VI        Question:   5.c
                   Definition:  Source separation option code for the Jth
                   trigger price at the Kth source:  if 0, option is not
                   offered; if 1 option is offered.

ITROG(600)         Mnemonic:  Identity TRansportation OriGin
                   Specification: I3      Key: 22       First Column:   10
                   Worksheet:   XIII
                   Definition:  The origin location number of the Kth
                   transportation activity.

ITRSM(600)         Mnemonic:  Identity TRansportation Site/Market
                   Specification: I2      Key: 22       First Column:   15
                   Worksheet:   XIII
                   Definition:  Offload identification of the Kth
                   transportation activity:  if category 3 or 9, ITRSM(K) is
                   market number; otherwise ITRSM(K) is site number.

ITTYP(600)         Mnemonic:  Identity Transportation TYPe
                   Specification: I1      Key: 22       First Column:   4
                   Worksheet:   XIII
                   Definition:  Category type code for the Kth transportation
                   activity:  if 1, ITTYP(K) is source-to-site; if 2, ITTYP(K)
                   is site-to-site; if 3, ITTYP(K) is site-to-market.

IVDRV      Mnemonic: Identity Variable cost DRiVer
Specification: I1   Key: 5   First Column: 58
Worksheet: Note C
Definition: Driver control for variable cost: if 0,
internally set figure is used in "urging in"; if 1, VDRIV
is used.

IXDED      Mnemonic: Identity eXclusion for DEDicated transfer
Specification: I1   Key: 1   First Column: 28
Worksheet: Note C
Definition: Dedicated transfer station control; if 0,
normal dedicated transfer station procedure operates; if 1,
dedicated transfer station procedure is suppressed.

KEMP       Specification: I2
KEY(1): 15     First Column: 5
KEY(2): 16     First Column: 5
Definition(1): Process number.
KEY(3): 19     First Column: 75
KEY(4): 20     First Column: 75
Definition(2): Market number.

KEY       Specification: I2
Definition: Card type control: appears in columns 1 and 2
of all numbered cards.

KFOUT      Mnemonic: Kontrol Forcing OUT
Specification: I1   Key: 1   First Column: 29
Worksheet: Note C
Definition: Control for forcing out only in site and
site-process forcing: if 0 through 8, procedure includes
forcing in and forcing out; if 9, procedure uses forcing out
only.

KITLE      Mnemonic: Kontrol tITLE
Specification: 19A4  Key: 2   First Column: 3
Definition: 76 alphanumeric digits for name of run.

KMIX       Mnemonic: Kontrol MIX
Specification: I1   Key: 3   First Column: 63
Worksheet: I    Question: 6.a
Definition: Run control for availability of unconditional
MSW as an option: if 0, option is not available; if 1 it
is.

KOPT       Mnemonic: Kontrol OPTion
Specification: I1   Key: 1   First Column: 7
Worksheet: Note C
Definition: Output control for the optimizer: 1 is full
output; 2 is matrix summary and final solution; 3 is matrix
summary and solution of phase 3 and 4, if phase 4 is
requested.

KOVER

Mnemonic:  Kontrol OVERride
Specification: I2        Key: 1        First Column:    5
Worksheet:    Note C
Definition:  Control for site and site-process forcing and
orverride of row/column limit control for double-forcing, as
in NFORC = 2.  If 0, a phase 3 or phase 4 solution will be
generated, according to the setting of LPHASE.  If 1, site
forcing will be undertaken, LPHASE will be reset to 3.  If
2, site-process forcing will be undertaken, LPHASE will be
reset to 3.  If 2, site-process forcing will be undertaken,
LPHASE will be reset to 3.  If 99, the NFORC = 2 matrix size
limit of 50 rows and 100 columns is overridden, to become 90
rows and 360 columns.  Any other value of KOVER is reset to
0.

KREVSP(80)

Mnemonic:  Kategory REVenue Site-Process
Specification: I2        Key: 17        First Column:   39
Worksheet:    X          Question:    5.c
Definition:  Energy category for EREVSP(K), the net energy
value of any implicit revenues associated with the Kth
site-process combination.

KSEPO

Mnemonic:  Kontrol SEParatiOn
Specification: I1        Key: 3        First Column:   64
Worksheet:    I          Question:    6.b
Definition:  Run control for availability of unconditional
source separation:  if 0, option is not available, if 1,
available with national paper market; if 2, available with
local paper market.

