BIOENERGY INDUSTRIAL LOCATION DECISIONS
EMPHASIZING RAW MATERIAL TRANSPORTATION COSTS

By

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ABSTRACT

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This dissertation describes the development of a model for comparing alternative bioenergy production locations based on raw material transportation costs. Although the focus of the developmental research is wood-energy production in Michigan's Northern Lower Peninsula, only minor changes would be required to adapt the model to crop-biomass production of synfuel. This research is unique because it integrates a regional forest biomass inventory based on Landsat satellite imagery and a computerized model which forecasts network biomass transportation costs based, in part, on this inventory. It is believed to represent the first integrated model of this type.

The model developed here consists of four major components: (1) a specification of the biomass supply location and quantity, (2) estimation of the cost of transporting biomass to each of the consumers, including both existing consumers and the hypothetical bioenergy plant, (3) application of a linear programming algorithm to select, from among all the possible combinations of biomass supply points and consumers, those combinations which produce the lowest network transportation costs for the entire network, and (4) a time simulation structure for

components 1.2 and 3.

Four sets of experiments were conducted using the model: (1) a series to develop preliminary statistical parameters for the network cost estimates, (2) a benchmark series of model runs every five years from 1982 through 2012 which included only the existing biomass consumer network, but no wood-energy plant, (3) a series covering the same time period simulating a small (25 MW) wood-energy plant at Rose City, Michigan, and (4) a series simulating the same size plant at Idlewild, Michigan. These experiments indicate information produced using this model will be valuable in bioenergy industrial location decisions.

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CHAPTER I

INTRODUCTION

Statement of the problem

During the last ten years increasing energy costs have changed the way Americans live:

> (t)he oil crisis of 1973-1974 constituted a turning point in post-war history, delivering a powerful economic and political jolt to the entire world. It interrupted or perhaps even permanently slowed postwar economic growth. And it set in motion a drastic shift in world power, in the very substance of international politics(Stobaugh and Yergin 1979.p.2).

One consequence of this shift has been a renewed interest in developing sources of energy other than petroleum. Among these alternatives is bioenergy. Basically bioenergy is simply the conversion of vegetation to fuel. Synthetic liquid fuel production, for example "gasohol", is the most highly developed bioenergy technology. A simpler form of bioenergy production has been used for several decades in the forest products industry: burning wood in steam boiler systems. The addition of turbines to these steam systems makes electricity production possible. Institutional heating with waste wood has become quite common in the Pacific Northwest. It has contributed to significant

increases in air quality when coal systems have been converted to wood-chip systems (Hisner 1977). Electricity produced from burning wood (wood energy) is a very new concept. As of 1982, one such plant exists in Burlington, Vermont. Its economic and environmental impact have been carefully monitored and extensively documented. Whether this plant will be able to survive economically depends on its ability to produce electricity profitably, which in turn depends on many factors. One of the most important is the utility's ability to obtain fuel at a reasonable cost. Stumpage costs are therefore important. In addition, because forests are inherently widely dispersed, the cost of transporting fuel from forest to plant is also important.

> "Transportation considerations will play a major role in design and locations of wood-fired power plants. The direct costs of transporting fuel place limits on the distance the plant can be located away from the harvest areas; transportation costs thus significantly affect fuel procurement costs" (Adler,Blakey,Meyer 1978 p. 3).

Development of a wood-energy plant does not however occur in a vacuum. In addition to the transportation cost question faced by the wood-energy plant, a more complex question exists: how will wood-energy development affect transportation costs of existing wood users who will be competing with the wood-energy plant for stumpage?

The purpose of this research is to develop an economic modeling system, which will use the forest biomass inventory system developed in my earlier research (Appendix A), to predict raw material transportation costs for the entire network of forest products industries in a region. This forest products network exists within a much more complex system composed of political, social, ecological and economic subsystems, which is discussed in the next chapter.

Study Objectives

The objective of the study is to develop a series of computer programs which, when applied in conjunction with a remote sensing-based regional biomass inventory, can be used to analyze bioenergy plant location decisions by explicitly considering:

1. the regional resource supply
2. existing and anticipated competition for this resource
3. cost of the resource
4. growth rate of the resource
5. a series of shock scenarios that will permit prediction of impacts of future structural economic change on the plant.

Specific objectives are:

1. For Program I, simulate random raw material supply origins and amounts for the entire network of resource users in the region as realistically as possible.
2. For Program II, develop a fully automatic conversion of straight line distances through the use of the Regional Transportation Factor (which is explained in Chapter IV) and compute transportation costs between all the origins simulated in Program I and all the resource users (destinations) in the region. That is, to compute all possible transportation costs in the region for the period.
3. For Program III, develop a linear minimization of these transportation costs for the regional network. Because origins simulated in Program I are random, this linear minimization will also outline the supply area of each resource user in the region.
4. To develop a simulation framework for the three Programs that can be used to

model time. This framework should permit:

a. stochastic annual transportation cost minimization

b. resource growth (or shrinkage) using generalized growth projections

c. shocks to be introduced into the system at specified future times that simulate structural economic changes in the system.

<u>Research Strategy</u>

Research was done in four stages:

A. study area forest inventory and biomass estimation

B. simulation of stumpage purchases for all wood pulp and chip users in the area every five years from 1982-2012 (Program I).

C. computations of transportation costs for all possible combinations of simulated chip and pulp origins and actual plant destinations (Program II).

D. linear programming minimization of the annual network transportation costs within a time simulation framework (Program III).

It was necessary to develop and test a forest biomass inventory system based on Landsat satellite imagery because only through use of Landsat can large areas be inventoried in a timely, cost effective way. Forest maps produced from Landsat images were compared to medium scale color infrared aerial photography of the same areas to determine whether Landsat imagery could successfully be used for this purpose. Forest stands were mapped as either hardwood, conifer or mixed from Landsat. The detailed composition of the stands was determined from the color infrared images. Biomass (in tons) per acre of these stands was estimated based on the best available sources. A complete description of the sources and why each was selected is contained in Appendix A. The percentage of forest cover in hardwood, conifer and mixed species and the per acre tonnage of these types was used in the stumpage purchase simulator by assigning random forested one-square-mile sections a forest type and a biomass per acre estimate based on variable probabilities. A full report of this stage also is contained in Appendix A.

During stage B, the stumpage purchase simulator, random forest sections were generated and the stumpage purchased until the pulp and chip demand of all the users in the system was met. These sections were withdrawn from the forest base. Computation of the cost of moving

all purchased biomass from its location in the forest to all the possible pulp and chip users in the region was done in stage C. Up to and including stage C, all computations were performed on a microcomputer.

Stage D, minimization of these biomass transportation costs, was done using the MSU CYBER 750 mainframe computer. All origins and destinations were input and a linear program compared alternative combinations of these to find the least expensive set which still met the consumer network's demands. Stages A through D were repeated every five years for the thirty years from 1982 through 2012.

Description Of Study Area

The study area is the northern 33 counties in the lower peninsula of Michigan (Table 1.1). A rectangular grid of the area covers approximately 28,000 square miles. Eliminating Great Lakes and inland lakes with surface areas larger than one square-mile reduces the area by 28 percent to approximately 20,000 square miles (Figure 1.1).

Individual grid cells in the modeling data base are one square mile in size. Modeling transportation costs is done using spatial relationships between the two dimensional (x,y) coordinates of the individual cells (sections). Since neither county nor township boundries represent significant political barriers to biomass

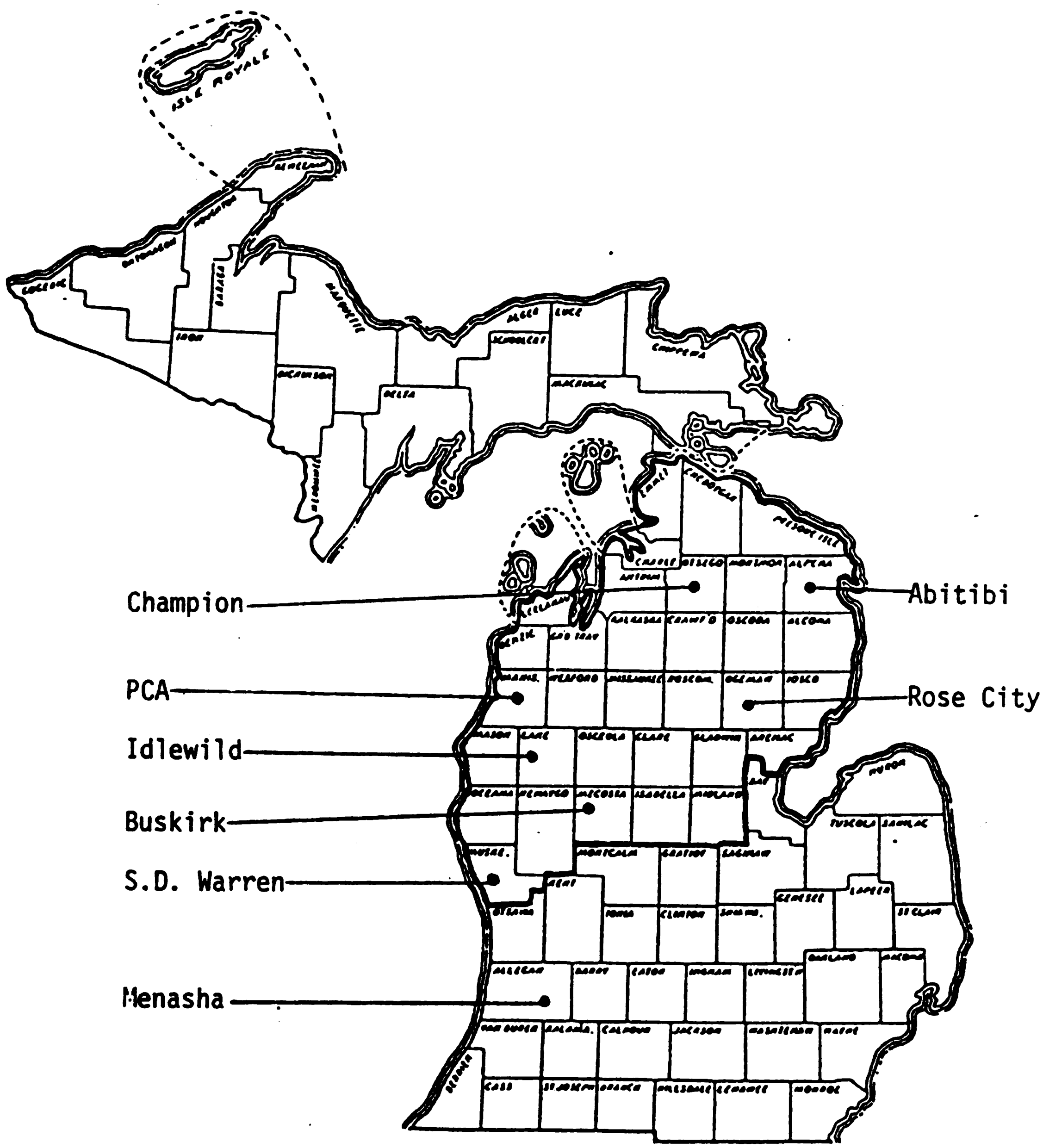

Figure 1.1. Study Area

transportation, there is no advantage to using them to stratify the grid. Each section in the study area is classified as being forested, non-forested, water or urban. Because the purpose of this research is to develop the analysis system rather than conduct an inventory of the region, United States Geologic Survey (USGS) 1:250,000 scale maps were used for this classification, rather than Landsat satellite imagery.

Table 1.1. Michigan counties in study area (North-to-South).

1. Emmet	18. Missaukee
2. Cheboygan	19. Roscommon
3. Presque Isle	20. Ogemaw
4. Charlevoix	21. Iosco
5. Antrim	22. Mason
6. Otsego	23. Lake
7. Montmorency	24. Osceola
8. Alpena	25. Clare
9. Leelanau	26. Gladwin
10. Benzie	27. Arenac
11. Grand Traverse	28. Oceana
12. Kalkaska	29. Newago
13. Crawford	30. Mecosta
14. Oscoda	31. Isabella

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(Table 1.1 continued)

15. Alcona	32. Midland
16. Manistee	33. Muskegon
17. Wexford	25. Clare

In general, forests within this study area are a mixture of northern hardwood and conifer. They are somewhat unique in that they are composed of quite poor quality stands. In their natural condition, many soils in the study region are sandy and contain only thin layers of organic material. They were of marginal fertility and could not tolerate much farming. Problems of three types occurred in various combinations and differing degrees: (1) clearcutting virtually all mature virgin white pine, (2) deliberate fires to clear slash and open land for farming and accidential caused by wildfire, (3) unsuccessful attempts at farming that often removed whatever fertility survived logging. Many subsequent disease and insect problems are caused by this pattern of soil abuse.

Poor though these stands are, they represent a major part of the raw material for 179 forest products firms in Michigan (Michigan Department Of Natural Resources 1977). Of these, 161 are sawmills. These are large numbers, more than five forest products companies per county, and would seem to suggest a thriving

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industry. Unfortunately, this is not the case. Most sawmills are small and operate only part time. To a large extent, development of a large scale forest products industry has been limited to those using low quality raw materials.

Six major pulp or chip users presently compete with each other for stumpage in the study area. Location and production capacities of these plants are discussed in Chapter II. Even pulp buyers have limited use for the "scrub" oak (primarily *Quercus ellipsoidalis*) stands which occupy many of the region's worst sites. Their products and technology require a mixture of wood pulp from several species. Although there is a great deal more poor oak than anyone can use, no one knows how much because much of it is on private land. U.S. Forest Service forest survey data can provide some insights into these stands. Forest survey data is not as helpful as it could be in this context because it is designed to provide accurate estimates over relatively large geographic areas. Most public forests have good forest inventories which provide this point oriented data. Private forest owners, on the other hand, as a group do not.

During the late 1970's Consumers Power, Inc. planned to construct a wood-energy plant at Hersey, Michigan. One of the important factors in Consumers

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Power's original plans for a wood energy plant was this large area of scrub oak (Hudson and Kittleson 1978). As a whole, given current product requirements and technologies, most scrub oak is unmarketable for anything except fuelwood and a wood-energy plant would be only partially competitive with other pulp users for stumpage. However, it is not safe to assume that this will continue to be the case. Paper, cardboard, particle board and plywood production technologies are developing rapidly. It is reasonable to expect changes in these technologies which would permit even more poorer quality stumpage to be used. The more poorer quality stumpage which is used by the forest products industries, the more those industries will compete with fuelwood users for stumpage.

Forest products industries are reluctant to discuss stumpage purchases with outsiders because they are afraid information will be used by their competitors to adjust stumpage bids. They regard as proprietary such information as how much of each tree species is required for a particular product, how much they might pay for stumpage, and how far they would be willing to travel to obtain it. When they were pressed during telephone conversations for these details and others, particularly their supply area, three of the six pulp users indicated they regarded the entire study area as their supply area and would be willing to make 400 mile round trips to harvest stumpage. In fact, a forest products firm might mak

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make 400 mile round trips in an emergency. However, they would not be able to continue making the trips regularly because they will lose money on each trip, given the high transportation costs detailed in Chapter III.

Railroads often provide a common solution to long-haul problems in forest products industries. Unfortunately, the railroad network is not well developed in this region and much of what has been developed is in the process of being dismantled at this time because of low use levels. One reason the companies are able to even consider these very long hauls is the high quality of the study area road network.

Major roads throughout the area are good quality, two lane asphalt with the exception of one four-lane interstate highway (I-75) which essentially bisects the area in a north-south direction. There are no natural or man-made obstacles (e.g. toll bridges or roads) anywhere in the area. The only real transportation constraint regularly encountered by forest products industries is winter weather. Assuming good harvest planning has left logging sites near main roads, these delays are usually one or two days long and occur less than a dozen times per winter. In the past larger pulp users have stock piled stumpage during the rest of the year for use during the winter. More recently, having found themselves with holding yards full of wood they couldn't use or sell beca

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because of an economy in recession, they are tending to buy on tighter schedules.

Very long distance stumpage purchases may become cost effective for both pulp and wood-energy users through the use of Great Lakes barges. A recent study of transporting logs, pulp, chips and firewood by barge on the Great Lakes predicts that, depending upon individual circumstances, for transportation distances of longer than approximately 100 miles the least expensive mode should be by barge (DenUyl 1982).

The wood-energy plant in Burlington, Vermont is on the shore of Lake Champlain. Faced with a fuel supply problem, they decided to try having wood chips hauled to a barge and then towing the barge to Burlington. Although the process is more expensive and time consuming, preliminary indications are that it can be done economically if the facility is located near a large body of water.

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CHAPTER II

RESEARCH CONTEXT

Political Context Of Wood-energy Development In Michigan

The political context of wood-energy development in Michigan is primarily a function of the state's present economic problems. Michigan's economic health depends primarily on the health of the U.S. automotive industry. This industry has changed a great deal recently, due in part to gasoline price changes and Japanese competition. Michigan's twin problems of unemployment and reduced tax revenue can be traced directly to these changes.

Considering these problems, newly elected Governor James Blanchard's heavy emphasis on diversifying the State's economy and creating new jobs makes a great deal of sense. Creating jobs in the forest products industry, in particular, has become a major objective of his new administration (Johnson 1983). Because so much of Michigan's forest is low quality timber, the emphasis has been on attracting companies which would utilize this resource, such as wood-energy, paper, particle board and more recently, flake board producers. A lower level effort has been underway for several years without much public fanfare, so this sudden exposure to the public spotlight has not caught foresters by surprise. However, w

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with the exception of a few small communities which were being considered as locations for this type of development, these efforts have gone largely unnoticed outside the forest products industry prior to the recent campaign season. Political campaigning in 1982 changed this pattern and brought the job creating potential of Michigan's forest resources to the attention of the general public.

The present forest products industry employs approximately 63,000 people in 2,300 firms (James, Heinen, Olson and Chappelle 1982). In an effort to quantify the general campaign theme of "forest jobs", many Michigan foresters have made claims that the resource has the potential to support " 50,000 new jobs by the year 2000" (Johnson 1983). Whether or not this much potential actually exists remains to be demonstrated. In any case, development of Michigan's forest products industry is presently the subject of widespread public interest and active political debate. While this interest may eventually be channeled to produce constructive development, it has important present implications for wood-energy research.

Commercial wood-energy is a new concept. Therefore, it is very difficult to predict what impacts development of it might produce. The purpose of the research discussed in this report is to develop and test a system that can be used to predict the impact of wood-

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energy development on raw material transportation costs under different sets of circumstances. While this is an important question for wood-energy development, there are other, equally important unknown factors which must be addressed before the overall potential of industrial scale wood-energy can be assessed. A detailed discussion of these other research needs is contained in Chapter V. However, one major source of uncertainty is influenced heavily by political factors: stumpage availability from private forests.

Obviously, whether a certain landowner is willing to sell his stumpage depends to a large extent on the price he can get. However, there are almost certainly many other factors which would influence his decision. Very little research has been done on this subject, primarily because of the physical difficulties involved in contacting and questioning stumpage owners about hypothetical circumstances. Although no solid information is available, the availability of a particular stand of timber is probably influenced by such factors as: (1) the stumpage owner's need for cash, (2) the proximity of the stand to a road, (3) the type of timber harvesting done (selective cutting is usually less objectionable to owners than clearcutting), (4) whether regeneration of the stand or conversion to another type can be assured in some way, (5) the extent to which wildlife and esthetics factors will be impacted by the harvest. There are almost certainly other factors in addition to these. In Michigan, an interesting set of conflicting incentives has developed to further confuse this subject.

The Commercial Forest Reserve Act (Public Act 94, 1925, ammended in Public Act 393, 1980) makes it possible for a landowner to defer a portion of his state tax if he agrees to harvest the stumpage at a later date. The purpose of the act was to help private forest owners grow timber more profitably by allowing them to defer their tax payments until harvest, thereby increasing the commercial wood supply. This act encourages forest landowners not to harvest now. On the other hand, because of the sharp reduction in state and federal aid available during the recent recession, rural townships have tended to increase the tax burden of their largest landowners. This increase has normally taken the form of either an increase in the reassessed value of a property or an across the board increase in the assessment rate for the entire township. The increased tax burden produces a need for cash which in turn encourages the landowner to harvest stumpage now since timber is usually the only product which has a ready market. In this case, a long-term state program to increase the commercial timber supply is being subverted by impoverished local governments.

Michigan's political and economic realities have

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another important implication for wood-energy development. The research which must be done before sound policy decisions can be reached is predisposed to misinterpretation or misuse because the results will be produced at a time when the entire subject is a lively political issue. Results of wood-energy research seem relatively straightforward compared to, for example, such technical subjects as eugenics. Perhaps it is. However, in terms of interpretation of research results, both subjects share the common problem that the research methods and technology used by scientists are so complex that any statements of results must be carefully qualified to preclude as much confusion as possible. In general, if the results are not for some reason controversial or politically interesting, these qualifications seem to be reasonably well maintained. However, in Michigan the subject is politically important and precise statements of results may be subjected to generalized interpretation without qualification. Therefore, given Michigan's present politicized context, it is very important to minimize misinterpretation of research results when they are published. One strategy for reducing misinterpretation or misuse is to provide as complete a statement of the results of the research as possible. The first component of the statement should be a list of the assumptions made during the research, not a

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one-sentence summary of the results themselves. Another strategy is to carefully select report and summary formats and use only those which contain reasonably balanced, informative statements.

How successful these strategies will be, given the difficult economic conditions and the broad, optimistic assertions coming from other foresters, remains to be seen. However inadequate these strategies may seem to be in coping with the potential for misinterpretation and misuse in a politically charged context, they appear to be the best available at this time.

Environmental Context

The following discussion of the environmental context for wood-energy development consists of four main sections: (1) general statutory , (2) air pollution, (3) harvesting site impacts and (4) future considerations. Considerable overlap exists between these catagories and other environmental impacts, notably water pollution concerns, could be discussed as well. However, within the study area for the current research these are of less importance. In particular, given Michigan's vast fresh water supply, high rate of flow and the small wood-energy plant modeled in this research, the impact of the plant on water quality should be negligible (Bechtel 1981,p.455).

1. General Statutory Context

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Whether the environmental impacts considered in the following analysis should be accepted by society depends in part on the extent to which wood-energy development can help meet our energy needs. If wood-energy development occurs in Michigan, it will probably occur elsewhere because conditions which make wood-energy desirable here will undoubtedly exist in other locations. In addition, Federal laws provide a common statutory context for wood-energy development anywhere in the nation. Therefore, it is necessary to look, at least briefly, beyond the study region to the national wood-energy picture.

> "At present in the United States, the fuel supplied by biomass is about ... 2 percent of the total U.S. energy consumption. By year 2000 with appropriate research and development, biomass has the potential of supplying the nation with about 5% percent of projected U.S. consumption." (Roddis 1981)

Regardless what forms it takes, bioenergy can have a only a limited impact on our energy needs in the near future. Obviously, the impact of direct conversion of wood-energy will be even less. With this limited potential, the environmental impacts of the bioenergy become more important. If bioenergy had the potential to meet a larger share of our energy needs, its negative environmental impacts, like those of coal burning, might be easier to overlook. As it is, whether or not the marginal energy producing potential of bioenergy should be developed will depend to a large degree on how successfully its negative environmental impacts can be minimized.

One of the statutory cornerstones of national policy on this subject is the 1978 Powerplant and Industrial Fuel Use Act. The primary purpose of the act " is to facilitate increased energy independence by providing for expanded use of alternative energy sources by the nation's electrical powerplants and major industrial installations" (Lublin and Pickholz 1980).

Specifically, the Act

> " clearly sets a national policy of requiring industrial and powerplant fuel users to increase their use of coal and other alternate fuels as primary energy sources for new and existing facilities. This requirement is a strict one, and it places the burden on the facilities that are capable of using an alternate fuel to either convert or seek a specific exemption. The statutory scheme reverses the framework of previous fuel conversion plans and should provide for a more efficient and effective fuel conservation and energy independence program" (Lubin and Pickholz 1980).

What has actually emerged from this legislation is an extremely complex set of provisions which have not been interpreted consistently. Many provisions are believed by industry representatives to conflict directly with provisions of the Clean Air Act (Dryburgh 1980, p.779).

> "PIFUA (the Act) simply reinforces the existing market pressure to use coal instead of gas or oil in new plants. ... The increased use of coal, however, presents hazards beyond the

scope of current environmental standards, and by establishing a national policy favoring coal conversion, PIFUA provides more support for industry's attempt to weaken air pollution standards" (Dryburgh 1980, p.780).