KSPA

Mnemonic:  Kode SEParation A
Specification: I2        Key: 4        First Column:    4
Worksheet:    I          Question:    13.e
Definition:  Energy category for collection of unseparated
waste.

KSPB

Mnemonic:  Kode SeParation B
Specification: I2        Key: 4        First Column:   16
Worksheet:    I          Question:    13.f
Definition:  Energy category for incremental energy
requirement due to source separation.

KSUPP

Mnemonic:  Kontrol SUPPression
Specification: I1        Key: 1        First Column:   30
Worksheet:    Note C
Definition:  Control for suppression of intermediate
information on search for an initial feasible solution:  if
0, information is suppressed; if 1, information is
provided.

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LEMP                 Specification: I1        Key: 16        First Column:    7
                     Worksheet:    IX         Question:  6.c
                     Definition:   Segment number for the subject process.

LIFC(50)             Mnemonic:  LIFe Capitalization
                     Specification: I3        Key: 8         First Column:    49
                     Worksheet:    III        Question:  5.b
                     Definition:   Years for capitalization of the loan for the
                     Kth cost category.

LIFU(50)             Mnemonic:  LIFe Useful
                     Specification: I3        Key: 8         First Column:    45
                     Worksheet:    III        Question:  5.a
                     Definition:   Years of useful life for the Kth cost
                     category.

LITLE(20)            Mnemonic:  List tITLE for distances
                     Specification: 20A4
                     Worksheet:    Note A
                     Definition:   80 alphanumeric digits available for naming the
                     distance files.

LLA(30)              Mnemonic:  Location LAndfill
                     Specification: I3        Key: 13        First Column:    4
                     Worksheet:    Note A
                     Definition:   Location number of the Kth landfill.

LMK(30)              Mnemonic:  Location MarKet
                     Specification: I3        Key: 18        First Column:    29
                     Worksheet:    Note A
                     Definition:   Location number of the Kth market.

LOPT                 Mnemonic:  Logic OPTimization
                     Specification: I1        Key: 1         First Column:    8
                     Worksheet:    Note C
                     Definition:   Optimization mode control:  if 0, minimum
                     discounted cost; if 1, minimum undiscounted cost, if 2,
                     maximum net energy; if 3, minimum linear form; if 4,
                     feasibility test of a specified plan.

LPHASE               Mnemonic:  Last PHASE
                     Specification: I1        Key: 1         First Column:    3
                     Worksheet:    Note C
                     Definition:   Last phase control:  if not 4, last phase is 3
                     (optimization with fixed costs, but without forcing); if 4,
                     last phase is 4 (column forcing, in accordance with setting
                     of NFORC).

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LSI(50)            Mnemonic:  Location SIte
                   Specification: I3      Key: 12        First Column:  29
                   Worksheet:    Note A
                   Definition:  Location number of the Kth site.

LSTLO              Mnemonic:  LaST LOcation
                   Specification: I3      Key: 1         First Column:  64
                   Worksheet:    Note A
                   Definition:  Last location in distance file.  Edit checked
                   against location numbers in input deck, but not against
                   distance file.

LSU(60)            Mnemonic:  Location SoUrce
                   Specification: I3      Key: 11        First Column:  29
                   Worksheet:    Note A
                   Definition:  Location number of Kth source.

NAMCC(50,5)        Mnemonic: ` NAMe of Cost Category
                   Specification: 5A4      Key: 8         First Column:  8
                   Worksheet:    III       Question:  1.a
                   Definition:  20 alphanumeric digits for the name of the Jth
                   cost category.

NAMCO(20,5)        Mnemonic:  NAMe of COmmodity
                   Specification: 5A4      Key: 10        First Column:  8
                   Worksheet:    V         Question:  1.a
                   Definition:  20 alphanumeric digits for the name of the Jth
                   commodity.

NAMCS(10,5)        Mnemonic:  NAMe of Cost Summation
                   Specification: 5A4      Key: 21        First Column:  8
                   Worksheet:    XII       Question:  1.a
                   Definition:  20 alphanumeric digits for the name of the Jth
                   cost summation category.

NAMEC(20,5)        Mnemonic:  NAMe of Energy Category
                   Specification: 5A4      Key: 9         First Column:  8
                   Worksheet:    IV        Question:  1.a
                   Definition:  20 alphanumeric digits for the name of the Jth
                   energy category.

NAMLA(30,5)        Mnemonic:  NAMe of LAndfill
                   Specification: 5A4      Key: 13        First Column:  8
                   Worksheet:    VIII      Question:  1.a
                   Definition:  20 alphanumeric digits for the name of the Jth
                   landfill.

NAMMK(30,5)        Mnemonic:  NAMe of MarKet
                   Specification: 5A4      Key: 18        First Column:  8
                   Worksheet:    XI        Question:  1.a
                   Definition:  20 alphanumeric digits for the name of the Jth
                   market.

NAMPR(30,5)          Mnemonic:  <u>NAM</u>e of <u>PR</u>ocess
                     Specification: 50A4      Key: 14        First Column:    8
                     Worksheet:    IX         Question:    1.a
                     Definition:  20 alphanumeric digits for the name of the Jth
                     process.

NAMSI(50,5)          Mnemonic:  <u>NAM</u>e of <u>SI</u>te
                     Specification: 5A4       Key: 12        First Column:    8
                     Worksheet:    VII        Question:    1.a
                     Definition:  20 alphanumeric digits for the name of the Jth
                     site.

NAMSU(60,5)          Mnemonic:  <u>NAM</u>e of <u>SoU</u>rce
                     Specification: 5A4       Key: 11        First Column:    8
                     Worksheet:    VI         Question:    1.a
                     Definition:  20 alphanumeric digits for the name of the Jth
                     source.

NBDMK(30)            Mnemonic:  <u>N</u>umber of <u>B</u>oun<u>D</u>s <u>M</u>ar<u>K</u>et
                     Specification: I1        Key: 18        First Column:   54
                     Worksheet:    XI         Question:    4.a
                     Definition:  Number of bounds for the Kth market.

NCC                  Mnemonic:  <u>N</u>umber of <u>C</u>ost <u>C</u>ategories
                     Specification: I2        Key: 1         First Column:   43
                     Minimum: 1               Maximum: 50
                     Worksheet:    Note B
                     Definition:  Number of cost categories.

NCOF(30)             Mnemonic:  <u>N</u>umber of <u>C</u>0e<u>F</u>ficients
                     Specification: I1        Key: 14        First Column:   32
                     Minimum: 0               Maximum: 7
                     Worksheet:    IX         Question:    5
                     Definition:  Number of output ceofficients for the Kth
                     process.

NCS                  Mnemonic:  <u>N</u>umber of <u>C</u>ost <u>S</u>ummation categories
                     Specification: I2        Key: 1         First Column:   71
                     Minimum: 0               Maximum: 10
                     Worksheet:    Note B
                     Definition:  Number of cost summation categories.

NEC                  Mnemonic:  <u>N</u>umber of <u>E</u>nergy <u>C</u>ategories
                     Specification: I2        Key: 1         First Column:   46
                     Minimum: 0               Maximum: 20
                     Worksheet:    Note B
                     Definition:  Number of energy categories.

NFORC             Mnemonic:  Number of FORCes
                  Specification: I1        Key: 1        First Column:   4
                  Worksheet:    Note C
                  Definition:  Column force control.  Operates only when
                  KOVER = 0 and LPHASE = 4.  If 1, single column force; if 2,
                  double column force; if 0 or greater than 2, NFORC is reset
                  to 1.

NLA               Mnemonic:  Number of LAndfills
                  Specification: I2        Key: 1        First Column:   61
                  Minimum: 0               Maximum: 30
                  Worksheet:    Note B
                  Definition:  Number of landfills.

NMK               Mnemonic:  Number of MarKets
                  Specification: I2        Key: 1        First Column:   68
                  Minimum: 0               Maximum: 30
                  Worksheet:    Note B
                  Definition:  Definition of markets.

NOINT             Mnemonic:  Number Of INTervals
                  Specification: I3        Key: 7        First Column:   3
                  Minimum: 1               Maximum: 200
                  Worksheet:    II         Question:   2.b
                  Definition:  Number of intervals in the paper market price
                  distribution function.

NPR               Mnemonic:  Number of PRocesses
                  Specification: I2        Key: 1        First Column:   55
                  Minimum: 2               Maximum:  30
                  Worksheet:    Note B
                  Definition:  Number of processes.

NPROSI(50)        Mnemonic:  Number of PROcesses at SIte
                  Specification: I2        Key: 12       First Column:   39
                  Worksheet:    X
                  Definition:  The number of processes offered at the Kth
                  site.

NREM(50)          Mnemonic:  Number years REMaining
                  Specification: I2        Key: 8        First Column:   56
                  Worksheet:    III        Question:   5.d
                  Definition:  Years of useful life remaining for existing
                  capital for the Kth cost category.