Whether we actually have a coherent national policy encouraging the use of coal and the development of alternative sources of energy in general and bioenergy specifically remains to be seen. For the purposes of this report, PIFUA confuses the statutory context for wood-energy development, and consequently, discourages new investment. Unfortunately, these results are the rule rather than the exception for recent energy-related legislation.

To a large extent, confusion in energy and environmental legislation is a function of a much larger Constitutional question: how far Congress can go in preempting or overiding what has been traditionally the responsibility of individual states to regulate (Fisher 1980.p.786). This issue often arises in environmental law in the form of questions concerning the extent to which Congress can demand that states enforce federal regulations. The Clean Air Act is an example of a sweeping environmental statute where these types of questions have produced a multitude of complex litigation. The Priority Energy Project Act of 1980 (PEPA) added a new twist to this complexity in the energy development arena.

The main purpose of PEPA was to provide a system for

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for "fast tracking" particularly desirable energy producing development through what, by 1980, had become a maze of legal constraints. The Energy Mobilization Board was to be responsible for overseeing this work. By comparison to other statutory processes, the PEPA system seems quite straightforward and wood-energy is precisely the kind of "geographically isolated" priority project PEPA was to have promoted (Fisher 1980, p. 798).

PEPA has not worked out well. What happened? Basically three things: (1) the energy crisis which had propelled PEPA subsided somewhat, (2) the Presidency changed parties, (3) PEPA's regulations raised some of the still unresolved Constitutional questions discussed above. Ultimately, PEPA and the Energy Mobilization Board quietly succumbed to changing political reality. The Energy Mobilization Board still exists on paper. However, they do not meet regularly and were never able to achieve their objectives. The problem is that the PEPA "approach is totally inconsistent with the needs of a decisionmaking system that is asked to approve or reject projects that have a significant effect upon the economy and environment of discrete geographic areas" (Fisher 1980, p. 866). The fate of PEPA is important for wood-energy development because it is part of a larger pattern of failed legislative efforts to establish a consistent regulatory context. These failures have pro

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produced confusion which in turn discourages investment, particularly in unproven technologies like wood-energy.

Another such confusing episode, at least in Michigan, has been the Public Utilities Regulatory and Policy Act of 1978 (PURPA). The main purpose of Section 210 of this statute was to " encourage the development of electric power production and energy conservation through the use of renewable energy sources" (Hinshaw 1982,p.1). Bioenergy is definitely a renewable source and PURPA has passed its most difficult legal hurdle in _Federal Energy Regulatory Commission v. Mississippi_, 102 S.Ct. 2126 (1982). Why wood-energy hasn't received much "encouragement" from PURPA is difficult to say. Perhaps because the recent oil surplus has reduced our perception of energy scarcity. However, there is evidence that PURPA's laudable objectives may have become bogged down in bureaucracy.

In Michigan, the Public Service Commission is charged with developing procedures for carrying out the Federal Energy Commission's guidelines. Following a lengthy study, one independent researcher has concluded that " the Michigan Public Service Commission's approach reveals a choice of confusing procedures" (Hinshaw 1982,p.ii). Hinshaw goes on to point out that there is no evidence that these confusing procedures have "compromised" the goals of PURPA yet.

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characteristic that all three of the statutes discussed so far have in common is that they have, for a variety of reasons, produced regulatory confusion in addition to their other contributions. Because most regulations, rules and procedures adopted along the way have added their share, the confusion itself seems to have gradually become the predominant factor in the general legal context of bioenergy development. So far we seem to be unable to do much to prevent these problems.

Ralph W. Walker II, past Chairman of the American Bar Association's Energy Resources Commission argues that these types of problems will continue until we stop entrusting basic energy research and development projects to private energy producing companies (Walker 1980,p.610). Walker suggests that the basic problem is that we don't have our energy facts straight. Because of the profit incentive, private research and development concerning energy will always produce results in their own interest. He continues that, since we don't have adequate information, we continue to make patchwork legislative decisions which guarantee confusion in the end. The Federal Government, according to Walker, should accept its responsibility to sponsor research on all aspects of energy development and regulation. He concludes that this research should be conducted in major universities because they are the only institutions we have which are capable of

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of reasonably unbiased research (Walker 1980,p.614).

2. Air Pollution Context

The Environmental Protection Agency (EPA) has recently developed a market system for trading air pollution entitlements. The market is based on three concepts: (1)"bubbles", (2) offsets and (3) banking to create a central clearinghouse. The "bubble" concept permits pollution controls to be based on single plants, or groups of plants, rather than individual stacks within a plant. The objective is to permit a firm to make decisions regarding individual stacks and still regulate the environmental impact of the plant. The offsetting concept means that major new industrial plants may be constructed in areas of the country which don't presently comply with Clean Air Act requirements. All the owner of such a plant needs to do is obtain offsetting reductions from existing sources of air pollution equal to the amount projected for the new plant. The purpose of banking is to provide one centralized trading location for these entitlements and permit controlled trading. Two important questions about entitlement trading are: does it work (or, can it be made to work) and is it legal?

The General Accounting Office recently completed a comprehensive review of air pollution entitlement trading (GAO 1982). As is its normal practice, the GAO concerned

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itself primarily with whether or not the trading is in the public interest. They did not address the question of trading legality. Basically, their conclusion was that the present problems are probably not unresolvable. They found that most of the problems were due to the novelty of the concept rather than serious flaws. From their perspective, entitlement trading appeared to be a good plan. In addition they predicted that, whether it is desirable or not, the energy industry will probably attempt to make widespread use of the bubble in attainment areas (Darrell,1982,p.36). However, since most development will probably occur in attainment areas use of the bubble concept may never become widespread in wood-energy. So, GAO, EPA and industry experts all appear to favor the bubble. But, is it legal?

The most recent judicial ruling available indicates it may not be. The U.S. Court of Appeals, District Of Columbia, decision in NRDC v Gorsuch states that " the EPA's regulatory change, its employment of the bubble concept to shrink to a relatively small size mandatory new source review in nonattainment areas, is impermissible" (17 ERC 1825). Apparently, whether or not new wood-energy firms will find themselves dealing with air pollution on a stack-by-stack basis or with their entire plant under one bubble remains to be seen, adding yet another unknown to the wood-energy legal context.

In contrast to this uncertain regulatory context, t

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the technical aspects of air pollution control seem relatively well known. The forest products industry has been using wood byproduct-fired boilers for many years and has reasonably reliable data on the air pollution control aspects of wood burning. Every wood processing plant generates some kind of residue. These residues range from sawdust coming from sawmills, to chunks of wood and peelings of bark from plywood mills. Because of the wide range of size, moisture content and combustion characteristics of these residues, the industry has developed multiple fuel handling and boiler systems. Without going into detail on how these systems work, it seems obvious that the chemical contents of stack gases can vary quite a bit depending on the fuel and how efficient a given boiler is in burning a particular fuel.

Three main types of emissions-control systems are commonly used with wood-fired boilers: dry mechanical collectors using cyclonic separators, wet scrubbers, and electrostatic precipitators (Flick 1976). The dry mechanical collectors are usually employed as the first stage of the treatment process and are followed by either wet scrubbing or electrostatic precipitators. Mechanical collection followed by wet scrubbing or electrostatic precipitators are the most effective in reducing particulate emission. In terms of cost, the mechanical collector and electrostatic precipitator combination is the most expensive, followed closely by wet scrubbing (Flick 1976,p.153.). Mechanical collectors alone are roughly one third the cost of either of the two combinations. The cost of these systems is important because it is one of the major points at which the air pollution regulations directly determines the economic viability of a wood-energy plant.

Efforts to comply with air pollution standards as inexpensively as possible has lead to considerable amount of creative experimentation. One of the most promising new techniques is the use of gravel bed filters for particulate control. The gravel bed is slowly moved through the escaping gas, trapping particles. Preliminary indications are that gravel bed filters are at least as efficient as wet scrubbing or electrostatic precipitation and probably less expensive to build and operate (Flick 1976,p.152).

Regardless which emissions control system is used, whether or not a plant can meet effluent quality standards is primarily determined by two additional groups of variables: the fuel burned in the boiler and the efficiency of the boiler operation. "(I)t is very important that everyone realize the impact fuel preparation and handling have on boiler performance and its effect on stack emissions" (McBurney 1976,p.166). Boilers can be designed, built and, to a lesser extent adjusted to accommodate a wide range of fuels. No matter ho

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how carefully the boiler is operated or how good the emissions control systems are, unless the fuel supply is consistent, the stack emissions will not consistently meet standards. Boiler operators cannot continuously adjust their equipment in response to changes in, for example, fuel size or moisture content. When they don't, violations often occur. The point is that given a consistent fuel supply and existing emissions controls systems, wood-fueled boilers can be operated cleanly.

At least one engineer believes that problems with wood-fired boilers are often caused by operators trying to reduce emissions by installing emissions control systems rather than directly addressing the cause of the problem which is usually either fuel or boiler related. He suggests that "regulations might be more acceptable and more practical if they addressed the cause of the problem of emissions rather than the symptoms" (Johnson 1976,p.170). Johnson indicates a system of tax credits for cleanly operated furnaces might produce better results than the present, penalty-oriented monitoring of stack effluent.

3. Harvesting Site Impacts

Until this point in the discussion of wood-energy's environmental impact, the focus has been on those impacts which would be produced at the plant by burning the wood. Wood-energy development will also produce environmental impacts at the logging site. In general, these fall into three classes: vegetation, water, and soil. Vegetation damage is the most readily perceived of the three types. As is discussed in Chapter V, recent research indicates between one quarter and one half of the trees left in a stand harvested using whole-tree methods will sustain some kind of damage during a harvest. Two thirds of this damage is caused by dragging entire trees from the stump to the chipping site (Kelley 1983). What, if any, long term impact this damage will have on the stand is not known. More research is needed in this area. Whole-tree harvests for wood-energy will probably have a negligible impact on water resources in the relatively flat glacial soils of Northern Michigan. In mountainous areas clearcutting has produced serious soil erosion which in turn decreases the quality of surface water below. Because the study region's soils are, overall, flat or contain only gentle slopes, erosion has not been a problem.

The most serious and least understood harvest-site impact of whole-tree chipping is soil nutrient depletion. Traditional harvesting removes only the main tree stem, leaving the branches and leaves. These decompose and eventually become soil nutrients available to support new vegetation. Little research has been done on this subject (Kittleson 1979,p.24). The work that has been done indicates that where soil nutrient supply is marginal, whole-tree removal may seriously limit the type of vegetation which can survive. As is detailed in Appendix A, many of the study region's poorest timber stands, the ones most desirable from a wood-energy perspective, are growing on soils which are very poor in nutrients and very sandy. In fact, the reason the stands are of such poor quality is that the soils are poor. It is likely that some fertilization of these sites after logging would be required.

4. <u>Future Context</u>

A major independent engineering firm has recently completed a multi-volume environmental and economic comparison of energy production from coal and biomass (Bechtel 1981). Although the study tends, predictably, to treat emissions standards and applications of these standards as though they were static, focusing instead on the engineering issues, it does come to an interesting conclusion regarding future environmental impacts of coal and biomass as sources of energy.

> "(S)mall biomass conversion plants do not appear to have an overall environmental advantage over coal counterparts on a relative basis ... . This environmental standoff is partly due to the extensive (air) pollution controls used in the coal conversion plants which reduce conventional pollutant emission to about the same overall levels as those from biomass conversion." (Bechtel 1981,p.vii).

A major Department of Energy study compared several development scenarios in models through the year 2000 (Habegger,et al 1981). Most of their conclusions are similar to Bechtel's. Although both studies are based on many assumptions, they both point toward wood-energy developers having to work hard to meet attainment standards and facing stiff competetion from coal.

In terms of economic viability, the Bechtel report is even less enthusiastic about biomass. Following a lengthy analysis of the cost of energy production with comparable systems including the cost of emissions controls, they conclude:

> "From these comparisons, it is evident that the coal conversion processes are more likely to become major routes to clean fuels than these biomass conversion processes, primarily because of better economics." (Bechtel 1981,p.ix).

The two sources of energy become cost comparable when the average delivered price of coal is $25/ton and the average delivered price of wood is nothing (Bechtel 1981, p.357). Sweeping conclusions regarding the environmental context for wood-energy are difficult to draw, primarily because so much is uncertain. As discussed above, questions exist concerning interpretation and application of each of the major pieces of legislation which determine environmental regulation. These environmental questions exist, in turn, within a larger context of Constitutional issues. By comparison to this legal and statutory confusion, the technical aspects of wood-energy environmental impact are reasonably well understood. Although most of this knowledge is based on the use of wood residues in forest products industries, experts believe they are valid for wood-energy plants as well. The economic aspects of environmental impact seem, in general, discouraging to wood-energy development. However, there are few regions of the U.S. where as abundant a supply of currently unmarketable wood exists as Northern Lower Michigan. If wood-energy development is to occur anywhere, the study region is one of the best locations.

The most important factor in analyzing the legal context of wood-energy development is that, as the above discussion suggests, wood-energy can be combined with other alternative sources of energy. For all practical purposes relevant statutes, administrative procedures and case law precedents treat wood-energy the same as they do any other source of energy. Therefore, future developments in energy law should be assumed to apply to wood-energy, regardless of what raw material they refer to specifically. Obviously the technical details will be different and there will be exceptions. However, based on developments so far, the legal context for wood-energy development is not significantly different from any other energy development.

Decisionmakers

Decisionmakers in all subsystems can be broadly divided into three groups: (1) private and commercial forest products users, (2) public resource managers and resource policy-makers and (3) concerned citizens. In general, private commercial decisionmakers will be interested in the current research to the extent it can improve their ability to achieve their goals. When the model developed in this research is applied to actual inventory data it will be a useful commercial planning tool. Public sector decisionmakers will be able to use the model to predict how wood-energy will affect publicly owned resources and how they can optimize their performance in the face of increasingly limited financial and natural resources. Concerned citizens reactions to this research will primarily be determined by their affiliation with a particular special interest group.

Raw material transportation costs are as important in crop biomass conversion as they are in wood-energy. So the model developed here will be valuable for crop-based synfuel conversion, as well. Another bioenergy technology that is becoming increasingly appealing to many urban planners is solid waste conversion to either electricity or gas. Waste transportation costs are a major factor in determining the economic viability of this energy source.

Regardless of whether a bioenergy plant is based on wood, crop biomass, or solid waste, the primary instrument for obtaining long term private capital is the corporate bond. Both bond ratings and bond coupon rates will be heavily dependent on demonstrating the existence of an adequate fuel supply within financially feasible hauling distances. Therefore, estimates of fuel transport costs should be valuable information for financial analysts considering bioenergy investment.

All these decisionmakers face three major sets of alternatives that will be affected by this model:

1. Should a bio-energy plant be built in a given region at all? Who will benefit and who will pay?
2. If so, where should it go? Public optimal location probably differs from private optimal location.
3. How large a plant will the regional resource base support given present and future uses?

The model developed in this research addresses these questions in several ways. First, it can be used to predict how the introduction of a bioenergy plant will affect transportation costs of the network of users competing with it for raw material. Second, because these costs are important to bioenergy and other forest products, the model will address the issue of whether a wood-energy plant should be built at all. Third, because the model permits wood-energy plants of any size to be simulated at any location, it can, in part, suggest where it should go and how large it should be.

The model will not answer any of these questions completely. It may, however, provide decisionmakers with useful information on all three subjects. The model can be applied with minor changes to industrial location decisions in the area of crop biomass conversion to alcohol. With more extensive modification, the model can be applied to urban solid waste processing and disposal location problems. Both of these applications are discussed in Chapter IV. In general, the purpose of the model is to provide decisionmakers with an analytical tool for systematically comparing alternative impacts which might come from development of wood-energy in a given region.

CHAPTER III

Model And Data Used

Program I. The Biomass Location And Supply Simulator

A. Timber Type

Each execution of Program I simulates the sale of enough biomass stumpage to meet the combined demand of all pulp and chip consumers in the regional network for one year. The locations of simulated timber sales are selected randomly from forested cells within the study area. Individual consumers undoubtedly have a higher preference for locations nearest their plants. However, because: (1) the consumers are quite evenly disturbed throughout the study area, and (2) at this time there is no way to predict the propensity of particular owners to sell stumpage, random sale locations are the most realistic process. Acres of biomass available in each sale are also generated randomly ranging from a minimum sale size of 10 acres to the sale of the entire section (640 acres).

The type of timber in the sale is classified as either hardwood, conifer, or mixed hardwood/conifer. The prob

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probability of a particular sale being simulated as hardwood, conifer or mixed is based on the proportion of these types mapped in earlier satellite-based forest biomass research (Appendix A). During this earlier research, sample forests in the study area were mapped from Landsat satellite imagery using a system developed during the research. One result of the research was a preliminary estimate of what proportion of the forests were hardwood, conifer and mixed stands (Table 3.1).

Table 3.1. -- Area of forest types (Appendix A).

Forest Type	Percent Of Forest
Hardwood	42.42
Conifer	19.40
Mixed	38.19

The current research extends this estimate to the entire study area. No quantitative basis exists for this extension. But, by the same token, there is no reason to suspect it is not accurate. The important point is that, as is discussed in Chapter IV, an actual application of the analysis system developed in this research must be based on a regional biomass inventory, rather than the small preliminary sample obtained for the system development. The only cost effective, timely way to accomplish this at present is using Landsat satellite imagery. The study reported in Appendix A developed and tested such a mapping system. Regional Landsat biomass mapping would produce actual proportions of hardwood, conifer, and mixed types that could be substituted for the preliminary estimates used here. In addition, no variable probability allocation would be required because the type of each forested cell in the system could be computed using the data base. The same reasoning applies to ton per acre estimates assigned to the three forest types.

B. Biomass Tonnage Per Acre

Biomass tonnage per acre estimates used in this research were also developed earlier (Table 3.2).

Table 3.2. -- Biomass of major forest types (tons/acre), (Appendix A).

Type	Biomass
Hardwood	39.55
Conifer	33.32
Mixed	33.90

Table 3.2 estimates are based on a small sample obtained during model development. Appendix A contains a detailed description of the sampling procedure. They are

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preliminary estimates and should not be interpreted as accurate representations of the per acre biomass available in the study area.

C. Biomass Growth

The most recent forest inventory information available (Michigan Department Of Natural Resources 1981, p.67) places the Michigan statewide annual forest growth at 16.2 million cords of sub-merchantable timber and 4.7 million cords of merchantable timber. This growth occurs on 19.4 million forested acres. Assuming the ratio of merchantable to sub-merchantable is the same for growth rate as it is for area, this is an average growth rate of .835 cords/acre/year for sub-merchantable timber and .242 cords/acre/year for commercial timber. An important advantage of wood-energy supply is that it will be able to utilize some of this sub-merchantable material. Therefore, overall merchantability standards will be lower making more low quality timber "commercial". How much more timber will become merchantable for wood-energy is not known. In practice, minimum merchantability standards for wood-energy harvests are so low that they are really quantitative rather than qualititative. That is, wood-energy buyers will not harvest a particular stand if it contains less than a minimum amount of biomass. The only reason some stands will not be harvestable for wood-energy is that they do not contain sufficient biomass to make the

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effort worthwhile. This is an important point because many stands in the region are quite open because of either site limitations, insect or disease problems or both as discussed in Chapter I. Therefore, minimum stand density will probably be a significant factor in determining merchantability of many stands for wood-energy. How these general principles will translate into quantitative estimates is difficult to predict. During model development it was assumed that an arbitrary value of 60 percent as an estimate of which stands would become commercial for wood-energy. Forty percent of the stands would then be non-commercial rather than the current 71 percent. Using these assumptions, preliminary average growth for the entire forest can be estimated in volume as follows:

$$.60(.242)+.40(.835) = .479 \text{ cords/acre/year.}$$

Translating this volume estimate into weight requires yet another set of assumptions regarding the species composition of wood-energy harvests.

Since one of the primary reasons for considering the Northern Lower Peninsula as a location for wood-energy is the availability of low quality northern hardwood, particularly as discussed above for various oak species, it is logical to conclude that these stands would make up a large proportion of the harvested stumpage. Again, translating this into quantitative terms requires a subjective estimate. Logically, wood-

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energy buyers should focus on these poor quality stands but two spatial constraints will prevent them from using oak exclusively: (1) better stands of aspen and softwoods are mixed with the northern hardwood, (2) wood-energy operators will find cost incentives in harvesting these better stands because they are growing near northern hardwood stands where they already have their equipment set up.

Considering these factors, this model assumes that only 70 percent of the stumpage harvested for wood-energy will actually be mixed northern hardwoods, and the remaining 30 percent will be composed of the more valuable forest types in the study area: aspen, balsam fir, pine (especially Jack pine) and spruce/fir which happen to be growing near low quality stands. Conversion of these assumptions into weight estimates was done using wood industry standards (Table 3.3).

Based on Table 3.3:

.30(4525)+.70(5075) = 4910 pounds/cord of wood-energy fuel.

Therefore, in one year, a wood-energy stand should grow:

(4910 pounds/cord) x (.479 cords grown/acre/year) =

= 2352 pounds/acre/year

= 1.18 tons/acre/year.

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Table 3.3. -- Weight of wood-energy stands.

Type	Weight (pounds/cord) (Source: Timber Mart 1981)
Aspen	4650
Balsam fir	4800
Pines	4300
Spruce	4350
(average =	4525)
Mixed northern hardwoods	5350
Lighter mixed northern hardwoods	4800
(average =	5075)

D. Competition For Stumpage In The Study Area

Based on stumpage market price analysis, only pulpwood harvesters should actually compete with wood-energy harvesters for stumpage because both veneer and sawlog consumers pay more for their stumpage (Table 3.4). In addition to average stumpage price differences, both pulp and chip harvesters commonly fell and skid trees larger than 10 inches dbh (diameter breast high), leaving them for either sawlog or veneer purchasers who negotiate prices with landowner (personal field observation 1979). Considering market prices and this informal practice, it is apparent that sawlog consumers do not compete with eith

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either pulp consumers or chip consumers for stumpage. Since the model deals with only the network of stumpage consumers who will compete with the wood-energy chip consumers, sawlog and veneer consumers are not included.

Table 3.4. -- 1981 average stumpage prices in the study region (Timber Mart 1981).

Type Of consumer	Average 1981 stumpage price (dollars/green ton)*
Veneer	40.45 ($267.00/MBF)
Saw	15.60 ($103.00/MBF)
Pulp	5.27 ($12.38/Std. Cord)
Whole-tree chips	12.50

* Conversion factors: 1MBF weighs 6.6 tons green, 1 std. cord weighs 2.35 tons green (Timber Mart 1981).

Six major pulp and chip companies harvest stumpage in the study area (Michigan Department Of Natural Resources 1977). Five are located within the study area and one is south of it (Table 3.5).

The existing pulp and chip using network will have an annual demand of 910,675 tons of stumpage per year, if all of the consumers are operating at capacity. Personal communications with company officials and DNR personnel failed to produce estimates of how close to capacity the cc

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companies were operating in 1981, although the consensus

Table 3.5. -- Pulp and chip consumers who harvest stumpage from the study area (Michigan Department Of Natural Resources 1977).

Company	Location	Plant capacity (tons/year)
Abitibi, Inc.	Alpena	156,950
Packaging Corp of America.	Manistee	146,000
S.D. Warren, Inc.	Muskegon	87,600
Menasha, Inc.	Otsego	82,125
Champion International, Inc.	Gaylord	365,000
Buskirk, Inc.	Paris	73,000
	Total =	910,675

was that that they were all well below capacity. It is difficult to tell because the companies regard this as proprietary information. The DNR faces the same type of problem but because of their combined roles as a management, regulatory and enforcement agency they provide the companies with even less incentive to cooperate. Forest products companies logically assume th

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that information provided to one branch of the Department for management could find its way into either enforcement or regulation branches and be used against them. Because of this problem, the model treated each consumer as functioning at plant capacity during development and testing, while recognizing that they do not do so currently. However, in the event this information becomes available, the model has been written to permit different demands for each industry in each year. The small (25 Megawatt) wood-energy plant studied with the model will need an estimated 285,000 tons/year of whole-tree chips. When this plant enters the system, the network demand for pulp and chips increases 31.3% to 1,195,675 tons/year.

Program I simulates stumpage sale: (1) location, (2) timber type, (3) acreage, on the basis described above until the entire network demand for one year is met (flowcharts and source code listings for all programs are in Appendix B). These sale locations, in two dimensional (x,y) grid coordinates, and tons of biomass available at each location simulated during one execution of Program I, are the basis for one execution of Program II. Program II computes transportation costs involved in moving all stumpage sold in the simulation to all possible combinations of network consumers.