NSEG(30)          Mnemonic:  Number of SEGments
                  Specification: I1        Key: 14       First Column:   33
                  Minimum: 1               Maximum: 3
                  Worksheet:    IX
                  Definition:  Number of linear segments in the Kth processes
                  cost/energy function.

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NSGMK(30)          Mnemonic:  Number SeGments MarKet
                   Specification: I1      Key: 18       First Column:   53
                   Minimum: 1             Maximum: 5
                   Worksheet:   XI        Question:   4.d
                   Definition:  Number of linear segments in the Kth market.

NSI               Mnemonic:  Number of SItes
                   Specification: I2      Key: 1        First Column:   52
                   Minimum: 1             Maximum: 50
                   Worksheet:   Note B
                   Definition:  Number of sites.

NSP               Mnemonic:  Number of Site-Processes
                   Specification: I2      Key: 1        First Column:   58
                   Minimum: 1             Maximum: 80
                   Worksheet:   Note B
                   Definition:  Number of site-processes.

NSU               Mnemonic:  Number of SoUrces
                   Specification: I2      Key: 1        First Column:   49
                   Minimum: 1             Maximum: 60
                   Worksheet:   Note B
                   Definition:  Number of sources.

NTRIG             Mnemonic:  Number of TRIGgers
                   Specification: I1      Key: 3        First Column:   65
                   Minimum: 0             Maximum: 5
                   Worksheet:   II        Question:   4.a
                   Definition:  Number of trigger prices used in the run.

NYR               Mnemonic:  Number of YeaRs
                   Specification: I2      Key: 1        First Column:   12
                   Minimum: 1             Maximum: 99
                   Worksheet:   I         Question:   1.b
                   Definition:  Number of years in the study period.

PCCAN             Mnemonic:  Per Cent CANs
                   Specification: F5.2    Key: 3        First Column:   13
                   Minimum: 0.0           Maximum: 90.0
                   Worksheet:   I         Question:   4.c
                   Definition:  The percentage of cans in MSW by weight.

PCGLA             Mnemonic:  Per Cent GLAss
                   Specification: F5.2    Key: 3        First Column:    8
                   Minimum: 0.0           Maximum: 90.0
                   Worksheet:   I         Question:   4.b
                   Definition:  The percentage of glass in MSW by weight.

PCPAP
        Mnemonic:  Per Cent PAPer
        Specification: F5.2    Key: 3       First Column:    3
        Minimum: 0.0          Maximum: 90.0
        Worksheet:   I        Question:   4.a
        Definition:  The percentage of paper in MSW by weight.

PCRES
        Mnemonic:  Per Cent RESidue
        Specification: F5.2    Key: 3       First Column:    18
        Minimum: 0.0          Maximum: 100.0
        Worksheet:   I        Question:   4.d
        Definition:  The percentage of residue in MSW by weight.

PRCAN
        Mnemonic:  PRice CANs
        Specification: F5.2    Key: 3       First Column:    40
        Minimum: 0.0          Maximum: 1000.0
        Worksheet:   I        Question:   7.c
        Definition:  The price of cans in the market in dollars per
        ton.

PRGLA
        Mnemonic:  PRice of GLAss
        Specification: F5.2    Key: 3       First Column:    35
        Minimum: 0.0          Maximum: 1000.0
        Worksheet:   I        Question:   7.b
        Definition:  The price of glass in the market dollars per
        ton.

PRPAP
        Mnemonic:  PRice PAPer
        Specification: F5.2    Key: 1       First Column:    75
        Worksheet:   I       Question:   7.a
        Definition:  Average price of paper as realized in the
        market in dollars per ton.  Used only if KSEPO=1; reset by
        internally generated PRPAP if NTRIG greater than 0 and
        INPAP = 1.

PTRIG(5)
        Mnemonic:  Price TRIGger
        Specification: F5.2    Key: 6       First Column:    7
        Worksheet:   II       Question:   4.a
        Definition: Kth trigger price in dollars per ton.

RATE(50)
        Mnemonic:  interest RATE
        Specification: F4.1    Key: 8       First Column:    52
        Minimum: 0.05        Maximum: 80.0
        Worksheet:   I        Question:   2
        Definition:  If IDCC(K) = 1, RATE(K) is the interest rate in
        percent for capitalization of the Kth cost category.  Not
        checked for IDCC(K) = 0.