Program II. Transportation Cost Computation

Program II estimates the cost of transporting all of the biomass harvested in the Program I simulation to all consumers in the network. All possible combinations of stumpage sales (origins) simulated in Program I and biomass consumers (destinations) are identified and costs of transporting biomass to each are computed. It is basically an algebraic problem and the same two dimensional spatial grid of the study area used in Program I is used in Program II (Appendix B contains flowchart and code). Program II's flow sequence is as follows:

1. X and Y coordinates for each origin and destination are input,
2. straight line distances between all possible origins and destinations are calculated,
3. straight line distances are converted to estimates of road travel distances required to cover the distance using a regional transportation factor (RTF, discussed below),
4. these distances are converted to round trip cost estimates using a cost/mile estimate.

The output from Program II, consisting of all possible transportation cost combinations, are coeff

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coefficients of the objective functions which is minimized by the Program III linear minimization.

A. Straight-line distance computations

Straight-line distance between all origins and all destinations is computed using the Pythagorean Theorem adapted to a two dimensional (x,y) axis grid. For example, the distance between two points (x_1,y_1) and (x_2,y_2) is:

1. X axis distance: the absolute value of the difference between x_1 and x_2
2. Y axis distance: the absolute value of the difference between y_1 and y_2

Therefore, the straight-line distance is:

3. Straight-line distance: the square root of the sum of the x-axis distance squared plus the y-axis distance squared.

This simple process works for all destinations (x_2,y_2) located within the study area. However, as discussed above, one of the major destinations for pulp cut in the study area is located outside the study area. The Menasha Corporation of Otsego, Michigan is 74 miles south of the southern boundary of the study area. Menasha is able to compete for stumpage in spite of this apparent handicap because a limited access interstate highway (I-

131) extends from this plant into the heart of the study area, making the raw material transport less expensive and time consuming than it would be over two-lane roads. This fact was compensated for in Program II by adding 74 miles to all the straight-line distances computed for the Mensha Corportation. This is done by simply adding 74 miles to each straight-line distance estimated. The corrected set of straight-line distances is converted to estimates of actual mileage that would be required to cover each distance using the regional transportation factor (RTF).

B. Regional Transportation Factor (RTF)

The RTF used in Program II is 1.36 miles. It means that an average of 1.36 miles of road travel is required to move one straight-line mile in any direction within the study area. The RTF substitutes for a computerized transportation network map of the study area. The Michigan Department of Transportation (MDOT) has developed a computerized transportation map of Michigan. This map was not used because: (1) the MDOT computer system is not compatible with the MSU CYBER 750 at this time, which would have severely limited the number of model runs possible, (2) areas other than Michigan where this model might be applied, in particular foreign countries, probably would not have such a complete computerized transportation network map. Considering these problems, it was decided to develop and document this model without using the MDOT data base. If such a data base and the computer programs to exploit it for trip distance computations are available, the RTF used in Program II can be easily replaced with actual distances.

The RTF is based on a sample of the straight line distances and actual road distances between 41 pairs of random points in the study area. Straight line distances were calculated using the Pythagorean Theorem method described above. Road distances between the pairs of points were estimated graphically using MDOT county road maps. The graphic procedure assumed (1) the vehicle was a large chip van so only the best roads were selected and (2) alternative routes were compared and the one chosen subjectively assesssed to be the best for this vehicle. Since the study area is well roaded in an almost exclusively east-west and north-south grid and contains no toll roads or bridges, routing decisions were not difficult. Each "best" route was mapped, measured and the mileage recorded. The variance of the RTF estimate is .378 miles so its standard deviation is .615 miles. This means that if, for example, 40 trips are made between any two points in the study area that are one mile apart, thirty eight of them (95 percent) will require between 1.17 miles and 1.55 miles of road travel, and that all 40 trips will average 1.36 miles in length.

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C. Transportation Cost Estimate

A base year (1982) estimate of 9.3 cents per mile was used in Program II (OTA 1980, Appendix I,p. 135). The 9.3 cents per mile is measured one way for the round trip and assumes a 40,000-50,000 pound payload. For example, transporting chips from a harvesting site 10 miles to a processing facility would, using this estimate, cost 9.3 cents/green ton/mile or 93 cents/green ton for the trip of ten miles. In this example, the round trip is 20 miles but the cost of the empty run is included in that of the loaded run. This estimate is for a tandem-rear-axle tractor and a tandem-axle trailer operated one shift per day.

Program II is designed to accommodate one or more changes in either this cost estimate or the rate of change of the cost estimate during a time series. For developmental purposes, an arbitrary real annual transportation cost growth rate of 5 percent was used in all model runs. The potential impacts of changes in the cost and the rate of changes is discussed in Chapter IV.

The output from Program II is the cost of transporting one ton of chips from each simulated origin to each destination in the system.

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Program III. Transportation Cost Minimization

Biomass stumpage sales simulated in Program I and the transportation costs computed in Program II are the input for this step in the Model. The minimization is accomplished using the MPOS (Multi-Purpose Optimizing System) software package available on the MSU CYBER 750 (Cohen and Stein 1978). IBM's MPSX and Control Data's APEX will also work. The primary reason for using a mainframe optimizing system rather than a microcomputer algorithm is time savings. Minimization problems as large as the ones developed in this research (approximately 500 variables in the objective function and and 100-150 constraint equations) are solved in under 15 seconds by MPOS. The same problem run on a microcomputer would, according to the MSU Computer Lab's senior statistical consultant, require at least 24 hours to solve and possibly twice that long.

To facilitate translation of Programs I and II outputs to a format MPOS can understand, an interactive matrix generator program called MAGEN was developed on the CYBER 750 (Appendix B). MAGEN permits the consumer to take advantage of the MPOS matrix format input rather than using the more time consuming equation format.

If (1) the supply of a raw material at any number of origins, (2) the amount demanded at any number of destinations and, (3) the cost of moving one unit of the

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raw material from each origin to each destination is input, MAGEN can be used in conjunction with MPOS to minimize the transportation costs for the entire network.

MAGEN should be particularly useful for teaching purposes because it permits the use of MPOS without requiring the student to understand the MPOS program language. MPOS need only be called, told the name of the data matrix, and a few general instructions and it can solve the problem. It permits the focus of the learning exercise to be on what is happening, rather than the computational details.

MAGEN was not used for production modeling in this research for two reasons: (1) it is expensive for large problems, (2) since all the problems considered here are similar, a system of creating MPOS equations using the microcomputer screen editor was developed which permitted input preparation on the microcomputer and later transfer to the CYBER. The screen editor input is more efficient than MAGEN provided the programmer fully understands the microcomputer editor, the CYBER editor, linear programming theory and MPOS. Since most potential modelers will not be familiar with these software packages, MAGEN should be useful in the future. A sample of MPOS input and output and the MAGEN flow chart and source code are contained in Appendix B.

As microcomputers with larger memory capacity be

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become available, MPOS-like optimizers will undoubtedly be created for them and interactive mainframe costs will no longer be a consideration.

The linear minimization of network transportation costs conducted using MPOS is an example of what are known as either transportation-type problems or classical transportation problems. Properties that these problems possess "enable one to solve them by methods that are considerably more efficient " than general linear problems (Swanson 1980,p.144). These properties can be most clearly stated symbolically. Symbols are defined as follows:

X(i,j) = biomass shipped from origin (i) to consumer (j) in tons,

A(i) = biomass harvested at origin (i) in tons,

B(j) = biomass demanded by consumer (j) in tons,

C(i,j) = the cost of shipping one ton of biomass from origin (i) to consumer (j) in dollars,

m = number of origins,

n = number of consumers

(Dantzig 1963,p.299)

The objective function of the linear minimization is

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is to minimize the cost of transporting a known quantity of biomass to destinations which require known amounts:

$$\text{Minimize: } \sum_{i=1}^{m} \sum_{j=1}^{n} C(i,j)\ X(i,j)$$

This minimization must be done subject to four constraints.

First, all of the biomass available at a given harvest location must be transported. In other words, harvesting, but not transporting wood is not permitted. Symbolically, this constraint can be stated as:

$$\sum_{j=1}^{n} X(i,j) = A(i)$$

Second, the amount of biomass needed by each of the consumers in the network must be supplied to them. This means the model cannot simulate transportation of biomass only to consumers nearer harvest locations and ignore those farther away. Every consumer's demand for biomass must be met during each time period. This constraint can be symbolically stated as:

$$\sum_{i=1}^{m} X(i,j) = B(j)$$

Third, the amount of biomass harvested must be equal to the total demand for the biomass in each time period. Symbolically, this is:

$$\sum_{i=1}^{m} A(i) = \sum_{j=1}^{n} B(j)$$

Fourth, is a mathematical necessity which simply reflects common sense. No empty shipments or returning of biomass from consumers to origins is permitted.

Symbolically, this is:

$X(i,j) \geq 0.0$

Constraint number three, that the amount harvested must be equal to the amount demanded can be circumvented by introducing artificial destination points in the initial problem structure (Swanson 1980, p.155).

Time Simulation Framework

Program I, the biomass supply simulator; Program II, the transportation cost computation; and Program III, the MPOS minimization of those costs together constitute one model run. Each model run produces an estimate of network transportation costs for one year. These estimates are not particularly meaningful by themselves. However, as components in a time series, they become more significant.

Estimates produced in this research cover the time period from 1982 through 2012. The model produces an estimate every five years beginning in 1982, for a total of seven estimates per time-series simulation. No separate computer program was required to produce the time simulator because Program I and Program II are written to permit changes in biomass growth and transportation cost factors based on the passage of time. As discussed above, running Programs I and II requires specification of a calendar year. Both programs translate this input into a definition of passage of time between the specified year and the model base year (1982) and recompute time sensitive variables as needed.

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Chapter IV

Results Of Modeling

Four series of model runs were made: (1) a series to develop preliminary statistical parameters for cost estimates produced in other model runs, (2) a benchmark series based on only existing wood consumers in the region with no wood energy plant in the system, (3) a series simulating a wood-energy plant at Rose City, Michigan and (4) a series simulating a wood-energy plant at Idlewild, Michigan.

Precision Of Estimates

To obtain preliminary statistical parameters for the transportation cost minimizations, nine model runs were made holding all variables, including time, constant. The only change made between these runs was the generation of a completely new set of random timber sales locations each time Program I was executed. These runs were made using 1982 stand growth and transportation cost estimates. Results of these runs are summarized in Table 4.1.

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Table 4.1 -- Summary of nine estimate precision runs.

Consumer	Mean Estimated Transportation Cost($)	90% Confidence interval*
1. Abitibi	617,558	+/- .072%
2. PCA	619,750	+/- .092%
3. S.D.Warren	357,343	+/- .105%
4. Menasha	1,299,014	+/- .037%
5. Champion	1,478,992	+/- .037%
6. Buskirk	341,535	+/- .126%
Network Total:	4,714,192	+/- .014%

* Expressed as percentage of mean estimated transportation cost. Formula:
mean +/- (t(05,n-1))x(std. deviation/(n**1/2))

As Table 4.1 illustrates, model estimates are precise. The high level of precision occurs because many Monte Carlo simulations of random timber sales were completed in Program I. A total of 759 timber sales (an average of 84 per run) were generated during the nine full model runs. All possible transportation costs between these origins and the six existing wood consumers in the system were computed in Program II. These possibilities were examined and total network cost minimized in Program III. Cost estimates in Table 4.1

are not minimized for each firm. They represent the average annual cost to that firm when the transportation cost for the network is minimized. Only the total, $4,714,192 has actually been minimized by the linear programming algorithm.

This precision series demonstrates that estimates made with this model will be grouped very closely together if the assumptions are held constant. This grouping occurs because:(1) Monte Carlo random generation is used in Program I and, (2) a large number of these random generations are required to simulate enough stumpage sales to meet network demand for one year. This is an important result because it suggests that little additional information will be obtained from making multiple model runs under identical assumptions. In other words, in this case the Monte Carlo simulation reduces the advantage normally obtained by using stochastic estimation. On the basis of this result, it was decided to develop deterministic estimates for each set of assumptions in a given year during development and testing of the model.

Results of the benchmark series (no wood-energy plant present at any location) are summarized in Table 4.2. Tables 4.3 and 4.4 present the model output for simulated wood-energy development at Rose City and Idlewild, respectively. The adjusted network totals in Tables 4.3 and 4.4 represent the totals for the entire network, minus the transportation costs of the wood-energy plant. That is, the adjusted total is the transportation cost estimated for the existing network.

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Table 4.2. Results of Benchmark Series (Series I).($)

Firm	1982	1987	1992	1997
1. Abitibi	617,558	830,327	639,799	1,484,284
2. PCA	619,750	1,201,489	792,422	975,647
3. S.D.Warren	357,343	603,231	262,613	571,744
4. Menasha	1,299,014	1,793,416	1,836,780	2,454,500
5. Champion	1,478,992	1,414,269	2,446,789	1,932,945
6. Buskirk	341,535	537,581	431,439	666,300
Network Total	4,714,192	6,380,313	6,409,842	8,085,420

(Table 4.2 continued)

Firm	2002	2007	2012	Firm Total
1. Abitibi	1,273,954	1,194,755	1,166,928	7,207,605
2. PCA	1,133,399	1,038,043	1,632,677	7,393,427
3. S.D.Warren	832,695	572,728	2,033,847	2,033,847
4. Menasha	1,996,034	2,721,575	3,182,345	15,283,664
5. Champion	3,999,351	2,768,955	3,870,913	17,912,214
6. Buskirk	561,810	245,603	589,922	3,374,190
Network Total	9,797,245	8,541,659	12,476,634	56,605,301

Table 4.3. Results of Rose City Series (Series II).($)

Firm	1982	1987	1992	1997
1. Abibiti	464,458	655,901	1,166,727	955,145
2. PCA	429,983	511,187	832,195	814,758
3. S.D.Warren	197,527	109,037	525,631	534,704
4. Menasha	1,115,101	1,365,095	1,776,806	1,594,878
5. Champion	1,632,671	2,003,994	2,275,666	2,582,555
6. Buskirk	269,507	174,448	446,665	236,567
7. Wood-energy	840,925	1,661,031	1,298,453	2,094,431
Network Total (raw)	4,950,172	6,480,693	8,322,143	8,813,038
Network Total (adj.)	4,109,247	4,819,662	7,023,690	6,718,607

Firm	2002	2007	2012	Firm Total
1. Abitibi	754,913	1,041,063	1,743,540	6,781,747
2. PCA	1,704,639	1,084,573	824,009	6,201,344
3. S.D.Warren	260,492	343,471	587,295	2,558,157
4. Menasha	2,058,872	2,362,228	2,987,228	13,260,206
5. Champion	2,469,277	4,299,307	4,749,266	20,012,696
6. Buskirk	558,331	410,088	530,751	2,626,357
7. Wood-energy	1,475,881	2,153,690	1,766,697	11,291,108
Network Total (raw)	9,282,405	11,694,420	13,188,786	62,731,615
Network Total (adj.)	7,806,524	9,540,730	11,422,089	51,440,507

Table 4.4. Results of Idlewild Series (Series III).($)

Firm	1982	1987	1992	1997
1. Abitibi	396,306	1,097,049	810,358	564,712
2. PCA	767,285	1,072,188	961,285	1,184,675
3. S.D.Warren	274,617	368,206	375,483	588,105
4. Menasha	1,306,766	1,630,235	2,234,817	1,726,426
5. Champion	1,484,047	1,569,124	2,261,787	2,825,379
6. Buskirk	528,677	628,205	916,651	754,072
7. Wood-energy	1,901,464	1,843,949	2,194,968	3,399,727
Network Total (raw)	6,659,162	8,208,956	9,755,349	11,073,100
Network Total (adj.)	4,757,698	6,365,007	7,560,381	7,673,373
Firm	**2002**	**2007**	**2012**	**Firm Total**
1. Abitibi	1,079,259	925,140	2,110,253	6,983,077
2. PCA	790,755	2,070,791	2,372,835	9,219,814
3. S.D.Warren	288,799	400,220	870,029	3,165,459
4. Menasha	1,655,631	2,534,438	3,703,170	14,791,483
5. Champion	3,132,336	3,463,896	3,205,203	17,941,772
6. Buskirk	459,913	1,726,347	946,065	5,959,938
7. Wood-energy	3,766,104	2,781,940	5,152,517	21,040,669
Network Total (raw)	11,172,797	13,902,773	18,360,073	79,102,204
Network Total (adj.)	7,406,693	11,120,833	13,207,556	58,061,535

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Comparison Of Series I,II and III.

Many trends appear when Tables 4.2, 4.3 and 4.4 are compared and it is possible to analyze them without addressing the question of whether the trends are statistically significant or not. More meaningful interpretations can be made with probability theory. It is not possible to compare individual cells within the tables, for example a particular firm in a given year, because the cells themselves are deterministic and have no statisitical parameters. However, it is possible to statistically compare the three series results in terms of: (1) individual firm costs for all years, (2) all firms' costs taken together for one year,(3) each firm's totals over all years and (4) network costs for all years. Meaningful combinations of these four types of comparisons were tested for statistical significance using the paired Student's-T method (Table 4.6). For example, the Series I (Benchmark) costs from Table 4.3 and the Series II (Rose City) costs from Table 4.4 which accrue to firm number one (Abitibi) from 1982 through 2012. is shown in Table 4.5.

The costs appear to be generally lower in Series II than Series I and the total of the seven modeled years is definitely lower for Series II. The question is, are these differences statistically significant? While it is not possible to test each annual cost estimate or the gra

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grand total, it is possible to use paired T-testing to compare Series I with Series II (and also Series III, wood-energy plant at Idlewild, Michigan) as a whole for individual firms.

Table 4.5--Example of comparison between Benchmark and Rose City for a single firm, Abitibi.

Year	I Benchmark Cost($)	II Rose City Cost($)
1982	617,558	464,458
1987	830,327	655,901
1992	639,799	1,166,727
1997	1,484,284	955,145
2002	1,273,954	754,913
2007	1,194,755	1,041,063
2012	1,166,928	1,743,540
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Total:	7,207,605	6,781,747

For example, comparing Series I for Firm 1 and Series II for Firm 1 produces only a 27 percent probability that they are in fact significantly different data sets. That is, there is 73 percent probability of stating they are different, when in fact they are not (Type I error). A similar test for Series I, Firm 1 against Series III, Firm 1 produces similar results: an 89 percent probability of concluding they are sig

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significantly different, when in fact they are not.

As discussed above, this testing procedure was used to separate statistically significant differences between the three Series from apparent, but statistically insignificant differences. Obviously, the level of confidence is very important in this kind of a test. In evaluative research, values of 90 or 95 percent (cumulative distribution function divided by 2) are preferred for most T-tests (Sokol and Rolph 1970,p.133). By contrast, the research discussed in this report is essentially developmental; its purpose being to create and test a bioenergy industrial location model. Within this context, probability theory is most useful as a tool for sorting meaningful results from the mass of meaningless data, rather than as a definitive comparison of competing alternatives. Therefore, developmental applications of T-tests need not be as sensitive. Consequently, the minimum confidence level (defined as the cumulative distribution function divided by two) discussed in this report is .8, rather than .9 or .95. Table 4.6 presents all meaningful comparisons between Series I, II and III which have at least a .8 confidence level.

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Table 4.6-- Significant differences between results of Series I, II and III.

Network Comparison

Network Totals For Series		One Minus Probability of Type I Error
I	II*	.85
II*	III*	.98
II	III	1.00 (.996)

* Adjusted network total=(Network total)-(wood-energy plant costs)

Individual Firm Comparison

Series-Firm	vs. Series-Firm	One Minus Probability of Type I Error
II-2	III-2	.82
I-3	II-3	.89
I-3	III-3	.88
II-3	III-3	.83
I-4	II-4	.96
II-4	III-4	.87
I-6	III-6	.89
II-6	III-6	.97
II-7	III-7	.98

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Detailed Analysis Of Significant Results

Network Totals

Three significant results were produced by comparing Series I,II and III network totals:

1. Existing consumer network will probably (.85 *) have lower transportation costs if a wood-energy plant is built at Rose City than if no wood-energy plant is built at all.
2. Existing consumer network, not including a wood-energy plant, will probably (.89) have lower transportation costs if the wood-energy plant is built at Rose City than if it is built at Idlewild.
3. Consumer network, including the wood-energy plant, will probably (.996) have lower transportation costs if the wood-energy plant is built at Rose City than if it is built at Idlewild.

The first result, that the existing wood consumers will probably have lower raw material transportation costs if a wood-energy plant is built in Rose City than if no wood-energy plant is built, is based on a

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* Significance level = 1 - (probability of Type I error.)

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statistical comparison of the Series I network totals for all seven model years (Table 4.2) with adjusted network totals in Series II (Table 4.3). This adjustment of Series II and III network totals is needed to produce existing network totals for these two series that do not include the wood-energy transportation costs. The Series II adjusted network cost is below the Series I cost for five of the seven model years. The total savings is $1,456,234, which translates to $6,241,002 over 30 years and $208,033 per year.

This result contradicts intuition which suggests that the net effect of adding an additional consumer to the network should produce higher transportation costs

Table 4.7-- Number of timber sale simulated in Series I and II.

Year	Series I	Series II	Difference
1982	84	99	15
1987	64	84	20
1992	64	74	10
1997	53	73	20
2002	51	60	9
2007	43	59	16
2012	46	52	6
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		Total:	96

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for the network rather than lower. One hypothesis which explains this contradiction involves the additional number of timber sales required to meet network demand including a wood-energy plant (Table 4.7).

The hypothetical explanation suggests that the additional 96 timber sales added to meet the wood-energy plant's raw material requirements permits more efficient allocation of sales to the other six consumers. This is directly analogous to more suppliers coming into a market in response to a perceived increase in demand. It represents a shift in the supply curve to the right .

The second significant result obtained from comparing network totals is that existing pulp and chip consumers would probably experience lower raw material transportation costs if the wood-energy plant were built at Rose City (Series II) than if it were built at Idlewild (Series III). This finding is based on the statistical comparison of the Series II network costs (adjusted to remove the costs of the wood-energy plant) with the Series III network costs (also adjusted). Testing indicated a 98% probability that the lower Series II costs represent a significant savings compared to Series III (Table 4.8).

This prediction means that, in terms of the raw material transportation costs of the existing network of consumers, Rose City is a better location for the wood-ener

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energy plant than Idlewild. In conjunction with result number one, that the existing network as a whole should experience lower transportation costs if the plant is built at Rose City than if it isn't built at all, these results suggest that existing consumers should encourage

Table 4.8 -- Adjusted* network transportation costs for Series II and III.($)

Year	Rose City	Idlewild	Savings at Rose City
1982	4,109,247	4,757698	648,451
1987	4,819,662	6,365,007	1,545,345
1992	7,023,690	7,560,381	536,691
1997	6,718,607	7,673,373	954,766
2002	7,806,524	7,406,693	-399,831
2007	9,540,730	11,120,833	1,580,103
2012	11,422,089	13,207,556	1,785,467
Total:	51,440,549	58,091,541	6,650,992

* Wood-energy plant raw material transportation costs removed for comparative purposes.

wood-energy development at Rose City. There may be untested locations which are better than Rose City by this criterion.

Consumer network raw material transportation costs, including wood-energy plant costs, at Rose City will

(.996 probability) be lower than the same costs with the plant at Idlewild (Table 4.9).

The $16.4 million total difference in Table 4.9 is only for the seven years actually modeled. Because these estimates are representative of the 30-year period as a whole, it is reasonable to expand estimates to fill in missing years. The mean difference in Table 4.9 is $2,342,936 (standard error $1131). Therefore, the

Table 4.9 -- Network raw material transportation costs with a wood-energy plant at Rose City compared to similar costs at Idlewild.($)

Year	Rose City	Idlewild	Difference
1982	4,950,172	6,659,162	1,708,990
1987	6,480,693	8,208,956	1,728,263
1992	8,322,143	9,755,349	1,433,206
1997	8,813,038	11,073,100	2,260,062
2002	9,282,405	11,172,797	1,890,392
2007	11,694,420	13,902,773	2,208,353
2012	13,188,786	18,360,073	5,171,287

network should expect approximately $70.3 million savings in raw material transportation costs if the plant is at Rose City rather than Idlewild.

Two more major questions were answered using the model: (1) what will the network costs be including the wood-energy plant, and (2) which individual consumers stand to gain or lose from wood-energy development? The first question is essentially a public policy analysis problem: where should public agencies encourage wood-energy development in terms of minimized raw material transportation costs? The second question, who among the existing consumers will benefit and who will pay for wood energy is obviously important to the operators themselves. In addition, this question has a public policy dimension because each of the consumers is a major employer and therefore a locally important source of social stability.

For the individual consumer, the important question is, to whom would these savings accrue? While the model developed here did not address all of the subjects necessary to provide a comprehensive answer, it did produce some insights within the context of the three Series tested.