RCAH
        Mnemonic:  Ratio CAn Haul
        Specification: F10.5   Key: 4       First Column:    48
        Worksheet:   I       Question:   12.c
        Definition:  Conversion factor for haul of cans to the
        market:  ratio of energy haul requirement per dollar cost of
        haul.

REVSP(80)      Mnemonic:  REVenue Site-Process
               Specification: F9.3      Key: 17      First Column:   22
               Worksheet:   X           Question:   5.b
               Definition:  Implicit revenue in dollars per input ton into
               the Kth site-process, net of cost of haul to the market.
               Represents the sum of net revenues arising from all
               recoverables not entered into the model (i.e., the commodity
               list) as explicit commodities.

RGLH           Mnemonic:  Ratio GLass Haul
               Specification: F10.5     Key: 4       First Column:   38
               Worksheet:   I           Question:   12.b
               Definition:  Conversion factor for haul of glass to the
               market:  ratio of energy haul requirement per dollar cost of
               haul.

RPAH           Mnemonic:  Ratio PAper Haul
               Specification: F10.5     Key: 4       First Column:   28
               Worksheet:   I           Question:   12.a
               Definition:  Conversion factor for haul of paper to the
               market:  ratio of energy haul requirement per dollar cost of
               haul.

RPRPAP         Mnemonic:  Ratio PRocessing PAPer
               Specification: F4.3      Key: 3       First Column:   69
               Minimum: 0.05            Maximum: 20.0
               Worksheet:   I           Question:   9.a
               Definition:  Ratio of paper to MSW as a cost driver in
               processing paper as waste.

RPRRES         Mnemonic:  Ratio PRocessing RESidue
               Specification: F4.3      Key: 3       First Column:   77
               Minimum: 0.05            Maximum: 20.0
               Worksheet:   I           Question:   9.b
               Definition:  Ratio of source separation residue to MSW as a
               cost driver in processing residue.

SIZINT         Mnemonic:  SIZe of INTerval
               Specification: F5.3      Key: 7       First Column:   6
               Worksheet:   II          Question:   2.c
               Definition:  Size of interval in the paper market price
               distribution function in dollars of price per ton.

TSU(60)        Mnemonic:  Tons SoUrce
               Specification: F10.3     Key: 11      First Column:   32
               Worksheet:   VI          Question:   4
               Definition:  Tonnage at the Kth source in thousands of tons
               per year.

USLA(30)
Mnemonic: USe of LAnd
Specification: F8.5    Key: 14        First Column:    35
Minimum: 0.0001 if ILACOF(K) = 1
Worksheet:    IX            Question:    4
Definition: Use of land on site by process K in acre feet
per thousand tons input.

VDRIV
Mnemonic: Variable cost DRIVer
Specification: F5.2    Key: 5        First Column:    59
Worksheet:    Note C
Definition: Variable cost used if IVDRV = 1 for urging into
the solution an acticity outside of the solution in site
and site-process forcing.

WTCC(50)
Mnemonic: Weight Cost Category
Specification: F8.3    Key: 8        First Column:    31
Worksheet:    III            Question:    3
Definition: Weight of the Kth cost category for use in
LOPT=3 or 4.  Should be positive or zero.

WTEC(20)
Mnemonic: Weight Energy Category
Specification: F8.3    Key: 9        First Column:    29
Worksheet:    IV            Question:    2
Definition: Weight for the Kth energy category for use in
LOPT = 3 or 4.  Should be negative or zero.

APPENDIX B   SAMPLE WORKSHEETS FOR THE NORTHEASTERN MASSACHUSETTS CASE EXAMPLE

The purpose of this appendix is to provide a detailed example of what a completed subset of the worksheets discussed in section 3.1 would look like. The Northeastern Massachusetts case example, which was discussed in detail in section 3.2, is used as a test vehicle.  There is one example of each worksheet.  The data recorded on the worksheets were extracted from the file (see exhibit 3.14).  Although this is not the way it would be done in practice, it helps to reinforce the crosswalk between the worksheets and the case study file.  Readers are encouraged to consult exhibit 3.14 and identify the card, columns and values entered on the worksheets.  The cross reference may be facilitated by consulting the Worksheet-Question portion of the glossary (appendix A) for the term under consideration.

Exhibit B.1  Completed General Information Worksheet

1.  a.  Base year for all cost comparisons:  1983.
    b.  Number of years in the planning period:  20  .
2.  Discount rate:  10%  .
3.  Inflation rate:  6%  .
4.  Waste stream composition (by weight):
    a.  Paper:  23.2%.          b.  Glass:  11.8%.
    c.  Cans:  8.0%.            d.  Residue:  57.0%.
5.  Energy values of key commodities in millions of Btu per ton (when
    processed as waste):
    a.  MSW:  5.2  .        b.  Paper:  6.0  .        c.  Residue:  5.0  .
6.  Source separation options:
    a.  No source seapration is to be offered for at least one source?  yes
    b.  Source separation of paper, glass and cans is to be considered for at
        least one source?  yes.
7.  Expected revenue per ton for source separated commodities when delivered
    at the market:
    a.  Paper:  20.00.      b.  Glass:  25.49.      c.  Cans:  15.00.
8.  Collection costs:
    a.  Total cost per ton:  20.00.
    b.  Added cost per ton due to source separation:  2.00.
9.  Cost conversion:
    a.  Ratio of the cost of processing a ton of paper to the cost of
        processing a ton of MSW:  0.80  .
    b.  Ratio of the cost of processing a ton of residue to the cost of
        processing a tone of MSW:  0.90.
    c.  Allocation of paper processing cost (due to higher capacity
        requirements) to actual paper processed as waste:  0.60  .
10. Energy values of source separated commodities (recycled at the market):
    a.  Paper:  20.0  .      b.  Glass:  2.0  .      c.  Cans:  2.0  .
11. Energy requirements associated with collection:  ·
    a.  Net energy required to collect a ton of MSW:  0.8  .
    b.  Additional net energy required due to source separation:  0.1  .
12. Energy conversions:
    a.  Energy required per dollar of haul cost to market for paper:  0.25  .
    b.  Energy required per dollar of haul cost to market for glass:  0.20  .
    c.  Energy required per dollar of haul cost to market for cans:  0.15  .
13. Energy categories:
    a.  Paper at the market:  Fuel Input.
    b.  Glass at the market:  Fuel Input.
    c.  Cans at the market:  Fuel Input.
    d.  BTU differentiation:  Steam Output.
    e.  Collection (net energy):  Fuel Input.
    f.  Source separation (net energy):  Fuel Input.
14. Cost categories:
    a.  Paper at the market:  Municipal Cost.
    b.  Glass at the market:  Municipal Cost.
    c.  Cans at the market:  Municipal Cost.
    d.  Collection:           Municipal Cost.
    e.  Source Separation:    Municipal Cost.

1.  Is the market local or national?  <u>National</u>.
2.  Critical paper market prices:
    a.  Lower limit on price:  <u>12.00</u>.
    b.  Number of intervals in paper price distribution:  <u>  5  </u>.
    c.  Size of intervals in paper price distribution (dollars per ton):
        <u>5.00</u>.
3.  Paper price distribution:

| Interval number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequency | 10.0 | 20.0 | 30.0 | 20.0 | 10.0 | | | | | |

4.  Issues related to the trigger price system:
    a.  Trigger prices to be considered (dollars per ton):
        1.  <u>15.00</u>;  2.  <u>20.00</u>;  3.  <u>25.00</u>;  4.  <u>      </u>;  5.  <u>      </u>.
    b.  Percent of paper burned for each trigger price (optional):
        1.  <u>      </u>;  2.  <u>      </u>;  3.  <u>      </u>;  4.  <u>      </u>;  5.  <u>      </u>.
    c.  Average price of paper sold in the market for each trigger price
        (optional):
        1.  <u>      </u>;  2.  <u>      </u>;  3.  <u>      </u>;  4.  <u>      </u>;  5.  <u>      </u>.


Exhibit B.3  Completed Cost Category Data Worksheet


1.  a.  Name of this cost category:  <u>Contractor Cap Cost</u>.
    b.  Number of this cost category:  <u>  3  </u>.
2.  Is this an operating or capital cost category?  <u>Capital</u>.
3.  Weight given to this cost category:  <u>1.00</u> .
4.  Differential inflation rate (in per cent per year) for this cost
    category:  <u>1.0%</u> .
5.  Answer sections a through d only if this is a capital cost category:
    a.  Useful life in years:  <u>20</u> .
    b.  Years to capitalization for the loan:  <u>15</u> .
    c.  Interest rate for the loan:  <u>9.00</u> .
    d.  If this cost category corresponds to capital which was already in use
        at the start of the study period (i.e., existing capital), then give
        the number of years remaining prior to its need for replacement:
        <u>NA</u> .

Exhibit B.4   Completed Energy Category Data Worksheet

1. a. Name of this energy category:  Fuel Input, MBTU.
   b. Number of this energy category:  ___1___ .
2. Weight given to this energy category:  __-1.00__ .