Analysis Of Results Affecting Individual Pulp And Chip Consumers

Testing all meaningful combinations of individual consumer costs in Series I,II and III produced nine statistically significant results (Table 4.6) and several times as many statistically insignificant results. In a general sense, these statistically insignificant results can be thought of as results which this research might have produced (because it dealt with these subjects), but didn't. They are important because, in many cases there is some evidence produced that tends to support them and because of this, they may provide hints for future research. However, regardless of how convincing the evidence seems, since statistical testing indicates they were not significant, they should not be interpreted as results of this research. Each of the nine significant results concerning individual consumers are discussed below on a firm-by-firm basis.

Firm Number 2: Packaging Corporation Of America (PCA), Manistee, Michigan.

The PCA would probably (.82) have lower raw material transportation costs if a wood-energy plant were built in Rose City than if it were built in Idlewild. On the other hand, the difference between the PCA costs in the Benchmark Series (Series I) and either the Rose City

Series (Series II) or Idlewild Series (Series III) was not significant. However, if a plant is to be built at one of the two tested locations, they should prefer Rose City. The apparent reason is that, at the Idlewild location, the wood-energy plant apparently competes too effectively with the PCA for nearby low cost stumpage.

Firm Number 3: S.D. Warren, Muskegon, Michigan

Three significant results were reached concerning S.D. Warren. They will : (1) probably (.89) have higher raw material transportation costs if the wood-energy plant is built in Rose City than if it is not built at all, (2) probably (.88) have higher raw material transportation costs if the wood-energy plant is built in Idlewild than if no plant is built, and (3) probably (.83) save more money on raw material transportation costs if the plant is built in Rose City than if it is built in Idlewild. Based on these results S.D. Warren should: (1) discourage wood-energy development in either location, (2) if forced to pick one, prefer the Rose City location.

S.D. Warren is located near the southern edge of the heavily forested part of Michigan's Lower Peninsula and the edge of the study area. They presently compete closely with Buskirk,Inc. in Paris and Menasha, Inc. in Otsego for raw material. It seems likely that the reason the results of the modeling develop as they do is that

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S.D. Warren is too close to its competition to benefit from the new stumpage supply drawn into the market by the wood-energy plant, whether the plant is built at Rose City or at Idlewild. If a plant is to be built at one or the other location, they should prefer Idlewild because it is farther away from Muskegon.

Firm Number 4: Menasha, Inc., Otsego, Michigan

Two significant results were reached for the Menasha Corporation: (1) they would probably (.96) have lower raw material transportation costs if the wood-energy plant were built in Rose City than if it were not built at all, and (2) the Rose City location is probably (.87) better than the Idlewild location.

Menasha consistently, because of their location outside the study area, has the highest cost per delivered ton of raw material (Table 4.10).

Development of wood-energy in Rose City (Series II) would, according to the model, stimulate enough new timber sales to allow Menasha a significant reduction in raw material transportation costs without being in a position to compete with Menasha for nearby stumpage. However, when the location of the wood-energy plant is Idlewild (Series III), the beneficial effect of the new stumpage locations is offset by the increase in competition between the two for the nearby stumpage.

Table 4.10 -- Mean annual projected transportation cost per ton of biomass 1982-2012 ($/ton).

Consumer	I	II	III
1. Abitibi	9.18	8.64	8.90
2. PCA	10.14	8.94^{1*}	12.63^{1}
3. S.D. Warren	11.91^{2}	5.84^{2}	7.22^{2}
4. Menasha	37.22^{3}	32.29^{3,4}	36.09^{4}
5. Champion	9.81	10.97	9.83
6. Buskirk	9.24^{5}	7.19^{6}	16.33^{5,6}
7. Wood-energy	----	7.92^{7}	14.73^{7}

* Superscript digit indicates statistically significant difference (above .8) with paired value.

__Firm Number 6: Buskirk, Inc. Paris, Michigan.__

Paris, Michigan is located only 20 miles from Idlewild, Michigan. Simulated development of a wood-energy plant at Idlewild indicated Buskirk would probably (.89) have higher raw material transportation costs than if no plant were built (Series I). In addition, model results also predict Buskirk would probably (.97) have lower transportation costs if the plant were located in Rose City (Series II) than if it were located in Idlewild (Series III). It seems likely that this occurs because Buskirk is in a position to take advantage of the new

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stumpage supply generated by the wood-energy plant without having to compete so directly with it for nearby stumpage. Buskirk's results, unlike those obtained for the Menasha Corp., do not support the hypothesis that Buskirk should favor wood-energy development at either tested location. On the contrary, the results do suggest that Buskirk should oppose development in Idlewild.

Firm Number 7: Wood-energy plant

A wood-energy plant in Rose City would probably (.98) have lower biomass transportation costs than if it were in Idlewild. Table 4.10 indicates the average annual cost per delivered ton between 1982 and 2012 would be $7.92 at Rose City and $14.76 at Idlewild, an 86 percent increase. The reason for the difference is that, at Idlewild, the plant would be competing more directly with Buskirk, S.D. Warren, the PCA and Menasha for stumpage because they are relatively close to Idlewild. There are no competitors near Rose City so it is not necessary to travel as far to get stumpage.

Optimal solutions for individual firms can be obtained if the firm is treated as a network. The objective function of the linear optimization then becomes minimizing the sum of the transportation costs for the firm, rather than the networks as was done in this research. Since most firms are sufficiently large to require rather complex wood procurement programs this would

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would probably not produce trivial solutions. An example of the type of situation in which this optimization would provide useful information is if a firm has 20 harvesting locations, 6 long distance truck-loading decks and 5 different cost/ton/mile factors (functions of either individual trucks or subcontactors). In this complex environment, the linear minimization of transportation costs would be helpful. In general, the more complex the individual firm's wood procurement system is, the more likely it is to benefit from transportation cost optimization.

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Apparent Trends: Results With Less Than .8 Significance Level

Because the purpose of this research was to develop a modeling system rather than evaluate alternative models, large sample sizes were not particularly desirable. Consequently, many results which might have emerged as statistically significant with larger sample sizes are just below the minimum level of .8 (calculated as cumulative distribution frequency divided by 2). Although these are not statistically significant, they may be important because they suggest trends which may be verified if larger samples are taken. Four such trends emerged in the results of this research: one concerning the PCA, two for Champion International, and one concerning Buskirk.

Comparing the PCA results in Series I and II indicates they should perhaps (.63) encourage wood-energy development at Rose City. Since they are a major factor in the regional industry and .63 indicates a reasonably strong trend, a larger sample could provide valuable confirmation of this trend.

Champion International in Gaylord, the largest production capacity facility in the region (and one of the largest particle board plants in the world, capable of producing 365,000 tons of board per year) had no statist

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statistically significant results. Like the PCA, they are a major regional influence on the industry and as such their perspective on wood-energy is important. Two trends emerged which indicate Champion might not benefit from wood-energy development in either tested location. Champion's estimated transportation costs with the wood-energy plant in Rose City (Series II) might (.56) be higher than if no plant is built (Series I). In addition, they might (.67) expect lower costs if the plant is built in Idlewild (Series III) and that the Idlewild costs would be almost the same (probability of difference is .014) as the no-plant costs. Subjective comparison of the Series I ,II and III Champion costs indicates they have no particular reason to support wood-energy at Idlewild and should perhaps discourage it at Rose City.

Buskirk, in Paris, might (.77) have lower raw material costs if the wood-energy plant is built in Rose City than if no plant is built at all (Series I, Series II). This is so close to the .8 threshold that a larger sample would almost certainly produce significant results.

The results of Series I,II and III indicate Abitibi, Inc., in Alpena, probably would not experience higher or lower transportation costs if the plant is built in either tested location. All Abitibi signifi

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significance levels were below .3. On this basis, they probably should have little concern over wood-energy development at these locations. This result is probably due to their relatively isolated location within the region.

Costs Of Modeling

A model of the type developed here can be run using a wide variety of computers. With the recent introduction of microcomputers with over 300K (approximately 300,000 bytes) of memory, it is possible to run the entire model with no time-sharing costs at all. However, a trade off may exist between time and money. For example, it may be faster to use an existing mainframe optimizing package to solve large linear programs than to write and operate a similar microcomputer package. However, time-sharing costs may make the mainframe too expensive. Obviously, the expense of modeling is, to a large extent, dependent on such factors as hardware availability, the rate structure of available time-sharing facilities and the skill and backgrounds of programmers available. The large number of possible combinations of administrative factors, equipment and personnel precludes detailed prediction of modeling costs under all circumstances. The development costs discussed below are presented in the hope they may help prospective modelers plan their research.

Programs I and II were run on a microcomputer, therefore no time-sharing costs accrued. However, there are other costs which occur in microcomputer programming such as equipment purchase and maintenance which were not included in this analysis. Program III, the minimization of the transportation costs was conducted on the MSU CYBER 750 mainframe using the MPOS optimizing package. Final analysis and statistical testing was done using small programs on both the microcomputer and the mainframe which did not appreciably increase the cost. These are modeling costs, not inventory costs. As discussed in Chapter I, the biomass inventory on which the modeling is based is a complex subject. Appendix A contains a detailed discussion of the the requirements for such a project.

Programs I and II occupy approximately 50 K of memory when compiled. Program I requires a large random number file and the inventory data base to execute. These data files occupy 15K and 200K, respectively, on a Z-80 based microcomputer.

Program I, the timber sales simulator, took twenty to thirty minutes to execute. Most of this time the program was reading through the inventory data base. A typical linear program created by Programs I and II had 475 variables in the objective function and 85 constraint equations. This size linear program required 62,080 (171.200 octal) words of CYBER memory, took six seconds to solve, and cost roughly ten dollars when run at batch job (low cost option) rates. The largest problem required 119,040 words (350.400 octal), took 15.5 seconds and cost twenty dollars to execute. Nine such programs were run to obtain statistical parameters for the network minimization, and seven each for Series I,II and III, for a total of 31 production runs. These runs cost roughly four hundred dollars for memory time and required another four hundred and fifty dollars of connect time and administrative charges (e.g. mounting tapes and disk file storage). Less well documented costs such as debugging and various special program development costs (notably, creation of the matrix generator program MAGEN) required approximately five hundred dollars. The total mainframe cost was approximately $1850. A substantial, but unknown amount, was saved in both development and production runs by creating most mainframe jobs on the microcomputer and transferring the finished file to the CYBER, rather than creating these files with the CYBER editor. Technical consultations were available at no charge through the MSU Computer Laboratory. In terms of time required for model operation, once models and hardware are configured and operating smoothly, three to four man hours are required to complete one run.

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Problems Encountered In Modeling

The two problems encountered during this research were both caused by the limited memory capacity of microcomputers used for Programs I and II. Because the microcomputer memory was 64K it was not possible to have the output of Program I read directly into Program II. The relatively large number of computations required in the simulation and the extensive input/output needed to read through the inventory data in Program I, left no room to dimension output arrays. In addition since the arrays used in Program I are reused for simulating subsequent stumpage sales, they could not be destroyed with an "in-place" output file. Therefore, it was necessary to use intermediary disk files to transfer the output from Program I to Program II. This increased the disk read/write time by a factor of four and caused an average delay of 30 minutes in the execution of Programs I and II.

The second problem was due to the number of bits (on/off elements of memory) allocated to each byte (basic unit of memory) by the microcomputer. The Z-80 microprocessor allocated eight bits per byte. Because of the size of arrays required in the model, it was not possible to assign more bits using FORTRAN's double

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precision capability. Therefore, rounding errors occurred in summation of the large amount of biomass needed to meet the demand of the entire network of consumers for one year. Correct summation is essential because, unless the amount of biomass in a complete run of Program I exactly equals the amount demanded by all the consumers, no solution exists for linear minimization of the transportation costs. It is possible to circumvent this problem within the minimization program by using a two step linear minimization. However, because software for this two step algorithm is not as readily available as software for the one step minimization, it was decided to keep the one step algorithm and adjust biomass tonnage totals for each run using a small mainframe program. Both problems disappear if the newer generation of microcomputer (those having 16 bits/byte and much larger memory capacity ranging up to 1000K) is used. On the basis of the experience gained in this research, one should either use one of these newer microcomputers having at least 128K of memory or a mainframe for this size model. Either option would eliminate both the time and accuracy problems experienced with the Z-80 microcomputer used in this research.

Chapter V

Using The Model In Decisionmaking

Much of the value of this model as a decisionmaking tool depends on how realistic it is. As discussed in Chapter II, the primary constraint on this realism is that some model components were simulated or held constant during development and preliminary testing. The purpose of this chapter is to explain how two of the most important of these may be altered to improve the model's performance and to discuss decisions regarding shock variable usage and stochastic estimation. The two model components discussed are: (1) forest biomass inventory and growth and (2) the regional transportation network. In addition, this chapter provides an estimate of the cost of applying this model to the study region and discusses its applicability to crop biomass and urban solid waste processing and disposal location decisions.

Forest Biomass Inventory And Growth Estimation

Estimating forest biomass represents a relatively new challenge and therefore few studies have been published (Kittleson 1979). In general, biomass inventory is similar to traditional timber volume inventory with the obvious exception of the special physical problems encountered in actually weighing entire trees. After individual-tree weight estimates are developed, they can be expanded to stand weight estimates using the same expansion factors developed for timber volume estimation. Without the use of remote sensing, further accurate expansion of these stand estimates to entire forests or regions has been prohibitively expensive. The preliminary research necessary to conduct such a remote sensing-based expansion within the study area has been completed during the first phase of this research (Appendix A).

This research focused on expanding field estimates of forest stand biomass to estimates of the biomass of stands as they appear on enhanced Landsat satellite images. Based on the results of this research, it is possible to produce a biomass map of the entire region using Landsat imagery. As discussed below, the expense and time required for such an inventory do not appear unreasonable. Actual application of the model to the region would require this type of complete biomass inventory, as opposed to the preliminary samples used during model development.

A more difficult obstacle to successful application of the model, especially over longer periods of time is estimating forest growth over large areas. While identifying and measuring forests on a regional scale has been made possible with remote sensing, no such technical solution has emerged for predicting how fast the forest will grow, nor does one seem imminent. For developmental purposes, statewide growth estimates from the MDNR were utilized. However, because of the low quality of timber and poor growing site conditions which typify the stands which are ideal for wood-energy, statewide growth estimates are probably too high. Several growth models have been developed for forests in the Great Lakes area. With one exception, they can not be applied to an area as large as the study area because they require too much detailed information. The exception is a generalized system developed recently which requires only site index in addition to timber parameters (Lundgren and Essex 1979). The combination of the Lundgren and Essex system and the preliminary research discussed in Appendix A provides an opportunity to include site index estimates for each of the Landsat forest types to produce growth estimates of wood-energy resources. Better estimates would probably be produced if these growth projections were stratified based on major soil groups in the region because it appears soil type is an important factor in determining biomass, particularly as the site index becomes critically low (OTA 1980 Vol.II,p.16).

Transportation Network

As discussed in Chapter II, transportation cost estimation during model development was based on the use of a general statistical factor (the RTF) which was used to expand straight-line distances within the region to estimated road-distance. This system will produce reasonably accurate transportation costs if roads are evenly distributed throughout a region. However, if roads tend to be concentrated in some areas and scarce in others as happens when there are major urban areas within a region, model estimates for facilities operating in heavily roaded areas will have unrealistically high transportation costs while those in more rural locations will have low transportation cost estimates. In an application of the model, it would be desirable to stratify the region and use several expansion factors (RTFs) to account for this variability. In most cases, this will probably be the only solution available.

In Michigan, however, a better alternative is available. The Department Of Transportation maintains a complete transportation network data base which includes roads for which they have primary responsibility and those for which state or federal funds have been spent. It would be very desirable to incorporate this data base into the model. The State data base was not included during model development because the microcomputer software used in model development is not compatible with the data base software. However, according to the MSU Computer Laboratory, this problem can probably be solved by: (1) dumping the data base on a computer tape in a generalized format, (2) loading the tape on the MSU CYBER, (3) writing a program to convert the generalized format to the CYBER format and (4) accessing the data base from a microcomputer while it resides on the CYBER.

If this sequence works, it would be productive to obtain improved estimates of the cost per mile per ton of biomass from truckers in the region. If it does not work, improved cost per mile estimates from truckers mile would probably not improve the model accuracy. To produce accurate estimates of the actual costs, it would be necessary to gain cooperation of the forest products industry in the region. Their actual costs and, equally importantly, components of these costs could then provide the basis of the cost estimates. These components would then become shock variables.

Shock Variables

A shock variable can be broadly defined as any variable that is changed for the purpose of studying the response of the model to change. Because the model's optimization occurs within a repetitive (but not recursive) time simulation, any variable in the model is a potential shock variable for the next time period. This would introduce an error compounding recursive structure which would need to be monitored during successive model years. In addition to this error compounding problem, meaningful analysis of shock variables often requires high data precision levels because the internal impacts of the shocks must be monitored as well as the output of the model itself.

In addition, new assumptions can be included in the model in the form of new variables, which can produce an entirely new range of values for a particular shock variable. Two pivotal variables which should be used as shocks in a production application of this model are the transportation cost per ton per mile, discussed above, and the forest growth factors discussed in the inventory section of this chapter.

Assumptions made concerning individual components of the transportation costs are particularly important and complex. Therefore, they must be made explicit. As an illustration, the price of diesel fuel for trucks is a major factor in determining transportation cost per ton per mile. Within the last decade this price has been extremely unstable because petroleum prices have fluctuated a great deal. In general, all assumptions should be made as explicit as possible in model documentation. Special care should be taken to explain assumptions made concerning shock variables. They must be defined and in addition, because by definition values of these variables change during the course of model execution, functions defining these changes must be defined. The direction, quantity and time of changes in each shock variable must be specified clearly prior to model execution to make possible meaningful interpretation of results.

Stochastic Estimation

The decision to produce estimates with statistical parameters for a particular variable in any given application depends to a large extent on the application's context. Two general observations may be of value in this decision:(1) stochastic estimation is important to the extent that results of modeling will be a primary basis for decisionmaking and (2) random number-based simulation tends to obviate stochastic estimation.

The latter situation occurs because estimates based on large random samples are extremely precise but their precision is a function of the data's randomness, rather than the precision of the estimator. As a rule, random simulation is less expensive and is therefore tempting when budgets are of concern. If simulation (using a random number generator) rather than stochastic estimation (using repeated simulations to obtain a distribution of outputs) were used in a decisionmaking-directed application of this model, it would be necessary to at least statistically test several sets of randomly produced data against sample field data to verify that they are sufficiently representative. If, on the other hand, stochastic estimation is chosen, it must be kept in mind that, because the model is large and complex, each run requires much time and effort. Consequently, a tradeoff emerges between stochastic estimation, an accurate and expensive approach and random simulation, a less expensive but probably less accurate approach in most cases.

One way to approach this question is to present decisionmakers with a series of three time/cost options: (1) emphasizing stochastic estimation, (2) combined stochastic estimation and random simulation, (3) emphasizing random simulation. They could then select the option which most closely met their needs.

Each of these decisions, from forest inventory through transportation cost estimation and shock variable use to decisions about estimator distributions, should be made by the decisionmakers who will use model results whenever possible. The more often decisionmakers are included in these types of decisions, the more confidence they will have in the model output.

In addition to involving decisionmakers in the modeling as much as possible, it is desirable to try to keep the model separate from the modeler in the eyes of decisionmakers. It is quite obvious to the modeler that the model's integrity, consistency and accuracy, as well as its more obvious attributes such as speed of computation, are distinctly different from his own. On the other hand, the only knowledge decisionmakers would normally have about the model must come from the modeler. Therefore, the modeler and model are closely associated from the decisionmakers' perspective. Obviously, to some extent this is inevitable. The point is that when ever possible, decisionmakers should be encouraged to focus directly on the model itself. On the other hand, how well a decisionmaker understands a model and its assumptions, and how well he works with a modeler, is probably as important as technical aspects of the model application in determining the ultimate quality of the decisions made using it, perhaps more so.

Cost Of Applying The Model For Planning

The cost of applying the model for decisionmaking within the study area depends to some extent on which of the suggestions discussed above are included in the application. In general, the best application would include as many of the suggested additions as possible. Cost of applying the model to the study area in the Northern Lower Peninsula of Michigan can be divided into three general catagories: biomass inventory, obtaining forest products industry inputs and the cost of modeling. A biomass inventory of the region would cost roughly

$11,000 in 1983:

- Landsat imagery	$2,000
- Biomass mapping	$5,000
- Site index factor experiments	$2,000
- Computerized data base creation and checking	$2,000
	$11,000

Obtaining inputs from the regional forest products industry would cost approximately another $2,000. These inputs would include: each plant's total requirements subdivided by tree species (to facilitate comparison with wood-energy), their recent past transportation costs and projected transportation costs, and their harvest schedules for as far into the future as possible. Unfortunately, it is unlikely that operators would be able to supply location specific harvest schedules more than one year in advance. This is because in the past operators made longer term contracts and were left with too much wood when they reduced production. As a result, now they are inclined to buy wood for the purpose of keeping their plant yards full rather than to meet projected production levels. This is a costly change because it places operators at a disadvantage in bargaining with wood growers. A plant's need for wood can be easily determined simply by estimating the amount in their yard. For purposes of modeling, their recent stumpage purchases and harvesting schedules on their own land are likely to be the best information available from the industry. Even if this is true and no other data is available, this input can be used to modify random location simulations. A modified random simulation has the important advantage of permitting construction of spatial demand cones around individual operators. Graphic presentation of these cones would make a major improvement in the interpretability of the model's assumptions and results.

The third major cost catagory, modeling, would cost from $8,000 to $10,000 using the model developed in this research. The breakdown of these costs would be very similar to those experienced in model development and are discussed extensively in Chapter III. On this basis, the total cost of the application is estimated to be $21,000 - $23,000. This estimate, which includes both personnel and supply costs, is based on five assumptions:

1. no subsidization of any kind occurs,
2. utilization of existing remote sensing, cartographic and computing facilities (no additional hardware or software needed),
3. no training of personnel beyond familiarizing them with the existing equipment and facilities,
4. no overhead costs are incurred,

5. technical specifications of the inventory would be identical to those detailed in the Appendix A discussion of developmental research specifications.

In terms of time, this application, would probably require four to eight months. In addition, MSU is the only facility in Michigan where the application could be done this inexpensively within this time frame. This is true because the great diversity of resources available here provides not just options that can be made to work, but a range of alternatives from among which an efficient system can be developed.

Agricultural Crop Biomass Conversion To Alcohol

Some resource planners regard potential competition for land between food and energy as bioenergy's most serious liability (Mitre Corp. 1977). The model developed in this research can be adapted to study this conflict very easily. The only significant change that would be needed is to include delivered price of the harvested crop for each competing use. To the extent crop biomass is more valuable per unit of weight than wood, the price paid at the elevator is more important to include than the price paid at the forest products plant for wood. If, at some point in the future, wood-energy industrial location analysis using models similar to the one discussed here becomes more sophisticated, it will probably be desirable to include delivered wood price.

Estimation of the impact of crop biomass-to-alcohol conversion facilities on transportation costs is possible using this model. The model can focus directly on the question of when, under a given set of circumstances, an economic incentive emerges for a particular farmer to sell his crop for energy rather than food. It appears likely that the trend away from food toward energy will begin to appear indirectly at first (OTA Vol.I,p.121). Farmers now producing dairy silage (unless they are also dairy products producers) will probably be the first group tempted to switch markets. The argument for this is that their crops are relatively high in bulk and low in value compared to cash crops produced for human consumption.

Locating Urban Trash Processing And Disposal Facilities

Municipal and industrial trash disposal, particularly in major urban areas, is becoming increasingly difficult and expensive. In response to rising costs, increasingly specialized equipment is being employed. It is no longer simply a matter of refuse being picked up and driven to the dump by one man with a light truck. Larger trucks with teams of men pick up and compress the rubbish. In our largest cities it is transferred from these trucks, compressed again, loaded on

semi tractor/trailers and driven to a remote landfill. It is a costly and complex process. Obviously, locations of the landfill and the intermediate transfer station, if one is needed, are very important factors in the cost equation.

This application of transportation cost minimization requires no product cost factors to account for market value. In fact, it can be argued that a benefit factor could be added to the transportation cost minimization as an estimate of how much people are willing to pay to have their trash removed. Trash producers, in this application, are directly analogous to biomass producers in wood-energy or crop-energy analysis. Therefore, it would be necessary to aggregate individuals into groups, for example city blocks or neighborhoods, so they could be treated like timber sales locations or crop fields were in the biomass analysis. Without this aggregation, the linear program could become too large to be solved. As in the biomass analyses, this aggregation would probably not seriously decrease the quality of the model's estimates.

One advantage metropolitan areas have over rural areas for purposes of this model is that almost all of them have very well developed road networks. In addition, most larger metropolitan areas have computerized data bases which can be used to obtain actual point-to-point road distances rather than estimates generalized for the entire area. With these few changes, the model would be capable of comparing either alternative trash disposal sites or transfer sites.

Chapter VI

Summary And Conclusions

As discussed in the introduction, the overall purpose of this research has been to develop a modeling system to support wood-energy policy analysis. To this end, two broad objectives were determined: (1) study the impact a wood-energy plant at a particular location would have on raw material transportation costs of the existing regional network of forest products consumers and (2) compare this impact with impacts produced with the plant at alternative locations under different conditions. The specific objectives of the research were as follows:

1. simulate a biomass supply based on actual market prices and actual regional consumers,
2. develop a system for estimating both: (1) the distance between the simulated biomass supply locations and the network of consumers and (2) the cost of transporting biomass from its location in the woods to consumers,
3. minimize transportation costs for the entire network for one time period,
4. repeat steps one through three within a time simulation which permits stochastic minimization, forest resource growth and the

introduction of shock variables at specified times to simulate anticipated future structural changes in the economy and ecology of the region.

These four objectives have been achieved. Program I simulates biomass harvests until enough has been harvested to meet the demand of all competing consumers in the network for one year. Program II computes distances between all possible combinations of simulated biomass harvest locations and consumers. It then converts these to estimated road-distances that would be required to move the biomass from each harvest location to each consumer and estimates of the transportation cost. Program III minimizes transportation costs for the entire network. Appendix B contains flowcharts and source code listings for Programs I and II and a sample of linear programming input and output as well as the small batch program needed to execute the Program III minimization. No independent computer program was required to simulate the passage of time because Program I and II were written to accomplish this during their other computations. Since Program III's only input is from Program I and II, its time simulation is automatic.

Results Of This Research

Four sets of experiments were conducted using this model: (1) a series of 1982 simulations to provide preliminary estimates of the statistical parameters of other estimates, (2) a Benchmark Series to model the existing network of consumers, (3) a series placing a hypothetical wood-energy plant at Rose City and (4) a similar series with the plant at Idlewild. The precision series demonstrated that the model system will produce extremely precise (less than one percent apart at the 90 percent confidence level) estimates.

Comparison of existing (benchmark) network costs with cost estimates which included the wood-energy plant at Rose City and Idlewild produced three statistically significant results. First, the existing consumer network will probably have lower transportation costs if a wood-energy plant is built at Rose City than if no plant is built at all. Second, existing consumers, not including the wood-energy plant, will probably have lower transportation costs if the wood-energy plant is built at Rose City than if it is built at Idlewild. Third, the consumer network, including the wood-energy plant will probably have lower transportation costs if the wood-energy plant is built at Rose City than if it is built at Idlewild. Overall, the model's demonstrated ability to distinguish between alternative potential locations for a wood-energy plant at a statistically significant level is the most important result. This indicates that the model probably has the potential to provide policymakers with useful analytical support in more complex, real-world situations. In addition to these results, statistically significant differences between transportation costs to individual firms were produced. Although transportation cost minimization actually occurs only for the entire network's cost, individual firms can use the model output with some limitations. Most importantly, individual firms must realize that the goal of the minimization is still to minimize the network transportation costs as a whole, not their own costs.

The only component of the model that was not computerized was a master program which would repeatedly execute Programs I,II and III. The master program was not possible because Programs I and II were run on a microcomputer while Program III ran on a mainframe computer. Under these circumstances, the most a master program could have done was to repeat Programs I and II several times. Their output would then have been transferred to the mainframe where another master program would have run repeated minimizations. With these limitations, it was determined that the master programs required more effort than they were worth. Single runs of Programs I, II and III do not not represent a significant burden.

The model should offer decisionmakers a useful tool for studying bio-energy industrial location when it is combined with a biomass inventory. Its utilization of the optimizing linear program within a simulation framework requires explicit objective functions and constraint specification while still permitting realistic simulation.

The primary objective of this research was to design and develop this model. Therefore, the preliminary estimates discussed extensively in Chapter III should not be interpreted as accurate estimates of network transportation costs. They are only examples of what the model can produce, although at this time they are the best estimates available. Model results will only be useful for decisionmaking if the assumptions upon which they are made are realistic (Chapter V).

Opportunities For Further Research

Five substantive catagories of further research have emerged during this study: (1) development of a forest resource data base for modeling from Landsat imagery of the study region, rather than from existing forest cover type maps, (2) creation of a general forest growth projection system which is compatible with forest type mapping done from satellite imagery, (3) changes in the model to permit differentiation among individual firms in terms of their efficiency in minimizing raw material transportation costs, (4) expansion in the model to permit direct interactive input of each factor determining cost/mile, (5) integration of transportation cost impact assessment, more general economic impact assessment (i.e. changes in stumpage price) and environmental impact assessment into one model. These needs are discussed sequentially below. They are viewed as being additions to further tests on the technical details of the model developed in this research. The two most important tests needed are: (1) making each estimate stochastic rather than deterministic, and (2) general sensitivity testing.

Appendix A reports the results of research which provides basic information necessary to conduct a regional forest biomass inventory. An inventory of this kind would produce a data base which should be substituted for the cartographically-derived data base used in the development of this modeling system. Linking satellite-based forest inventory with the transportation cost analysis model developed in this research would provide a useful overall system for analysis of bio-energy location decisions. As detailed in Appendix A, no technological barrier exists to this link. The major obstacle is money. Conducting a computerized inventory of a large area is expensive. As the availability of computer systems capable of coping

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with enormous amounts of data increases, the seriousness of this obstacle will decrease.

Research concerning regional forest growth projection systems also a high priority. Growth forecasting has traditionally been confined to small areas because the primary factors which determine growth are not easily generalized. One approach to this problem which seems to have promise is integrating the computerized data base produced during a satellite-based biomass inventory with computerized soil and hydrologic data bases. This three layered system could provide the basis for expanding site-specific growth tables to provide estimates for the entire region.

From the perspective of either an existing chip-consumer or a hypothetical wood-energy plant, results of the current study should appear tantalizingly useful. They demonstrate how the technique might work but don't spell out the details. Another important area research is to increase the model's applicability to decisionmaking in individual firms. The major constraint preventing this is that the transportation cost minimization accomplished with linear programming, if it is used within the model structure tested here, has the objective of minimizing of the entire network's transportation costs rather than one consumer. If the entire network is defined as the subject of the research, there is simply no way to minimize an individual firm's

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costs. However, individual firms could make good use of the model structure, and probably much of the data as well, by treating each of their harvesting locations as an origin in the system and their plant or wood yard as the destinations. This concept could also be useful for harvest scheduling.

It would also be helpful to change the model to permit individual consumers to be treated differently in terms of their efficiency in minimizing their transportation costs. For example, if a consumer is able to have consistently lower transportation/mile costs, he would have a comparative advantage over his competition. This factor could be included in the model.

An application of this model not discussed in the present research is the increasing role of independent truckers in transporting raw material to Michigan forest products industries. An operator could minimize his costs using the model structure as it is defined in this research. Applied research translating the general concepts of linear transportation cost minimization into terms that are meaningful to the transportation specialist is needed.

Long-term research priorities for bio-energy industrial location research are similar to those in many other regional resource areas. Decisionmaking concerning these subjects is difficult for many reasons. A

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synthesis of economic and ecological impact forecasting is needed to provide a comprehensive policy model. Industrial bio-energy is a new use of a resource and it will probably occur on a large enough scale to be economically feasible. Therefore, it will probably develop relatively quickly and be important to both the economic and ecologic health of a region. So the need to integrate economic and ecological models is particularly pressing.

As discussed extensively in Appendix A, the issue of soil nutrient depletion from whole-tree harvesting is important in wood-energy planning. This is primarily an ecological impact that would occur away from the wood-energy plant. A similar problem is damage to timber reproduction due to dragging (known as skidding) of whole trees from their growing locations to chipping locations. Recent research in forests similar to those of this study region suggests that between 27 and 47 percent of unharvested trees are wounded during whole-tree harvesting and that skidding causes at least two-thirds of the damage (Kelley 1983). This kind of information should be coordinated with growth forecasts, especially if reharvesting is anticipated.

Air and water pollution caused by burning the chipped wood at the power plant are the other major class of environmental impacts which need to be studied. To provide policymakers with comprehensive models for

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planning, models must include these factors as well as the purely economic considerations.

Application Of The Model

At this time it is not possible to predict when wood-energy will begin to become a profitable enterprise, if ever. Obviously, the price of oil is an important consideration. However, there are many other factors, including such imponderables as what the prevailing interest rates might be at any time in future. High on the list of uncertainties faced by prospective wood-energy producers is the question of how the social and environmental impacts of industrial scale wood-energy development will be evaluated by regulatory agencies. Will developers meet with assistance or resistance to their plans?

No reason has emerged why this model should not be a useful tool for wood-energy (and, as discussed in Chapter IV, bio-energy in general) industrial location analyses. Like most other tools produced by modern science, this model cannot itself prevent misuse or, in particular, biased application. In any application, the only real guarantee available that the model is being correctly applied is the intent of the modeler, which is difficult if not impossible to ascertain. Decisionmakers who will use the model output are, by default, responsible for providing a context which encourages unbiased applications.

REGION

APPENDIX A

REGIONAL FOREST BIOMASS INVENTORY AND ANALYSIS SYSTEM

A Regional Forest Biomass Inventory and Analysis System

(Final Report on Title V funded system development)

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Abstract

This report (1) describes the development and testing of a regional scale forest biomass inventory system, (2) presents preliminary biomass-per-unit-area estimates and (3) discusses ongoing development of a regional economic modeling system which will use the biomass inventory to forecast effects of bio-energy resource development. The inventory system is based on Landsat satellite imagery. Maps produced using the Landsat imagery are compared to Michigan Department of Natural Resources (DNR) forest cover type maps of two study areas in the northern lower peninsula of Michigan. Detailed stand composition of the Landsat derived maps is obtained from the DNR maps. Biomass-per-acre estimates of DNR types are developed by expanding individual tree biomass equations to stand equations using DNR stocking data (size and density) supplemented with field observations. In turn, these stand biomass estimates are expanded to the more general Landsat forest types.

The regional economic model necessary to effectively utilize the inventory has been developed and is being documented. It is a hybrid computer model based on a linear programming minimization of biomass transportation costs. The model allocates biomass resources among the network of competing pulp users in the region. Application of the linear programing model within a simulation framework will permit some of the economic impacts of development of a bio-energy industry to be forecast under a variety of possible future economic conditions.

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INTRODUCTION

The purpose of this study was to develop a system for inventory and analysis of forestry biomass in northern Michigan. The specific objective of the inventory portion of the study was to create a system for mapping Michigan forest biomass on a regional scale. The specific objective of the analysis portion was to create a regional economic modeling system which could efficiently use the inventory output to predict some potential impacts of a wood-burning electric power plant on the region. Comparison of alternative inventory methods resulted in the decision to develop a system based on a combination of enhanced Landsat satellite imagery, existing forest type maps and field checks. Several alternatives were explored including the use of medium scale color infrared aerial photography. The major reason for including existing type maps in the inventory system was to make the best possible use of existing sources.

Alternative economic modeling systems were evaluated to determine their potential for effeciently utilizing the inventory data and providing useful impact predictions. It was determined that no single existing modeling system could meet the requirements of the project as well as a modeling system that could be developed within the Resource Development Department. This system has been created.

It is a hybrid, computer-based model containing a linear programming minimization of regional forest products network transportation costs within a stochastic simulation framework. It takes advantage of the potential of linear programming for efficient optimization by placing it in economic environments that simulate the future based on a variety of assumptions.

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By combining this model with accurate, timely information gathered using the inventory system it will be possible to predict impacts of bio-energy development on this region. It will also be possible to predict the optimum development location. An important additional capability of the combined systems is that it permits the impacts of development at alternative locations to be compared against each other quickly enough to be meaningful within realistic time constraints. Applied together, the inventory and analysis systems should assist public and private decisionmakers by providing them with a method for making systematic comparisons of alternatives for bio-energy development by combining recent scientific advances in remote sensing, mathematical modeling, regional economics and systems simulation in a useable package.

FUNDING

Initial development of the inventory and analysis systems and quantification of the inventory for modeling was supported by a Title V grant from the Cooperative Extension Service at Michigan State University. Development of the regional economic model is being supported by McIntire/Stennis Act project number 1075. This research is being conducted within the Resource Development Department, College of Agriculture and Natural Resources, Michigan State University.

I. INVENTORY SYSTEM DEVELOPMENT AND TESTING

The inventory system was developed and tested in four phases:

a) sample area selection and map base selection and reproduction,

b) Landsat image enhancement and mapping,

c) field surveying and

d) analysis.

A. Sample Area and Map Base Selection and Reproduction

The primary objective of this phase was to select a study area that was both representative of the region and, if possible, of special significance for wood-energy development. Early proposals focused on forests around Hersey, Michigan because Consumers Power Company plannned to construct a wood-fired electric plant there. However, before research began, Consumers abandon the Hersey site. Subsequent discussions with Consumer's planners, analysts in the Michigan Public Service Commission's Scientific and Technical Research Section and foresters from the Michigan Department of Natural Resources revealed roughly a dozen locations in the northern lower peninsula were being considered as potential locations for such a plant.

Analysis of wood supply area radii for these locations resulted in two significant findings. Approximately half of the potential locations of fuel supply radii overlapped forested portions of central Osceola county and fuel supply radii from all the potential locations included some of Michigan's poorest soils. Low productivity, sandy soils are of special concern in wood-energy because the most cost effective harvesting method, whole-tree chipping, removes the entire tree, leaves and all. Numerous studies have shown that whole-tree chipping can adversely effect nutrient recycling on sites where nutrient supply is marginal (Malkonen 1973 and Kittleson 1979). In addition, a preliminary survey of over sixty (60) biomass prediction equations and tables confirmed the common sense idea that forest biomass is often significantly lower on poor soils than on better soils (Hudson and Kittleson 1978).

Based on these considerations, two sample areas were selected: one in central Osceola County and one of lower productivity, sandy soil in Kalkaska County. In Osceola County, the townships were:

1. T19N,R8W:T19N,R9W
2. T18N,R8W;T18N,R9W.

In Kalkaska County, the townships were:

1. T26N,R5W;T26N,R6W
2. T25N,R5W;T25N,R6W.

In both of these areas a majority of the forested land is owned by the State of Michigan. Therefore, access for field checks was not a problem and forest cover type maps were readily available which were typical of the quality and vintage of maps in the region. Osceola County type maps were updated in 1968. Kalkaska County type maps were updated in 1969. Both counties will be remapped in the near future based on U.S. Forest Service forest inventory data. Each study area included all state land within the 144 square mile (four township) areas.

Because the region forest covertype has been mapped extensively on medium scale color-infrared aerial photography, the reliability, expense and time required are relatively well known. By contrast, how well Landsat imagery and existing forest cover type maps compare and might be effectively used together has not been extensively studied. To be as efficient as possible, any inventory

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inventory system must make use of existing data. Consequently, the decision was made to develop a system using the existing forest type maps. Medium scale CIR type mapping can be substituted directly for these maps if needed.

The map base for each sample area was a 1:24,000 scale mylar reproduction of a mosaic made from U.S. Geological Survey topographic maps (7.5 and 15 minute maps were used) Michigan Department of Natural Resource (DNR) forest type maps of the areas were reduced slightly in scale from 1:15,840 to 1:24,000 and registered to the topographic base using a cartographic pin bar. Landsat imagery was interpreted and manually mapped directly on pin registered mylar overlaying these maps. The product of this process was three layers of maps: (1) topographic map mosaic, (2) DNR forest type map and (3) Landsat map. Procedures used in Landsat mapping are discussed in Section B.

B. Landsat Mapping of Forest Types

One midsummer 1978 Landsat image covered both the Kalkaska County and Osceola County study areas. The black and white transparencies of this image were contrast-stretched to enhance the difference between major forest types. Enhancement was based on densitometric sampling of the major forest types in each of the four spectral bands of the image. Diazo color copying of the black and white images produced a color transparency composed of a yellow band 4 image, a magenta band 5 image, and a cyan band 7 image. Placed together, these images form a color composite similar in appearance to a typical Kodak 2443 color-infrared (CIR) image exposed through a Wratten 12 filter. This similarity is an important advantage in interpretation because most photointerpreters have experience with CIR and are, therefore, able to correctly interpret the similar Landsat image. This greatly increases the speed and accuracy of mapping. For this reason, the "pseudo CIR" Landsat image was selected for mapping in spite of the fact that other combinations of bands produced better edge definition between forest types. For example, a contrast-stretched ratio of positive 5 and negative 7 (+5/-7) bands produces significantly better contrast between jack pines (Pinus bauksiana Lamb.) and mixed swamp conifers. Distinguishing between these two types is sometimes a problem is this region using the "pseudo CIR" Landsat image. However, the +5/-7 ratio produces color combinations that are so unlike any other film/filter combination that it is impossible to interpret them visually without additional training. Imagery of unusual ratios of various bands has been successfully used to supplement "pseudo-CIR" imagery in northern Michigan (Sicuranza and Carpenter 1980). Use of this imagery requires extensive experience in regional natural vegetation mapping and dual image projection systems. Most problems interpreting natural vegetation on a pseudo-CIR Landsat image can be solved by an interpreter with intimate knowledge of the regional vegetation patterns if he uses topographic maps during interpretation.

The diazo color composite was copied at 1:1 on Kodachrome 25 film using a Hasselblad copy camera system because diazo film fades quickly under the intense light of cartographic projection equipment. Mapping from the Landsat image was done on the MSU Remote Sensing Center's cartographic equipment using 16X magnification to bring the Landsat scale from 1:1,000,000 to 1:62,500. This 1:62,500 scale map was later enlarged to 1:24,000 for analysis.

The sample areas were mapped into the following catagories: hardwood forest, conifer forest, mixed hardwood and conifer forest and nonforested, these being the Level II forest categories in the Michigan Land Cover/Use

Classification System (Michigan Land Use Classification and Referencing Committee 1975). The only supplemental reference used during mapping was the topographic mosaic to which the projected Landsat image was registered on the mapping surface. To duplicate production inventory mapping as closely as possible no reference was made to other aerial photography or the DNR forest type maps of the region to resolve questions. Questionable stands were identified and overall 120 locations required field checks to determine the correct type.

C. <u>Field Checking Procedure</u>

Field checking Landsat interpretations required approximately 18 man-days. An average of 13 stands per day were visited per day by a two-man team using a four-wheel drive vehicle. These Landsat field checks compromised approximately one half of the actual field time for the project. The other half of the field was devoted to checking the accuracy of the DNR type maps and gathering data on timber stand size and density to supplement DNR stocking estimates. In general, the DNR type maps were accurate in both counties. Differences between the maps and the stands today are due mostly to growth since the maps were published. Ninety-four percent of all stands checked were typed correctly, However, over the years size and density has changed of the classes changed in approximately one-eighth of the stands. Due to time constraints, no comprehensive statistical sample of the maps was possible. Therefore, these figures should be interpreted as preliminary orders of magnitude, not statistically reliable estimates.

In addition to the Landsat field checks, sixty stands in both study areas were cruised for type, diameter (dbh), height and basal area. One plot was recorded for each stand. The location of the plot was systematic and subjective and was based on what was judged the representative or typical part of each stand. Identification of sample stands was done randomly from the DNR maps. Fifty unique types were identified which were representative of the types in the study area. These plus ten samples allocated to aspen and hardwood reproduction made up the stand size sample (Figure 1). The sample drawn from mixed types was very small and diversity encountered in them large. In light of these problems and time constraints, it was decided to use the average of conifer and hardwood size/density figures for mixed types.

Figure 1. represents the results of a sample of only 60 plots. Considering the large number of other variables that must be assumed to be constant to provide meaningful statistical analysis and the developmental purposes of this research, it was determined to use this data for developmental purposes without distributional parameters. Stochastic estimates are necessary before this type of data can be used in a production inventory.

D. Analysis

Based on average stand size and density as determined in the field and from the DNR data (Figure 1), individual tree weights (Figure 2) were expanded to stand weights per acre (Figure 3). Over two hundred forest types composed of combinations of these types were used as estimates of

Figure 1. Average Hardwood and Conifer Stand Sizes

Size/Density Class*	dbh (inches)	height (feet)	stems/acre
Hardwood			
1	3	25	250
2	"	"	550
3	"	"	1000
4	7	50	94
5	"	"	206
6	"	"	375
7	12	65	31
8	"	"	70
9	"	"	127
Conifer			
1	3	15	250
2	"	"	550
3	"	"	1000
4	7	39	94
5	"	"	206
6	"	"	375
7	12	70	23
8	"	"	51
9	"	"	94

*Michigan Department of Natural Resources numbering system (Michigan Department of Conservation, 1968).

Figure 2. Individual Tree Weight (green pounds)

Forest Type	Restocking	Pole Timber	Saw Timber
1. Aspen (Populus tremuoides, Mich*)	38(3)	401(3)	1515(3)
2. Maple (Acer spp.)	70(1)*	437(2)	1594(2)
3. Oak (Quercus spp.)	42(4)	429(4)	1884(4)
4. Mixed lowland hardwood** (predominantly Fraxinus, Ulmus, Acer spp.)	70(1)	437(2)	1594(2)
5. Balsam fir (Abies balsamea L.)	41(10)	421(6)	1990(8)
6. Hemlock (Tsuga canadensis (L.) carr)	21(7)	396(8)	2118(8)
7. Jack pine (Pinus banksiana Lamb.)	84(12)	629(12)	2475(11)
8. Red pine (Pinus resinosa Ait.)	30(11)	363(6)	2358(6)
9. Spruce (Picea spp.)	109(5)	449(6)	2111(6)
10. White cedar (Thuja occidentalis L.)	25(7)	261(9)	817(9)
11. White pine (Pinus strobus L.)	30(11)	410(8)	2344(8)
12. Mixed lowland conifer*** (predominantly Abies, Picea, Thuja spp.)	67	355	1464

* Sources for biomass equations appear by number in Appendix A.

** Maple data used because no mixed lowland hardwood biomass data available.

*** Spruce and cedar averages used because no mixed lowland conifer biomass data available.

Figure 3. Stand Weight Per Acre (pure types only, in green pounds)

Coniferous Types

SPRUCE (Picea spp.)		HEMLOCK (Tsuga canadensis (L.) Carr.)		CEDAR (WHITE) (Thuja occidentalis L.)	
S1	27,250	H1	5,250	C1	62,500
S2	59,950	H2	11,550	C2	13,750
S3	109,000	H3	21,000	C3	25,000
S4	42,206	H4	37,224	C4	24,534
S5	92,494	H5	81,576	C5	53,766
S6	168,375	H6	148,500	C6	97,875
S7	48,553	H7	48,714	C7	18,791
S8	107,661	H8	108,018	C8	41,667
S9	198,434	H9	199,092	C9	76,798

BALSAM FIR (Abies balsamea L.)		WHITE PINE (Pinus strobus L.)		RED PINE (Pinus resinosa Ait.)	
F1	10,250	W1	7,500	R1	7,500
F2	22,550	W2	16,500	R2	16,500
F3	41,000	W3	30,000	R3	30,000
F4	93,574	W4	38,540	R4	34,122
F5	86,726	W5	84,460	R5	74,778
F6	157,875	W6	153,750	R6	136,125
F7	45,770	W7	53,912	R7	54,234
F8	101,490	W8	119,544	R8	120,258
F9	187,060	W9	220,336	R9	221,652

JACK PINE	MIXED LOWLAND CONIFERS
(Pinus banksiana Lamb.)	(predominantly Abies, Picea, Thuja spp.)
J1 21,000	Q1 16,750
J2 46,200	Q2 36,850
J3 84,000	Q3 67,000
J4 59,126	Q4 33,370
J5 129,574	Q5 73,130
J6 235,875	Q6 133,125
J7 55,775	Q7 33,672
J8 123,675	Q8 74,664
J9 227,950	Q9 128,666

Hardwood Types

ASPEN	OAK	MAPLE
(Populus tremuloides Michx.)	(Quercus spp.)	(Acer spp.)
A1 9,500	O1 10,500	M1 17,500
A2 20,900	O2 23,100	M2 38,500
A3 38,000	O3 42,000	M3 70,000
A4 37,694	O4 40,326	M4 41,078
A5 82,606	O5 88,374	M5 90,022
A6 150,375	O6 160,875	M6 163,875
A7 46,655	O7 58,435	M7 49,414
A8 105,350	O8 131,950	M8 111,580
A9 191,135	O9 239,395	M9 202,438

MIXED LOWLAND HARDWOODS

(predominantly Fraxinus, Ulmus, Acer spp.)