Exhibit B.5   Completed Commodity Category Data Worksheet

1. a. Name of this commodity category:  MSW in PKR,KTON.
   b. Number of this commodity category:  ___1___ .
2. Haul costs (categories may be used for cost sharing):
   a. First cost category for hauling this commodity:  Municipal Cost.
   b. First cost factor (e.g., cost per ton mile) for hauling this
      commodity:  __1.00__ .
   c. Second cost category for hauling this commodity:  __NA__ .
   d. Second cost factor for hauling this commodity:  __NA__ .
3. Energy haul requirements (energy factors are energy requirements for haul
   per ton-mile:
   a. First energy category for hauling this commodity:  Fuel Input, MBTU.
   b. First energy factor for hauling this commodity:  __0.20__ .
   c. Second energy category for hauling this commodity:  ___NA___ .
   d. Second energy factor for hauling this commodity:  __NA__ .

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Exhibit B.6  Completed Source Data Worksheet


1.  a.  Name of this source:  __Lynn__ .
    b.  Number of this source:  __1__ .
2.  Depth of tracing requested:  __9__ .
3.  Location of this source:  __1__ .
4.  Kilotons per year of MSW generated by this source:  __340.0.__
5.  Source separation options:
    a.  No source separation:  __No__ .
    b.  Unconditional source separation:  __yes__ .
    c.  Conditional source separation; market paper according to the
        following set of triggers:
        1.  __yes__ ;    2.  __yes__ ;    3.  __yes__ ;    4.  ____ ;    5.  ____ .
6.  Marketing considerations:
    a.  Cost category for haul of paper, glass and cans to the market:
        __Municipal Cost.__
    b.  Energy category for haul of paper, glass and cans to the market:
        __Fuel Input, MBTU.__
    c.  Cost per ton to haul paper to the market:  __2.00__ .
    d.  Cost per ton to haul glass to the market:  __1.50__ .
    e.  Cost per ton to haul cans to the market:  __1.20__ .




Exhibit B.7  Completed Site Data Worksheet


1.  a.  Name of this site:  __Saugus Proc.__ .
    b.  Number of this site:  __1__ .
2.  Depth of tracing requested:  __9__ .
3.  Location of this site:  __5__ .
4.  Incoming commodity:  __MSW__ .
5.  Site preparation information:
    a.  Cost category for site preparation:  __Site Prep (4).__
    b.  Total site preparation costs:  __1000.__ .
    c.  Energy category for site preparation:  __Fuel Input.__
    d.  Total energy required for site preparation:  __250__ .
6.  Capacity considerations:
    a.  Is the site capacitated?  __Yes__ .
    b.  Is landfill possible at the site?  __No__ .


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1.  a.  Name of this landfill:  <u>Amesbury Landfill.</u>
    b.  Number of this landfill:  <u>1</u> .
2.  Location of this landfill:  <u>7</u> .
3.  Land available at the landfill in acre-feet:  <u>99800.</u>

Exhibit B.9  Completed Process Data Worksheet

1.  a.  Name of this process:  <u>Transfer Station.</u>
    b.  Number of this process:  <u>1</u> .
2.  Input commodity:  <u>MSW</u> .
3.  Was this process in use at the start of the study period?  <u>No</u> .
4.  If landfill is to perform on site, how many acre feet per kiloton of input are required for on-site disposal?  <u>NA</u> .
5.  Output commodities:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Name | MSW | | | | | | |
| Coefficient | 1.00 | | | | | | |

6.  Cost allocations:
    a.  Number of first cost category:  <u>2</u> .
    b.  Number of second cost category:  <u>3</u> .
    c.  Estimated costs for this process:

| | First Segment | | Second Segment | | Third Segment | |
|---|---|---|---|---|---|---|
| | Fixed | Variable | Fixed | Variable | Fixed | Variable |
| First Cost Category | 20 | 1.80 | 40 | 0.50 | 60 | 0.26 |
| Second Cost Category | 20 | 1.80 | 35 | 0.61 | 55 | 0.24 |

7.  Energy requirement:
    a.  Number of first energy category:  <u>1</u> .
    b.  Number of second energy category:  <u>NA</u> .

| | First Segment | | Second Segment | | Third Segment | |
|---|---|---|---|---|---|---|
| | Fixed | Variable | Fixed | Variable | Fixed | Variable |
| First Energy Category | 0.80 | 0.50 | 0.70 | 0.40 | 0.60 | 0.30 |
| Second Energy Category | | | | | | |

Exhibit B.10   Completed Site-Process Combination Data Worksheet


1. a. Name of candidate site:  Saugus Processor.
   b. Number of candidate site:  ___1___.
2. a. Name of candidate process:  Water-Wall Incinerator.
   b. Number of candidate process:  ___2___.
3. Capacity limit:  360.0.
4. Linear segments offered:  1. yes;  2. NA ;  3. NA .
5. Implicit revenues for recoverables not defined through output
   coefficients:
   a. Number of cost category for process revenues:  ___2___.
   b. Process revenues (dollars per ton input):  ___1.00___.
   c. Number of energy category:  ___1___.
   d. Energy value of implicit revenues produced by this site-process
      combination:  ___0.20___.




Exhibit B.11   Completed Market Data Worksheet


1. a. Name of this market:  G.E. Lynn Steam.
   b. Number of this market:  ___1___.
2. Location of this market:  ___5___.
3. Commodity being sold:  steam.
4. Market structure:
   a. Market bounds (measured in cumulative commodity units):
      1. ___900___;   2. ___1800___;  3. _____;   4. _____;  5. _____.
   b. Number of first cost category:  ___2___.
   c. Number of second cost category:  ___1___.
   d. Revenue per unit by segment:

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| First Cost Category | 3.00 | 2.00 | | | |
| Second Cost Category | 0.00 | 0.00 | | | |

5. Energy allocation:
   a. First energy category for the energy value of the commodity in the
      market:  ___2___.
   b. First energy value of the commodity in the market:  ___5.40___.
   c. Second energy category for the energy value of the commodity in the
      market:  ___1___.
   d. Second energy value for the commodity in the market:  -0.20.


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Exhibit B.12    Completed Cost Summation Data Worksheet

1.  a.  Name of this cost summation category:  <u>Contractor Cost.</u>
    b.  Number of this cost summation category:  <u>    1    </u>.
2.  Cost categories to be aggregated:
    a.  First cost category:    <u>    2    </u>.
    b.  Second cost category:   <u>    3    </u>.
    c.  Third cost category:    <u>         </u>.
    d.  Fourth cost category:   <u>         </u>.
    e.  Fifth cost category:    <u>         </u>.
    f.  Sixth cost category:    <u>         </u>.
    g.  Seventh cost category:  <u>         </u>.
    h.  Eight cost category:    <u>         </u>.
    i.  Ninth cost category:    <u>         </u>.
    j.  Tenth cost category:    <u>         </u>.


Exhibit B.13    Completed Transportation Data Worksheet


Type 1:    Source-to-Site (card 69)

1.  Origin (source number):      <u>    1    </u>.
2.  Destination (site number):   <u>    1    </u>.


Type 2:    Site-to-Site (card 77)

1.  Origin (location number of site):    <u>    6    </u>.
2.  Destination (site number):    <u>    1    </u>.
3.  Commodity number of the output hauled along this linkage:   <u> 2(MSW) </u>.


Type 3:    Site-to-Market (card 82)

1.  Origin (location number of site):    <u>    5    </u>.
2.  Destination (market number):    <u>    1    </u>.
3.  Commodity number of the recoverable hauled along this linkage:   <u> 6 (steam)</u>.

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**4. TITLE AND SUBTITLE**

The Resource Recovery Planning Model:  A New Tool for Solid Waste Management

**5. AUTHOR(S)**

Robert E. Chapman and Edward B. Berman

**11. ABSTRACT** *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

The Resource Recovery Planning (RRPLAN) model is designed with three purposes in mind.  First and foremost, is the ability to generate a preferred plan for resource recovery.  Second is the capability to evaluate a scenario specified by the decision maker for technical and economic feasibility.  Third is its use as a tool to facilitate the decision making process by providing answers to many what-if questions through an in-depth sensitivity analysis.  This report presents a non-technical discussion of the RRPLAN model.  The basic philosophy behind the model is one of optimization.  This approach was taken because it permits the economic and engineering data associated with the problem (e.g., waste generation rates and the location of processing facilities) to be organized in an objective manner.  Although the model can focus on energy as its main objective, the minimization of the costs of processing a region's solid waste stream is believed to be the objective most often emphasized by decision makers.  An example based on this objective is critically analyzed and used to illustrate how the model would be applied in practice.

**12. KEY WORDS** *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Economic analysis; facility location; fixed-charge problem; mathematical programming; optimization; resource recovery; solid waste management

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