E1	17,500
E2	38,500
E3	70,000
E4	41,078
E5	90,022
E6	163,875
E7	49,414
E8	111,580
E9	202,438

Over two hundred forest types composed of combinations of these pure types occured in the study. Double type tonnage (for example A504, an aspen-oak pole sized stand) was calculated on a 60%/40% basis:

.6(A5 tons/acre) + .4(04 tons/acre) = A504 tons/acre.

Triple types were calculated on a 50%/30%/20% basis:

M5A4J1 tons/acre = .5(M5 tons/acre) + .3(A4 tons/acre) + .2(J1 tons/acre).

Individual tree weights (Figure 2) were obtained by applying equations from the sources indicated. These weights were multiplied by the stems/acre in the stand (Figure 1) to obtain stand weights per acre (Figure 3). Figure 4 illustrates the sequence.

Figure 4. Summary of Stand Biomass Estimation Process.

Step	Activity
1.	Average stand dbh, height and trees/acre data gathered from existing sources and supplemented with field surveys (Figure 1).
2.	Weight per-tree obtained from best available source (Figure 2).
3.	(Trees per acre) x (weight per tree) = stand weight per-acre (Figure 3).
4.	Combination types weights calculated: Double: 60% of dominant type weight per acre plus 40% of subordinate type weight per acre. Triple: 50% of dominant type weight per acre plus 30% of intermediate type weight per acre plus 20% of minor type weight per acre.

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II. MAPPING PROCESS

Comparison of the Landsat forest cover type maps (Level II) with the DNR forest cover type maps was conducted as follows:

1. Overlay pin-registered Landsat and DNR maps with a dot grid (5 acre/dot).

2. For each DNR stand record:

   a. DNR type
   b. Level II type
   c. number of dots

The major goal of this analysis was to determine which DNR types were mapped as hardwood, conifer, mixed, or nonforested on the Level II Landsat map. Another important objective was to develop a biomass-per-acre estimate for hardwood, conifer and mixed types that could provide a starting point for future Landsat biomass mapping projects.

Three FORTRAN programs were written for a micro computer which analysed and summarized the data that was extracted from the map comparison. All data analysis was conducted on a 64K RAM Vector Graphics, Inc. micro computer equipped with dual 635K disk drives.

Results and Conclusions of Inventory System

Two thousand one hundred and nine (2,109) DNR stand were mapped on seventy thousand three hundred fifteen (70,315) acres. Sixty-one thousand ten (61,010) acres or 87% were forested. Hardwood types dominated (Figure 6).

Figure 6. Level II Acreage Summary (both study areas, based on DNR data).

Type	Acres	% of Total	% of Forested
Hardwood	29,820	42	49
Conifer	13,640	19	23
Mixed	17,550	26	29
Non-forested	9,305	13	—

The small non-forested area (13%) is a consequence of both study areas being contained within state forests. It should not be taken as representative of the region as a whole. Figure 7 summarizes the Level II and DNR acreage results by township.*

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*Townships are numbered as follows:

Number	Name	Location
1	Cedar, Osceola Co.	T 18N, R9W
2	Osceola, "	T 18N, R8W
3	Rose Lake, "	T 19N, R9W
4	Hartwick, "	T 19N, R8W
5	Oliver, Kalkaska Co.	T 26N, R6W
6	Bear Lake (Middle), Kalkaska Co.	T 26N, R5W
7	" (South) "	T 25N, R5W
8	Garfield, Kalkaska Co.	T 25N, R6W

Figure 7. Landsat Mapping Accuracy and System Error Level, by Township.

Township Number	% Correctly Mapped on Landsat*				
	Hardwood	Conifer	Mixed	Non-forested	Cartographic and analysis-induced error**
1	85	95	80	99	0
2	98	98	90	96	0
3	93	100	86	95	1
4	88	99	88	98	1
5	89	98	67	85	5
6	80	90	70	99	0
7	98	95	85	84	2
8	100	88	80	93	1

---

* Assumes DNR type maps are correct

** Total Landsat acres minus total actual acres (measured as Total Level II acres minus total DNR acres)

Figure 8. Problem areas, by type and township.

Township Number	Hardwood	Conifer	Problem %* Mixed	Nonforested	Township Average
1	15	5	20	1	10
2	3	3	10	4	5
3	7	0	14	6	7
4	11	1	12	2	6
5	10	2	32	15	15
6	20	10	31	1	15
7	2	5	14	16	9
8	0	12	20	7	10

* (Landsat acreage - actual acreage)/Total acreage mapped in township.

Figure 8 provides a clearer picture of where Landsat mapping errors occured. Mixed forest mapping errors accounted for roughly 49% of all errors. Of this 49%, 40% came from townships 5 and 6. Based on acreage estimates, townships 5 and 6 should have accounted for only 29% of the error. The difference between Landsat and DNR maps of mixed types in these townships is due to the shrubby nature of the vegetation occupying poor sites on outwash plains. These areas were mapped as upland shrub (U) on DNR maps but mapped as mixed forest on Landsat. Typically, they contain shrubs (primarily various cherry species) having no main stem or leader. From an aerial perspective, they appear to be tree crowns. However, from the ground they are obviously open-crowned shrubs. Stereo interpretation of medium scale CIR imagery, as opposed to Landsat, would have prevented this discrepancy. Regardless of whether they are incorrectly mapped as mixed forest or correctly as shrub, these sites contain little biomass.

Figure 9 summarizes the results of the study in broad terms. Overall, 89% of the Landsat mapping was "correct" (accepting the DNR maps as completely accurate). This means that 89% of the area mapped on Landsat as either hardwood, conifer, mixed or nonforested was mapped the same way on the DNR maps. As indicated earlier, 94% of the sampled types were correct on DNR maps when field checked. However, the 89% accuracy figure for Landsat is aggregated for an entire township and therefore are not directly comparable to the location-by-location accuracy of the DNR maps.

Figure 9. Weighted Average Landsat Accuracy.

1 Township Number	2 Acreage Mapped	3 % of Total (rounded)	4 % Correct on Landsat overall in twp.	5 Weighted Value (rounded)*
1	6455	9.18	89.49	8.21
2	3170	4.51	95.19	4.29
3	1495	2.13	93.27	1.98
4	2550	3.63	93.42	3.39
5	8660	12.32	84.67	10.43
6	11970	17.02	84.66	14.41
7	19365	27.54	90.38	24.89
8	16650	23.67	90.11	21.34
TOTAL	70315	100.00		88.94

Weighted average % correct landsat mapping (on township basis) = 88.94% (89%)

* weighted value = % of total acres mapped x % correctly mapped over all Level II types in township (column 3 x column 4 = column 5).

The 89% accuracy figure for the Landsat should be interpreted as meaning that, for an entire township, one could expect an 11% difference between the acreage actually growing there and the acreage a Landsat survey (using similar methods) predicts is growing there at Level II. The important components of this definition are:

1. aggregation of acreages to township levels
2. similar mapping methods
3. Level II mapping.

The results of this study do <u>not</u> mean that for any point in these townships the probability that it is correctly mapped at Level II is 89%. The probability of the Landsat map being accurate on a location-by-location basis, although unknown, is certainly lower than 89%.

Figure 10 indicates that just over 80% of the area mapped was in Kalkaska county. This occured because the size of the state forest holdings in the study areas were four times as large in the Kalkaska county area as they were in the Osceola county area. The imbalance has the effect of weighing the biomass estimates from the poor Kalkaska county sites four times as heavily as those from the Osceola county sites. This produces what can be interpreted as a conservative biomass estimate since the poor Kalkaska sites produce less biomass/acre than the Osceola county sites.

Figure 10. Comparison of acreage mapped in Osceola and Kalkaska study areas.

	Osceola	Kalkaska
1. Acres	13,670	56,645
2. % of Total	19.5	80.5

III. BIOMASS OF FOREST TYPES

Biomass was estimated for each Level II forest type. Estimates were aggregated to township level as follows:

1. For each stand on the DNR map, the biomass per acre was multiplied by the number of acres to obtain the stand biomass.
2. This biomass was allocated to the Level II type given it during the Landsat mapping.
3. These stand biomass estimates were summed for the township by Level II type and divided by the acreage the type occupied in the township. The result was the Level II biomass per acre estimate for that type in that township.

Biomass was allocated on the basis of Level II Landsat mapping, not DNR maps. This means, if a stand was mapped as hardwood based on its Landsat image, it was included in the hardwood estimate regardless of its actual (DNR) type. Consequently, several coniferous, mixed and nonforested stands are included in the level II hardwood data. A similar situation exists for the Level II coniferous and mixed types.

Estimates were produced this way because the purpose of the study was to develop a regional biomass inventory system. An application of this system would probably result in similar mistyping. Within this context, it is not significant whether the Level II types are pure, as long as the the mix of species composing each type is constant. Figure 11 contains Level II biomass per acre estimates for each township in the study.

Figure 11. Level II Biomass Estimates (green tons per acre).

Township	Hardwood	Conifer	Mixed
Osceola Co.			
1	45.3	39.9	46.5
2	58.0	35.6	56.7
3	61.3	none*	60.0
4	55.3	29.3	53.4
Kalkaska Co.			
5	28.9	40.3	30.9
6	58.4	47.1	39.1
7	29.4	24.2	29.7
8	28.1	28.1	26.7

* No conifer types were mapped in this township.

Average weighted biomass for each Level II type was computed as follows:

1. Level II type acreage in each township multiplied by its biomass per acre equals its weighted value.
2. Weighted values summed for each type over all townships and divide by the total of all acres mapped in the type in all townships. The result is the weighted biomass per acre estimate for each type (Figure 11).

For example, in one township 4,380 acres were mapped as hardwoods. Hardwood biomass for the township was estimated to be 45.3 tons/acre. Therefore, the weighted biomass/acre for hardwood in this township is: 4580 x 45.3 = 207,474. County and total weighted biomass estimates are presented in Figure 12. Data was not aggregated on a county level to reach the overall biomass estimates.

Figure 12. County and Overall Biomass Estimates (green tons per acre).

	Hardwood	Conifer	Mixed
Osceola County	52.3	36.2	50.3
Kalkaska County	32.7	33.3*	31.6
Overall	39.5	33.3*	33.9

* Actual data: Kalkaska Co. = 33.291, Overall = 33.324. The numbers are nearly identical because Kalkaska County contained 99% of the conifers mapped.

As Figure 12 indicates, biomass estimates in the Osceola County study area were higher for all three types than were the same estimates from Kalkaska County. Because the same set of DNR type biomass per acre tables were used in both counties, the difference between the counties suggests there may be a wide range of biomass values occuring on different quality sites.

The causes of these differences, although beyond the scope of this study, may be related to differences in site quality or the way in which type differences are translated into spectral signature of a forest type on Landsat. How these signature differences are affected by the contrast enhancement process employed here probably also influences the estimates.

IV. REGIONAL ECONOMIC MODELING STATUS

Development of an analysis system to utilize data gathered from a regional inventory based on the above process has been recently completed and will be documented in my dissertation. Basically, the system consists of a linear programming minimization of network biomass transportation costs within a simulation framework.

For developmental purposes it is composed of four models:

I. A Simulation of regional biomass supply using biomass estimates and variable probabilities for sampling developed in this study.

II. Calculation of a transportation costs matrix from each supply location to each pulp user in the region.

III. Linear programming minimization of annual regional transportation costs.

IV. Simulation of time and repeated runs of models 1, 2 and 3 to obtain annual estimates of network transportation costs.

The simulation of biomass supply (Model I) may be elminated when a regional biomass inventory is available. However, during the developmental phases, Model I made repeated random supply locations possible in the linear program. This has the effect of outlining the approximate supply area (spatial demand cone) of each pulp user.

Using this four-model system, hypothetical new bio-energy using plants were introduced to the region. The impact of these plants on the existing wood users was predicted for alternative plant locations. The time simulation tracked the cumulative effect of modeling errors.

Summary

Seventy thousand three hundred fifteen (70,315) acres were mapped at Level II in Kalkaska and Osceola Counties, Michigan. Twenty-one hundred and nine (2,109) forest stands covering sixty-one thousand ten (61,010) acres were compared to Michigan DNR forest cover type maps to estimate (1) the accuracy of the Level II Landsat maps and (2) forest biomass for Level II types in Michigan. Results indicated Landsat mapping was 89% correct on a township by township basis. Individual tree biomass prediction equations were expanded to produce stand biomass prediction equations using a combination of DNR size and density data and field surveys. These stand biomass estimates formed the basis of preliminary Level II biomass estimates presented.

No major obstacles were encountered during the development and testing of this system; therefore, a regional biomass inventory based on a similar system should be successful. Although requiring considerable computational support, the analysis system of linear programming minimization of biomass transportation costs within a simulation model is an effective method of converting the regional biomass inventory data into information that decisionmakers should find useful.

Appendix A

Sources for individual tree biomass (Figure 2). Numbers indicate footnotes in Figure 2.

1. Average data used for restocking biomass. Average of biomass estimates from sources 4, 7, 8 and Young, H.E., 1972. Biomass sampling methods for puckerbrush stands. Forest Biomass Studies. pp. 179-192. Orono, Maine: University of Maine.

2. Steinhilb, H.M and Winsaver, S.A., 1973. Sugar Maple: Tree and Pole Weights, Volumes, Centers of Gravity and Logging Residues, NC-132. St. Paul, Minnesota: U.S. Forest Service.

3. Schlaegel, B.E., 1975. Estimating Aspen Volume and Weight for Individual Trees, Diameter Classes, or Entire Stands, NC-20. St. Paul, Minnesota: U.S. Forest Service.

4. Wiant, H.V., 1977. Sampling for Weight in Appalachian Hardwoods. Agricultural Experiment Station Paper 1516. Morgantown, West Virginia: West Virginia University.

5. Whittaker, R.H.; Bormann, F.H.; Liken, G.E.; and Siccama, T.G., 1974. The Hubbard Brook ecosystem study: forest biomass and production. Ecological Monographs. 44: pp. 233-252. Durham, N.C.: Duke University Press.

6. Steinhilb, H.M. and Erickson, J.R., 1972. Weights and Centers of Gravity for Red Pine, White Spruce and Balsam Fir, NC-75. St. Paul, Minnesota: U.S. Forest Service.

7. Young, H.E. and Carpenter P.N., 1967 . Weight, Nutrient Element and Productivity Studies of Seedling, and Saplings of Eight Tree Species in Natural Ecosystems, Tech. Bull. 28. Orono, Maine: University of Maine, Ag. Experiment Station.

8. Young, H.E.; Strand, L.; and Altenberger, R., 1964. Preliminary Fresh and Dry Weight Tables for Seven Tree Species in Maine, Tech. Bull. 12. Orono, Maine: University of Maine, Ag. Experiment Station.

9. Dryer, R.F. , 1967. Fresh and Dry Weight, Nutrient Elements and Pulping Characteristics of Northern White Cear (Thuja accidentalis), Tech. Bull. 27. Orono, Maine: University of Maine, Ag. Experiment Station.

10. Baskerville, G.L., 1965. Dry matter production in immature balsam fir stands. Forest Science Monograph, No. 9. Washington, D.C.: Society of American Foresters.

11. Schlaegel, B.E., 1975. Yields of four 40-year-old conifers and aspen in adjacent stands. Can. J. For. Res., 5, 278, 280.

12. Green, D.C. and Grigal, D.F., 1978. Generalized Biomass Estimation Equations For Jack Pine (Pinus banksiana Lamb.), Minnesota Forest Research Note No. 268. St. Paul, Minnesota: University of Minnesota, College of Forestry.

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Kittleson, K., 1979. A Discussion of Recent Forest Biomass Literature Concerning Survey Designs, Sampling and Modeling Procedures, Variable Selection and Nutrient Reserves. East Lansing, Michigan: (Mimeograph).

Malkonen, E., 1973. Effect of complete tree utilizations on the nutrient reserves of forest soils. IUFRO Biomass Studies. pp. 375-386. Orono, Maine: University of Maine.

Michigan Department of Conservation, 1968. Forest Type Mapping Instructions and Type Symbols, Department Letter #176. Lansing, Michigan: Michigan Department of Natural Resources.

Michigan Land Use Classification and Referencing Committee, 1975. Michigan land cover/use classification system. Lansing, Michigan. Michigan Department of Natural Resources (mimeograph).

Sicuranza, L.P. and Carpenter, G.F., 1980. Future Pipeline Development in the Northeastern Michigan Coastal Zone and Niagaran Trend: A Regional Analysis of Environmental Resources and Land Use. Lansing, Michigan: Michigan Public Service Commission, Scientific Research and Evaluation Office.

APPENDIX B

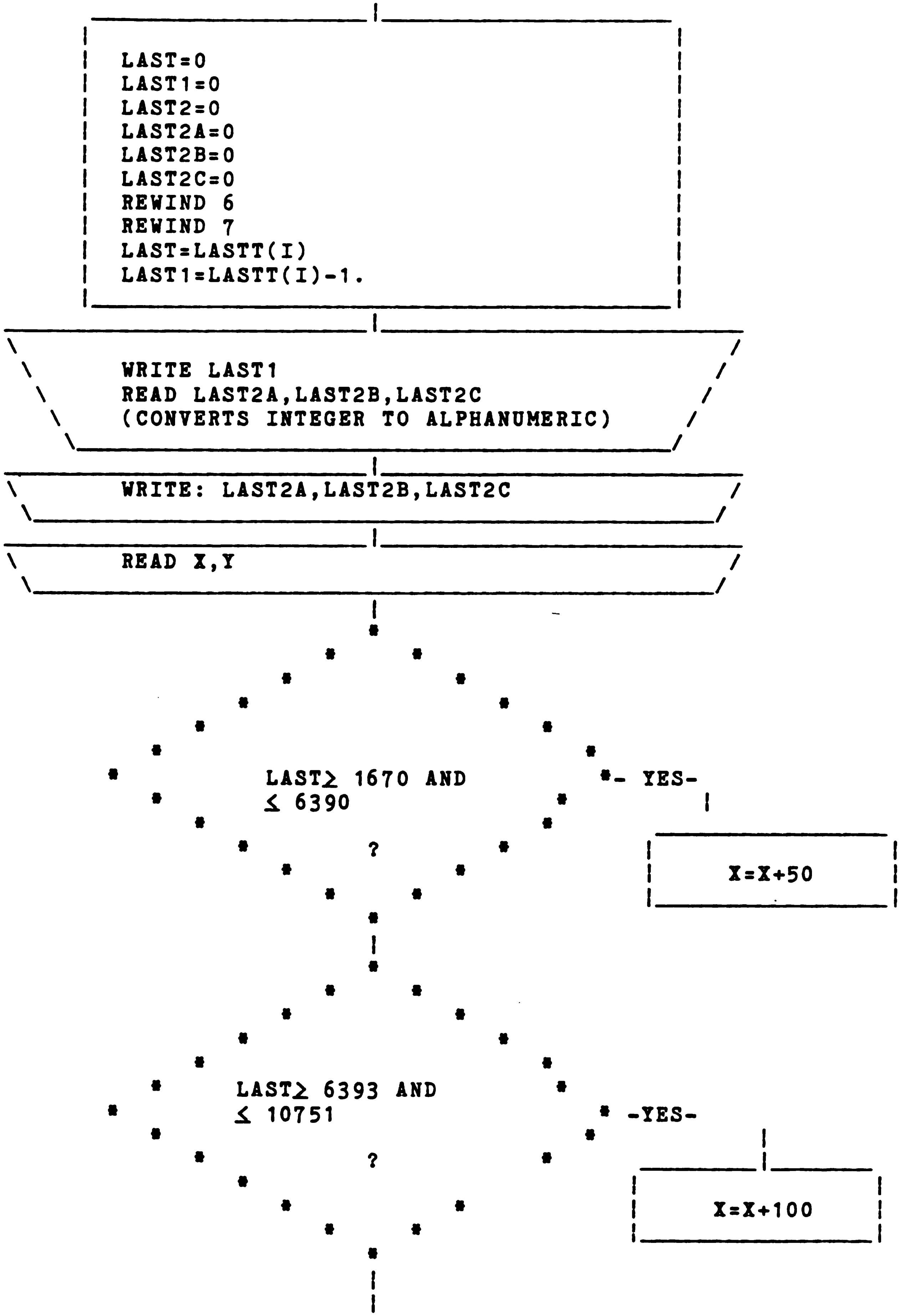
1. PROGRAM FLOWDIAGRAMS AND FORTRAN SOURCE CODE LISTINGS FOR PROGRAMS I AND II AND MAGEN

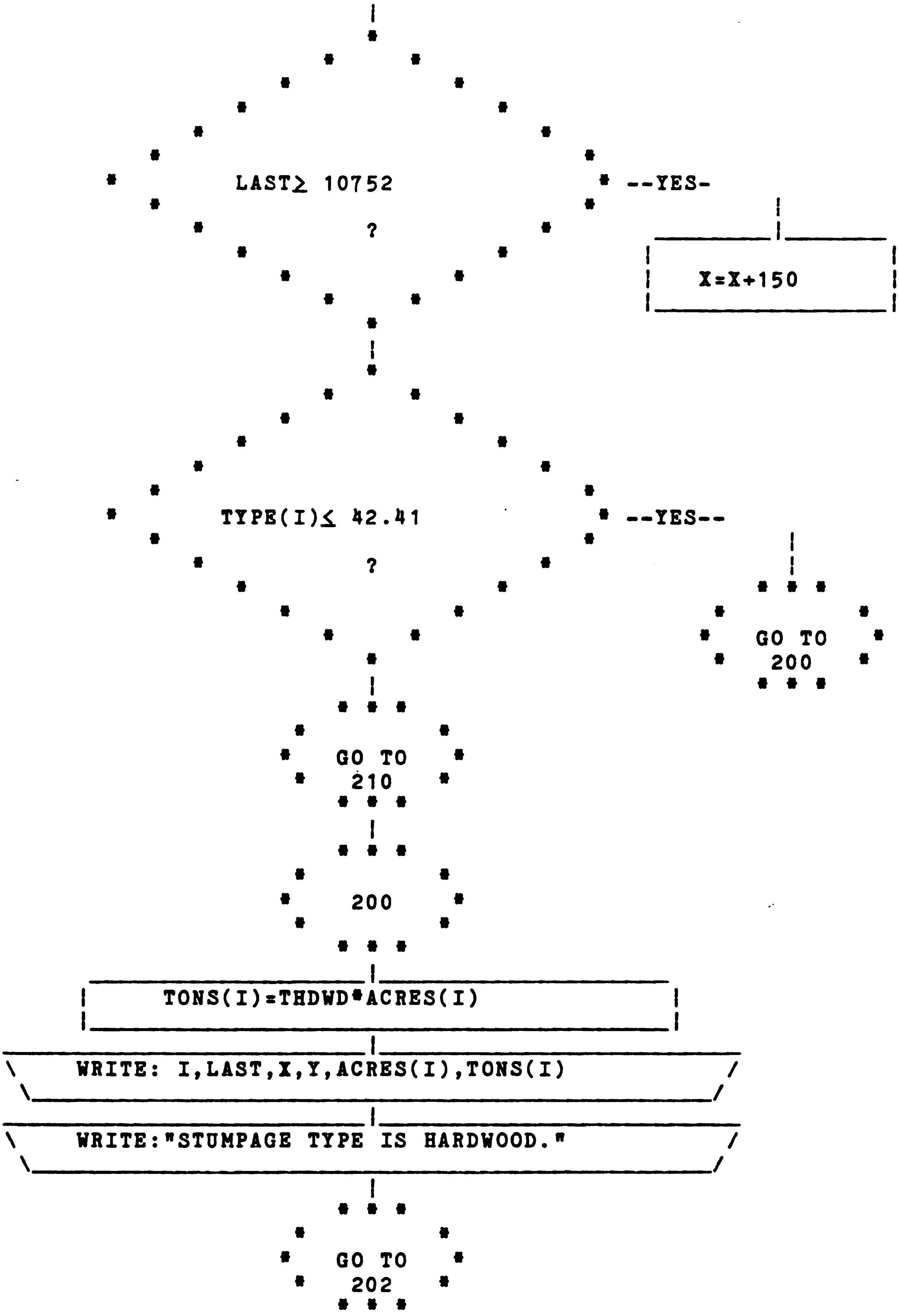
2. EXAMPLE OF MPOS TRANSPORTATION COST MINIMIZATION INCLUDING: BATCH PROGRAM, MPOS PROBLEM PROGRAM AND MPOS OUTPUT

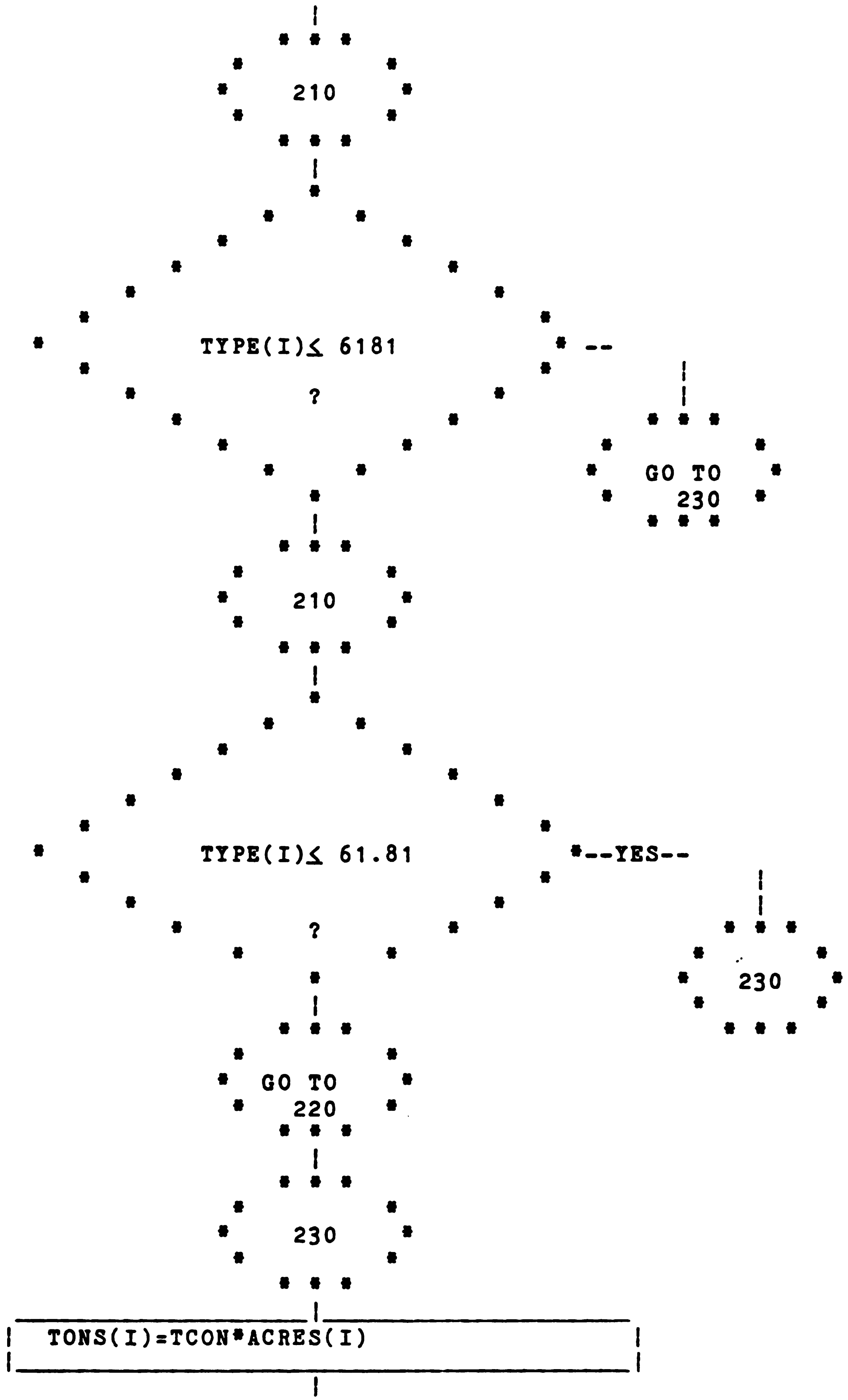
PROGRAM I

```
                 * * * * * * *
                *     START     *
                 * * * * * * *
          _______________|_______________
         | DIMENSION ACRES,TYPE,FMT,LASTT       |
         | REAL ACRES,TYPE TONS,INDEM,LAST,LAST1 |
         | INTEGER YESNO,X,Y,RANUM,FMT          |
         |_______________________________________|
          _______________|_______________
         |DATA INDEM = 1195675,YEAR = 1982,      |
         |     GROWTH = 1.16, GF = YEAR-1982     |
         |     FMT(1)=2H1                        |
         |     FMT(2)=2HX,                       |
         |     FMT(6)=2H(/                       |
         |     FMT(7)=2H),                       |
         |     FMT(8)=2H1X                       |
         |     FMT(9)=2H,2                       |
         |     FMT(10)=2H(I                      |
         |     FMT(11)=2H3,                      |
         |     FMT(12)=2H1X                      |
         |     FMT(13)=2H))                      |
         |_______________________________________|
     /|                  |
    / |                  |
   / 1|      I=1,150     |
  /___|__________________|
          _______________|_______________
         |                                       |
         |  ACRES(I)=0.                          |
         |  LASTT(I)=0.                          |
         |  TYPE(I)=0.                           |
         |  TONS(I)=0.                           |
         |_______________________________________|
  |\                     |
  | \                    |
  | 1 \                  |
  |____\_________________|
          _______________|_______________
         |                                       |
         |  SUMTNS=0.                            |
         |  X=0.                                 |
         |  Y=0.                                 |
         |_______________________________________|
                         |
     ____________________|____________________
     \                                       /
      \ WRITE: YEAR, "HAVE YOU SET THE SKIP LOOP /
       \   CORRECTLY? (Y=YES,N=NO)"          /
        \                                   /
         \_________________________________/
                         |
                         |
```

```
 ______________________________|______________________________
 \                                                           /
  \   READ: YESNO                                           /
   \                                                       /
    \                                                     /
     \___________________________________________________/
                               |
                               *
                           *       *
                       *               *
                   *                       *
               *                               *
           *                                       *
       *               YESNO=NO                        * ---YES--
           *                                       *            |
               *               ?               *            * * *
                   *                       *             *         *
                       *               *                 * GO TO 5000*
                           *       *                     *         *
                               *                            * * *
                               |
                              NO
 ______________________________|______________________________
 \                                                           /
  \   SKIP USED RANDOM NUMBERS IN DATA FILES                /
   \          NUMBER 8,9 AND 10.                           /
    \                                                     /
     \___________________________________________________/
      /|                       |
     / |                       |
    / 2 |     I=1,150          |
   /____|______________________|
 ______________________________|______________________________
 \                                                           /
  \         LASTT(I),ACRES(I),TYPE(I)                       /
   \                                                       /
    \                                                     /
     \___________________________________________________/
 |\                            |
 |  \                          |
 | 2  \                        |
 |_____\_______________________|
         ______________________|_____________________
        |                                            |
        |  GFA=GF*GROWTH                             |
        |  THDWD=GFA+39.55                           |
        |  TCON=GFA+33.32                            |
        |  TMIX=GFA+33.90                            |
        |____________________________________________|
      /|                       |
     / |                       |
    / 3 |      I=1,150         |
   /____|______________________|
                               |
                               |
```


LAST=0
LAST1=0
LAST2=0
LAST2A=0
LAST2B=0
LAST2C=0
REWIND 6
REWIND 7
LAST=LASTT(I)
LAST1=LASTT(I)-1.
WRITE LAST1
READ LAST2A,LAST2B,LAST2C
(CONVERTS INTEGER TO ALPHANUMERIC)
WRITE: LAST2A,LAST2B,LAST2C
READ X,Y
LAST≥ 1670 AND
≤ 6390
?
YES
X=X+50
LAST≥ 6393 AND
≤ 10751
?
YES
X=X+100


LAST≥ 10752 ?
--YES-
X=X+150
TYPE(I)≤ 42.41 ?
--YES--
GO TO 200
GO TO 210
200
TONS(I)=THDWD*ACRES(I)
WRITE: I,LAST,X,Y,ACRES(I),TONS(I)
WRITE:"STUMPAGE TYPE IS HARDWOOD."
GO TO 202


210
TYPE(I)≤ 6181
?
GO TO 230
210
TYPE(I)≤ 61.81
?
YES
230
GO TO 220
230
TONS(I)=TCON*ACRES(I)

```
 _____________________________|_____________________________
 \        WRITE: I,LAST,X,Y,ACRES(I),TONS(I)               /
  \_______________________________________________________/
 _____________________________|_____________________________
 \    WRITE:"STUMPAGE TYPE IS CONIFER"                     /
  \_______________________________________________________/
                              |
                            * * *
                          *       *
                         *   220   *
                          *       *
                            * * *
                ______________|______________________
               |  TONS(I)=TMIX*ACRES(I)              |
               |_____________________________________|
 _____________________________|_____________________________
 \    WRITE:I,LAST,X,Y,ACRES(I),TONS(I)                    /
  \_______________________________________________________/
 _____________________________|_____________________________
 \    WRITE: "STUMPAGE TYPE IS MIXED."                     /
  \_______________________________________________________/
                              |
                            * * *
                          *       *
                         *   202   *
                          *       *
                            * * *
                ______________|______________________
               |  SUMTNS=SUMTNS+TONS(I)              |
               |_____________________________________|
 _____________________________|_____________________________
 \    WRITE: SUMTNS "TONS SOLD SO FAR."                    /
  \ _____________________________________________________/
                              |
                              |
                          *       *
                       *             *
                    *                   *
                 *                         *
              *                               *
           *         SUMTNS≥ INDEM               *--YES--
              *                               *         |
                 *                         *            |
                    *                   *             * * *
                       *             *              *       *
                          *       *                *   203   *
                              *                     *       *
                              |                       * * *
                            * * *
                          *       *
                         *   222   *
                          *       *
                            * * *
                              |
                              |
```

```
 ________________________________|________________________________
\                                                                /
 \  WRITE: "TOTAL INDUSTRIAL NETWORK                            /
  \        DEMAND HAS BEEN MET.  SIMULATION                    /
   \       COMPLETE." SUMTNS  "TONS SOLD."                    /
    \________________________________________________________/
 ________________________________|________________________________
\                                                                /
 \  WRITE: I,"LOCATIONS, ACREAGES, AND TYPES                    /
  \         VALUES USED IN THIS RUN."                          /
   \                                                          /
    \________________________________________________________/
                                 |
                               * * *
                          *             *
                        *     GO TO       *
                          *    1005     *
                               * * *
                                 |
                               * * *
                          *             *
                        *      5000       *
                          *             *
                               * * *
 ________________________________|________________________________
\   WRITE: " THEN DO IT NOW."                                    /
 \______________________________________________________________/
                                 |
                               * * *
                          *             *
                        *      1005       *
                          *             *
                               * * *
                                 |
                        * * * * * * *
                      *      END        *
                        * * * * * * *
```

```
      PROGRAM 1
C                   (LOCATION AND SUPPLY SIMULATOR...)
C
      DIMENSION ACRES(150),TYPE(150),TONS(150),FMT(13),LASTT(150)
C*******************************************************************
C ***REMEMBER TO:
C     REDIMENSION ALL ARRAYS TO 140 WHEN ADDING WOOD ENERGY PLANT..
C*******************************************************************
C
C***  THINGS TO DO BEFORE EACH RUN:
C             1. SET SKIP READ
C             2. SET YEAR
C
      REAL ACRES,TYPE,TONS,INDEM,LASTT,LAST,LAST1
      INTEGER YESNO,X,Y,RANUM,FMT
C
C                            (SET INDUSTRIAL DEMAND...)
C     910675 IS IND. DEMAND FOR BASIC SET,NO WOOD ENERGY PLANT
C     1195675 WITH WOOD ENERGY PLANT
      DATA INDEM/1195675./
      DATA YEAR/2012./
      DATA GROWTH/1.16/
C
      GF=YEAR-1982.
C
      FMT(1)=2H(1
      FMT(2)= 2HX,
      FMT(6)= 2H(/
      FMT(7)= 2H),
      FMT(8)= 2H1X
      FMT(9)= 2H,2
      FMT(10)= 2H(I
      FMT(11)=2H3,
      FMT(12)=2H1X
      FMT(13)=2H))
C
C                           (ZERO OUT ARRAYS AND VARIABLES...)
      DO 13 I=1,150
      ACRES(I)=0.
      LASTT(I)=0.
      TYPE(I)=0.
      TONS(I)=0.
13    CONTINUE
      SUMTNS=0.
      X=0
      Y=0
C
      WRITE(1,234)YEAR
      WRITE(2,234)YEAR
234   FORMAT(///,1X,'** YEAR IS ',F5.0,'  **',/)
      WRITE(1,1001)
1001  FORMAT(1X,5(/),70('*'),////,1X,' HAVE YOU
     + SET THE SKIP LOOP AND GROWTH FACTOR CORRECTLY ???
     +      (Y=YES,N=NO) ',/)
C
      READ(1,1002)YESNO
1002  FORMAT(1A1)
      IF(YESNO.EQ.1HN) GO TO 5000
C
C**********************************************************************
```

```
C                                   (USE SKIP LOOP ONLY AFTER 1ST RUN...)
C
C   ----=  RANDOM NUMBERS USED SO FAR(LINES
C          TO SKIP)                             SUM      DATE
C          -                                    ---      ----
C
C
C                  (NEW ACRES AND TYPES  (5000 OF EACH) CREATED 12JAN82...)
C         64              PN12                  64       7FEB82
C         64              PN13                  128      7FEB82
C         38              PN14                  166      7FEB82
C         51              PN15                  217      7FEB82
C         43              PN16                  260      7FEB82
C         16              PN14CORRECTION        276      10FEB82
C         46              PN17                  322      ?
C         99              II82                  421      13FEB82
C         84              II87                  505      14FEB82
C         74              II92                  579      15FEB82
C         73              II97                  652      15FEB82
C         60              II02                  712      15FEB82
C         59              II07                  771      16FEB82
C         52              II12                  823      ?
C         109             III82                 932      6MAR82
C         98              III87                 1030     6MAR82
C         76              III92                 1106     6MAR82
C         77              III97                 1183     6MAR82
C         59              III02                 1242     8MAR82
C         56              III07                 1298     8MAR82
C
C
C
          READ(9,1006)
          READ(8,1006)
          READ(10,1006)
 1006     FORMAT(1X,     1298(/))
C*********************************************************************
C                                      (READ RANDUMS ACRES AND TONS...)
          DO 20 I=1,150
          READ(8,110)LASTT(I)
          READ(9,110)ACRES(I)
 110      FORMAT(1X,F10.0)
C
          READ(10,110)TYPE(I)
 20       CONTINUE
          GFA=GF*GROWTH
          THDWD=GFA+39.55
          TCON=GFA+33.32
          TMIX=GFA+33.90
C*************************************** MAIN LOOP
C
          DO 222 I=1,150
          LAST=0
          LAST1=0.
          LAST2=0
          LAST2A=0
          LAST2B=0
          LAST2C=0
          X=0
          Y=0
C
```

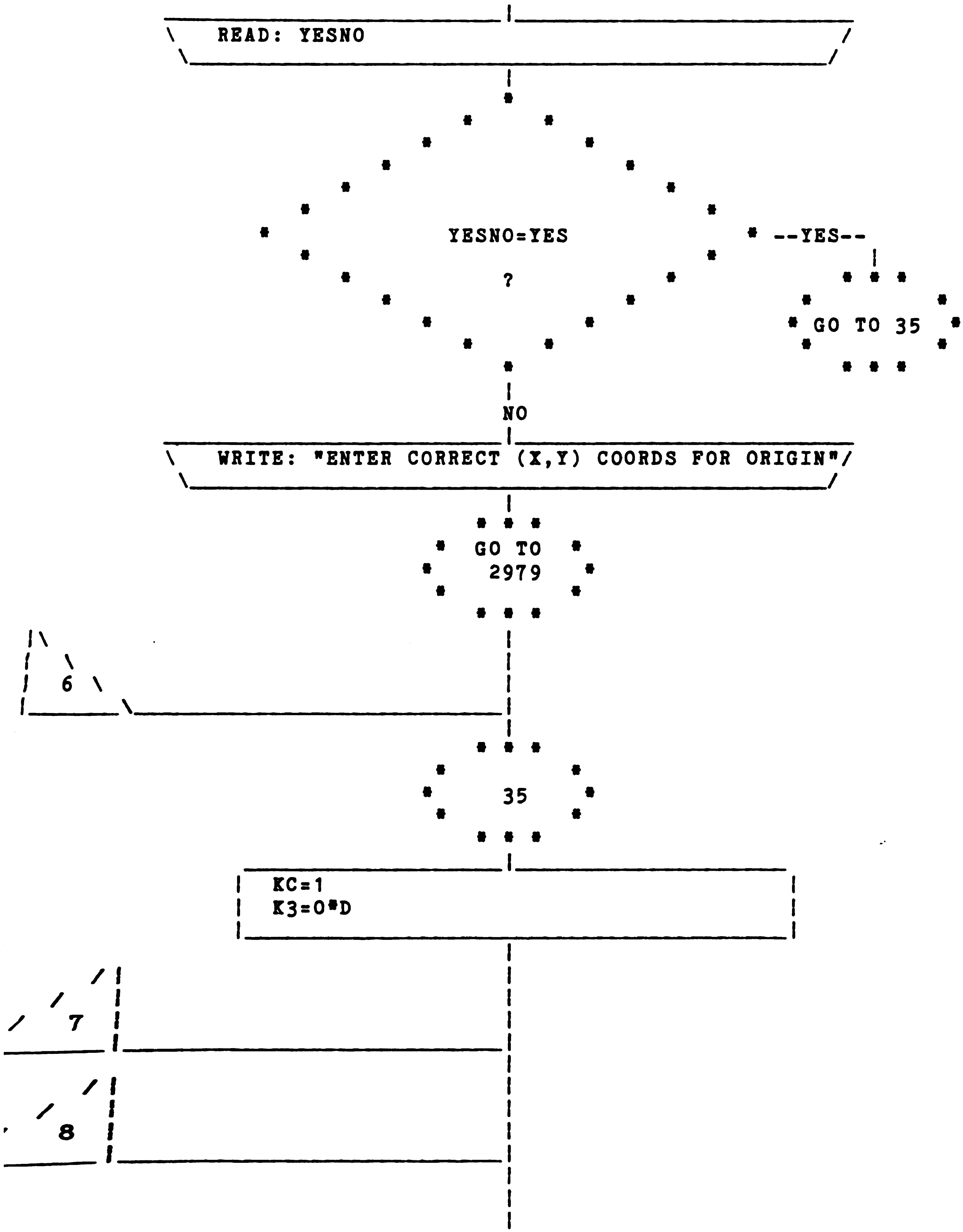
```
      REWIND 7
      LAST=LASTT(I)
      LAST1=LASTT(I)-1.
C
C****************************************** BOUNCE
      REWIND 6
       WRITE(6,164)LAST1
      REWIND 6
       READ(6,165)LAST2A,LAST2B,LAST2C
164   FORMAT(1X,F10.0)
165   FORMAT(5X,A1,2A2)
C****************************************** CRT VERIFICATION PRINT
      WRITE(1,166)LAST2A,LAST2B,LAST2C
166   FORMAT(1X,' SKIP=',1X,A1,2A2)
C
      FMT(3)= LAST2A
      FMT(4)= LAST2B
      FMT(5)= LAST2C
C
      X=0
      Y=0
      READ(7,FMT)X,Y
C
      IF(LAST.GE.1670..AND.LAST.LE.6392.)X=X+50
      IF(LAST.GE.6393..AND.LAST.LE.10751.)X=X+100
      IF(LAST.GE.10752.)X=X+150
C
C  ******************************************
      IF(TYPE(I).LE.42.41) GO TO 200
      GO TO 210
200   TONS(I)=THDWD*ACRES(I)
C     ORIG HDWD TONS=39.55
      WRITE(1,111)I,LAST,X,Y,ACRES(I),TONS(I)
      WRITE(2,111)I,LAST,X,Y,ACRES(I),TONS(I)
111   FORMAT(/,1X,' LOC. NUMBER= 'I3,' RANUM= ',F6.0,/
     +,1X,' STUMPAGE SALE LOCATION COORDINATES = ',
     +2(1X,I5),/,1X,' ACRES IN SALE = ',1X,F6.0,/,1X,' TONS OF BIOMASS
     + SOLD = ',1X,F10.0)
      WRITE(1,112)
      WRITE(2,112)
112   FORMAT(1X,' STUMPAGE TYPE IS HARDWOOD ')
      GO TO 202
C
C
210   IF(TYPE(I).LE.61.81) GO TO 230
      GO TO 220
230   TONS(I)=TCON*ACRES(I)
C     ORIG CONIFER TONS=33.32
      WRITE(1,111)I,LAST,X,Y,ACRES(I),TONS(I)
      WRITE(2,111)I,LAST,X,Y,ACRES(I),TONS(I)
      WRITE(1,113)
      WRITE(2,113)
113   FORMAT(1X,' STUMPAGE TYPE IS CONIFER ')
      GO TO 202
C
C
220   TONS(I)=TMIX*ACRES(I)
C     ORIG MIXED TONS=33.90
      WRITE(1,111)I,LAST,X,Y,ACRES(I),TONS(I)
      WRITE(2,111)I,LAST,X,Y,ACRES(I),TONS(I)
```

```
      WRITE(1,114)
      WRITE(2,114)
114   FORMAT(1X,' STUMPAGE TYPE IS MIXED ')
C
202   SUMTNS=SUMTNS+TONS(I)
C
      WRITE(1,365)SUMTNS
      WRITE(2,365)SUMTNS
365   FORMAT(40X,F15.0,' TONS SOLD SO FAR ')
      IF(SUMTNS.GE.INDEM)GO TO 203
C
222   CONTINUE
C*****************************************************************
203   WRITE(1,115) SUMTNS
      WRITE(2,115) SUMTNS
115   FORMAT(//,1X,' TOTAL INDUSTRIAL NETWORK DEMAND HAS BEEN MET.
     + SIMULATION COMPLETED. ',/,1X,F15.0,' TONS SOLD ',/)
C
      WRITE(1,1004)I
      WRITE(2,1004)I
1004  FORMAT(/,1X,I5,' LOCATIONS,ACREAGE AND TYPE VALUES
     + USED IN THIS RUN.')
C
      GO TO 1005
5000  CONTINUE
      WRITE(1,1003)
1003  FORMAT(1X,10(/),1X,' THEN DO IT NOW YOU DUMMY!!! ')
C
1005  CONTINUE
      END
```

PROGRAM 2

```
                                * * * * * * *
                               *    START    *
                                * * * * * * *
                     ____________________|____________________
                    | DIMENSION ORIGIN,DESTIN,XDIST,YDIST,    |
                    | DIST,RDIST,NITSED,COST                  |
                    |                                         |
                    | INTEGER O,D,YESNO                       |
                    |                                         |
                    | REAL NITSED                             |
                    |_________________________________________|
                     ____________________|____________________
                    | DATA RTF/1.36/                          |
                    |      NITSED/134.,153.79.,12.,9.,14.,    |
                    |      25.,55.,131.,92.,46.,52.,55.,39./  |
                    |                                         |
                    |      D/7/                               |
                    |_________________________________________|
      /|                                 |
     / |                                 |
    / 1|            I=1,10               |
   /___|_________________________________|
      /|                                 |
     / |                                 |
    / 2|            J=1,2                |
   /___|_________________________________|
                     ____________________|____________________
                    | ORIGIN(I,J)=0.                          |
                    | DESTIN(I,J)=0.                          |
                    |_________________________________________|
 |\                                      |
 | \                                     |
 | 2 \                                   |
 |____\__________________________________|
|\                                       |
| \                                      |
| 1 \                                    |
|____\___________________________________|
      /|                                 |
     / |                                 |
   / 3 |            I=1,1100             |
 ______|_________________________________|
                     ____________________|____________________
                    | XDIST(I)=0.                             |
                    | YDIST(I)=0.                             |
                    | DIST(I)=0.                              |
                    | RDIST(I)=0.                             |
                    |_________________________________________|
```

```
                                     |
 |\                                  |
 | \                                 |
 | 3 \                               |
 |____\______________________________|
      _______________________________|___________________________
      \   WRITE:"WHAT YEAR IS IT?                               /
        \______________________________________________________/
      _______________________________|___________________________
      \   READ: YEAR                                            /
        \______________________________________________________/
            _________________________|_________________________
            |   COUNT=YEAR-1982                                |
            |   C=COUNT*.05                                    |
            |   COSTPM=.093                                    |
            |__________________________________________________|
      /|                             |
     / |                             |
    / 4|            I=1,D            |
   /___|_____________________________|
      /|                             |
     / |                             |
    / 5|        J=1,2                |
   /___|_____________________________|
            _________________________|_________________________
            |   DESTIN(I,J)=NITSED(J,I)                        |
            |__________________________________________________|
 |\                                  |
 | \                                 |
 | 5 \                               |
 |____\______________________________|
      _______________________________|___________________________
      \   WRITE:"HOW MANY ORIGINS DO YOU HAVE IN THIS          /
       \  SYSTEM? (MAX IS 150 WITHOUT REDIMENSIONING          /
        \ ORIGIN.)"                                          /
         \__________________________________________________/
      _______________________________|___________________________
      \   READ:O                                                /
       \_______________________________________________________/
      /|                             |
     / |                             |
    / 6|                             |
   /___|_____________________________|
      _______________________________|___________________________
      \   WRITE:"ENTER (X,Y) COORD OF ORIGIN IN                  /
       \  (F4.0,1X,F4.0) FORMAT"                               /
        \_____________________________________________________/
      _______________________________|___________________________
      \   READ: (ORIGIN(I,J),J=1,2)                             /
        \______________________________________________________/
      _______________________________|___________________________
      \   WRITE: (ORIGIN(I,J),J=1,2)                            /
        \ "CORRECT? (Y=YES,N=NO)                               /
         \____________________________________________________/
```


READ: YESNO
YESNO=YES
?
--YES--
GO TO 35
NO
WRITE: "ENTER CORRECT (X,Y) COORDS FOR ORIGIN"
GO TO
2979
6
35
KC=1
K3=0*D
7
8

```
                       ____________________|____________________
                      | XDIST(KC)=ABS(ORIGIN(I,1)-DESTIN(J,1)   |
                      | YDIST(KC)=ABS(ORIGIN(I,2)-DESTIN(J,2)   |
                      | DIST(KC)=SQRT(XDIST(KC)**2+YDIST(KC)**2 |
                      |_________________________________________|
                                           |
                                           |
                                           |
                                           *
                                        *     *
                                     *           *
                                  *                 *
                               *                       *
                            *                             *
                         *             J = 4                 * --YES--
                            *                             *         |
                               *         ?             *    ________|________
                                  *                 *      | DIST(KC)=       |
                                     *           *         | DIST(KC)+74     |
                                        *     *            |_________________|
                                           *                        |
                                           |________________________|
                                   ________|________
                                  |                 |
                                  |     KC=KC+1     |
|\                                |_________________|
|  \                                       |
| 7  \                                     |
|______\___________________________________|
                                           |
|\                                         |
|  \                                       |
| 8  \                                     |
|______\___________________________________|
                                           |
      /|                                   |
    /  |                                   |
  / 9  |            I=1,K3                 |
/______|___________________________________|
                       ____________________|____________________
                      | RDIST(I)=DIST(I)*RTF                    |
                      | COST(I)=RDIST(I)*COSTPM                 |
|\                    |_________________________________________|
|  \                                       |
| 9  \                                     |
|______\___________________________________|
                ___________________________|___________________________
                \   WRITE: "ORIGINS IN THIS SET ARE..."                /
                 \____________________________________________________/
      /|                                   |
    /  |                                   |
  / 10 |                                   |
/______|___________________________________|
                                           |
```

```
              ___________________________|_______________________
              \   WRITE:(ORIGIN(I,J),J=1,2)                      /
               \________________________________________________/
|\                                       |
|  \                                     |
| 10 \                                   |
|_____\__________________________________|
                                         |
              ___________________________|_______________________
              \   WRITE: "ORIGIN DESTINATION TRANSPORT COSTS    /
               \  ($/GREEN TON)"                               /
                \_____________________________________________/
                    _____________________|____________________
                    |  KK=1                                  |
                    |________________________________________|
         /|                              |
       /  |                              |
     / 11 |         I=1,O                |
   /______|______________________________|
         /|                              |
       /  |                              |
     / 12 |         J=1,D                |
   /______|______________________________|
              ___________________________|_______________________
              \   WRITE: KK,I,J,COST                             /
               \________________________________________________/
                    _____________________|____________________
                    |  KK=KK+1                               |
                    |________________________________________|
|\                                       |
|  \                                     |
| 12 \                                   |
|_____\__________________________________|
              ___________________________|_______________________
              \   WRITE: LINE FEED                               /
               \________________________________________________/
|\                                       |
|  \                                     |
| 11 \                                   |
|_____\__________________________________|
              ___________________________|_______________________
              \   WRITE: PAGE FEED                               /
               \________________________________________________/
                                         |
                                 * * * * * * *
                                *     END     *
                                 * * * * * * *
```

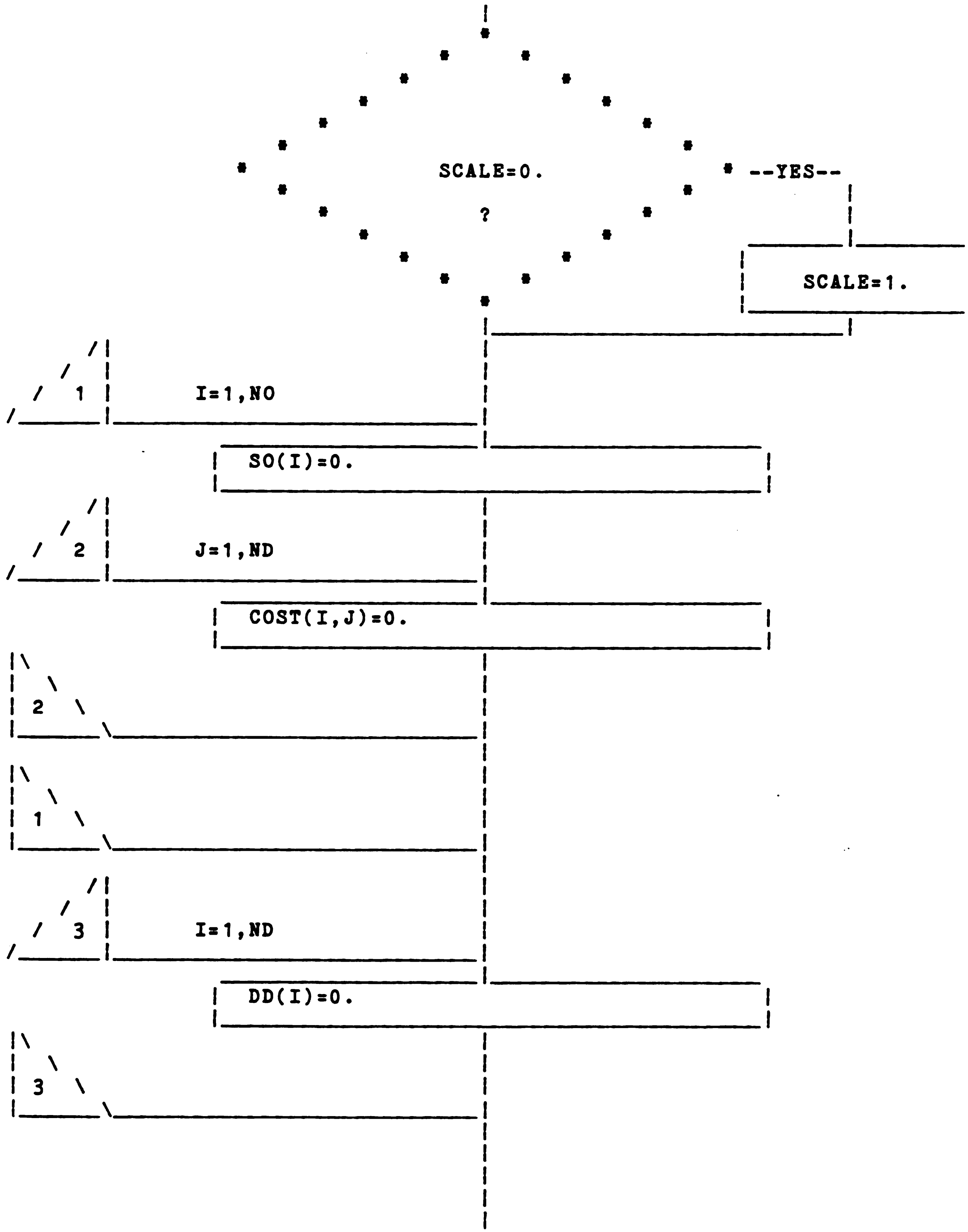
```
      PROGRAM 2
C
      DIMENSION ORIGIN(150,2),DESTIN(150,2),XDIST(1100),YDIST(1100),
     + DIST(1100),RDIST(1100),NITSED(2,7),COST(1100)
C
      INTEGER O,D,YESNO
      REAL NITSED
C                                                  ROW 90, COL 120
C     FOR II SERIES, WOOD ENERGY PLANT AT ROSE CITY(90,120)
C     FOR III SERIES, WOOD ENERGY PLANT AT IDLEWILD (55,39)
C                                                   (I,J) NOT (X,Y)!!!
      DATA RTF/1.36/
C
      DATA NITSED/134.,153.,  79.,12.,  9.,14.,  25.,55.,  131.,92.,
     + 46.,52.,55.,39./
C
      DATA D/7/
C ********************************************************************
C                                               (ZERO OUT ARRAYS...)
      DO 200 I=1,10
      DO 200 J=1,2
      ORIGIN(I,J)=0.
      DESTIN(I,J)=0.
200   CONTINUE
      DO 201 I=1,1100
      XDIST(I)=0.
      YDIST(I)=0.
      DIST(I)=0.
      RDIST(I)=0.
C
201   CONTINUE
      DO 222 I=1,10
      DO 222 J=1,10
222   CONTINUE
C  ******************************************************************
C                                         SET YEAR...
      WRITE(1,9999)
9999  FORMAT('1')
C
      WRITE(1,545)
545   FORMAT(/,1X,' WHAT YEAR IS IT? ',/,1X,'(F5.0)',/)
      READ(1,546)YEAR
546   FORMAT(F5.0)
      COUNT=YEAR-1982.
      C=COUNT*.05
      COSTPM=.093+C*(.093)
C
      DO 211 I=1,D
      DO 211 J=1,2
      DESTIN(I,J)=NITSED(J,I)
211   CONTINUE
C
      WRITE(1,37)
37    FORMAT(//,' HOW MANY ORIGINS DO YOU HAVE IN THIS SYSTEM?',/
     + 1X,'(MAX IS 150 WITHOUT REDIMENSIONING ORIGIN.) ',/)
      READ(1,38)O
38    FORMAT(I10)
C
C                             (READ COORDS OF ORIGINS FROM CRT...)
      DO 35 I=1,O
```

```
          WRITE(1,34)I
34        FORMAT(//,1X,'ENTER (X,Y) COORD OF ORIGIN',I3,' IN
     +    (F4.0,1X,F4.0)
     +    ',/)
2979      READ(1,33)(ORIGIN(I,J),J=1,2)
33        FORMAT(F4.0,1X,F4.0)
          WRITE(1,333)(ORIGIN(I,J),J=1,2)
333       FORMAT(1X,2(F4.0,1X))
C
          WRITE(1,2976)
2976      FORMAT(/,1X,' CORRECT ?  (Y=YES,N=NO) ',/)
C
          READ(1,2977)YESNO
2977      FORMAT(1A1)
          IF(YESNO.EQ.1HY) GO TO 35
          WRITE(1,2978)I
2978      FORMAT(/,1X,' ENTER CORRECT (X,Y) COORDS FOR ORIGIN',I3,/)
          GO TO 2979
C
35        CONTINUE
C
          KC=1
          K3=O*D
C
          DO 20 I=1,O
          DO 20 J=1,D
          XDIST(KC)=ABS(ORIGIN(I,1)-DESTIN(J,1))
          YDIST(KC)=ABS(ORIGIN(I,2)-DESTIN(J,2))
          DIST(KC)=SQRT((XDIST(KC)**2)+(YDIST(KC)**2))
C                                                  +74 MILES FOR DESTINATION 4
          IF(J.EQ.4)DIST(KC)=DIST(KC)+74.
          KC=KC+1
20        CONTINUE
C
          DO 31 I=1,K3
          RDIST(I)=DIST(I)*RTF
C                                    COST(I,J) CALCULATED ON $/GREEN TON/MILE
          COST(I)=RDIST(I)*COSTPM
31        CONTINUE
C
          WRITE(1,234)
          WRITE(2,234)
234       FORMAT(///,1X,' ORIGINS IN THIS SET ARE...',/)
          DO 235 I=1,O
          WRITE(1,236)I,(ORIGIN(I,J),J=1,2)
          WRITE(2,236)I,(ORIGIN(I,J),J=1,2)
236       FORMAT(1X,I3,1X,2(F4.0,1X))
235       CONTINUE
C
          WRITE(1,237)
          WRITE(2,237)
237       FORMAT(//,10X,'ORIGIN   DESTINATION    TRANSPORT COSTS
     +    ($/GREEN TON) ')
          KK=1
          DO 30 I=1,O
          DO 95 J=1,D
          WRITE(1,117)KK,I,J,COST(KK)
          WRITE(2,117)KK,I,J,COST(KK)
          KK=KK+1
95        CONTINUE
```

```
      WRITE(1,186)
      WRITE(2,186)
186   FORMAT(/)
30    CONTINUE
117   FORMAT(1X,3(I3,7X),F10.2)
C
      WRITE(2,9999)
      WRITE(2,9999)
      END
```

PROGRAM MAGEN

```
                    * * * * * * * *
                   *     START      *
                    * * * * * * * *
                           |
      _____________________|_____________________
     |  DIMENSION COST,BOTUM,SO,DD,COSTT          |
     |                                            |
     |  INTEGER OUTPUT                            |
     |  INPUT=1                                   |
     |  MPOS=2                                    |
     |  BOUNCE=3                                  |
     |  OUTPUT=4                                  |
     |____________________________________________|
                           |
 __________________________|__________________________
\   WRITE:"WELCOME TO THE RESOURCE DEVELOPMENT       /
 \  DEPARTMENT TRANSPORTATION COST LINEAR PROGRAM/
  \ HOW MANY ORIGINS DO YOU HAVE?(MAXIMUM IS       /
   \150)? DON'T USE A DECIMAL POINT!"             /
    \____________________________________________/
                           |
 __________________________|__________________________
\   READ:NO                                          /
 \__________________________________________________/
                           |
 __________________________|__________________________
\   WRITE"HOW MANY DESTINATIONS DO YOU HAVE          /
 \  (MAXIMUM IS 50)? DON'T USE DECIMAL POINT        /
  \ HERE. EITHER.)                                 /
   \______________________________________________/
                           |
 __________________________|__________________________
\   READ:ND                                          /
 \__________________________________________________/
                           |
 __________________________|__________________________
\   WRITE:"IF YOU WANT TO USE A SCALING FACTOR,      /
 \  ENTER IT. (USE DECIMAL POINT.) IF NOT, TYPE     /
  \ 1.0 AND TYPE RETURN."                          /
   \______________________________________________/
                           |
                           |
                           |
                           |
 __________________________|__________________________
\   READ:SCALE                                       /
 \__________________________________________________/
                           |
                           |
                           |
                           |
                           |
                           |
                           |
                           |
                           |
```

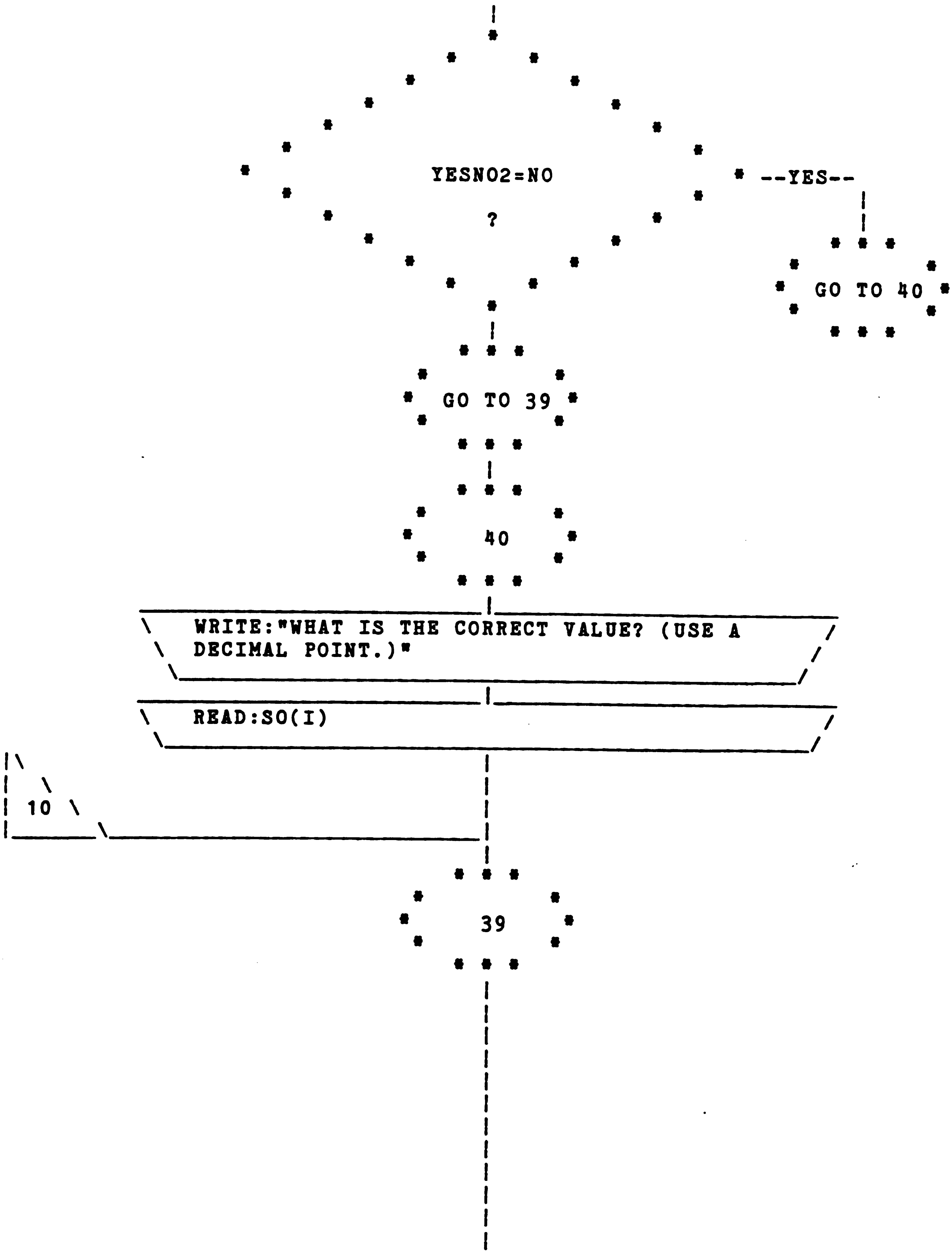

SCALE=0.
?
--YES--
SCALE=1.
1
I=1,NO
SO(I)=0.
2
J=1,ND
COST(I,J)=0.
2
1
3
I=1,ND
DD(I)=0.
3

```
                                        |
                 ______________________|______________________
                |  YESNO=0.                                   |
                |  YESNO1=0.                                  |
                |  YESNO2=0.                                  |
                |  YESNO3=0.                                  |
                |  YESNO4=0.                                  |
                |  YESNO5=0.                                  |
                |  YESNO6=0.                                  |
                |_____________________________________________|
           ____________________________|___________________________
           \ WRITE:"INPUT COST MATRIX STARTING IN UPPER LEFT /
            \ HAND CORNER.  ENTER ONE ROW AT A TIME, FROM   /
             \ LEFT TO RIGHT.(TYPE RETURN AFTER ENTERING   /
              \  EACH ELEMTNT). (DON'T FORGET TO USE A    /
               \ DECIMAL POINT!)"                         /
                \________________________________________/
                 ______________________|______________________
                |    KKK=1                                    |
                |_____________________________________________|
        /|                             |
       / |                             |
      / 4 |      I=1,NO                |
     /____|____________________________|
                                       |
        /|                             |
       / |                             |
      / 5 |                            |
     /____|____________________________|
           ____________________________|___________________________
           \ WRITE:KKK                                            /
            \____________________________________________________/
           ____________________________|___________________________
           \ READ:COST(I,J)                                       /
            \___________________________________________________ /
                 ______________________|______________________
                |    KKK=KKK+1                                |
                |_____________________________________________|
     |\                                |
     | \                               |
     | 5 \                             |
     |____\____________________________|
                                       |
     |\                                |
     | \                               |
     | 4 \                             |
     |____\____________________________|
           ____________________________|___________________________
           \ WRITE:"INPUT SUPPLY AT ORIGINS 1 THROUGH " NO        /
            \ "(IN ORDER)(ENTER ONE SUPPLY VALUE (WITH A         /
             \  POINT) AND TYPE RETURN.)"                       /
              \                                                /
               \______________________________________________/
                                       |
                                       |
                                       |
```

```
                 ____________________|____________________
                |     KKK=KKK+1                           |
                |_________________________________________|
       /|                            |
      / |                            |
     / 6|            I=1,NO          |
    /___|____________________________|
           __________________________|______________________
           \ WRITE:KKK                                     /
            \_____________________________________________/
           __________________________|______________________
           \ READ:SO(I)                                    /
            \_____________________________________________/
                 ____________________|____________________
                |     KKK=KKK+1                           |
                |_________________________________________|
    |\                               |
    | \                              |
    | 6 \                            |
    |____\___________________________|
           __________________________|______________________
           \ WRITE:"INPUT DEMAND AT DESTINATIONS 1 THROUGH"  /
            \ ND "(IN ORDER) ENTER ONE DEMAND VALUE (WITH   /
             \  DECIMAL POINT) AND TYPE RETURN.)"          /
              \___________________________________________/
                 ____________________|____________________
                |     KKK=1                               |
                |_________________________________________|
       /|                            |
      / |                            |
     / 7|            I=1,ND          |
    /___|____________________________|
           __________________________|______________________
           \ WRITE:KKK                                     /
            \_____________________________________________/
           __________________________|______________________
           \ READ:DD(I)                                    /
            \_____________________________________________/
                 ____________________|____________________
                |     KKK=KKK+1                           |
                |_________________________________________|
    |\                               |
    | \                              |
    | 7 \                            |
    |____\___________________________|
           __________________________|______________________
           \ WRITE:"PLEASE CHECK ALL YOUR INPUT CAREFULLY.  /
            \ THE FOLLOWING ARE YOUR COST MATRIX ELEMENTS. /
             \ VERIFY OR CORRECT EACH ELEMENT AS IT       /
              \ APPEARS."                                /
               \________________________________________/
                                     |
                                     |
                                     |
                                     |
```

```
                                      |
                                    * * *
                                  *       *
                                 *   44    *
                                  *       *
                                    * * *
     /|                               |
    / |                               |
   / 8 |           I=1,NO             |
  /____|______________________________|
                                      |
     /|                               |
    / |                               |
   / 9 |           J=1,ND             |
  /____|______________________________|
               _______________________|_______________________
               \ WRITE"FROM ORIGIN" I "TO DESTINATION" J      /
                \  "UNIT TRANSPORT COST IS" COST(I,J)        /
                 \__________________________________________/
               _______________________|_______________________
               \ WRITE: "IS THIS THE CORRECT VALUE?(Y=YES,N=NO) "/
                \____________________________________________/
               _______________________|_______________________
               \ READ:YESNO1                                  /
                \____________________________________________/
                                      |
                                      *
                                   *     *
                                *           *
                             *                 *
                          *                       *
                       *                             *
                    *           YESNO1=NO               *  --YES--
                       *                             *          |
                          *           ?           *             |
                             *                 *              * * *
                                *           *               *       *
                                   *     *                 * GO TO 38 *
                                      *                     *       *
                                      |                       * * *
                                    * * *
                                  *       *
                                 * GO TO 37 *
                                  *       *
                                    * * *
                                      |
                                    * * *
                                  *       *
                                 *   38    *
                                  *       *
                                    * * *
               _______________________|_______________________
               \   WRITE:"WHAT IS THE CORRECT VALUE? (USE A   /
                \  DECIMAL POINT.)"                          /
                 \__________________________________________/
```

```
                                         |
                ________________________|_________________________
                \   READ:"COST(I,J)                               /
                 \_______________________________________________/
|\                                       |
|  \                                     |
| 9  \                                   |
|______\_________________________________|
                                         |
|\                                       |
|  \                                     |
| 8  \                                   |
|______\_________________________________|
                                         |
                                     *  *  *
                                   *         *
                                  *    37     *
                                   *         *
                                     *  *  *
                                         |
                                         *
                                      *     *
                                   *           *
                                *                 *
                             *                       *
                          *                             *
                       *           YESNO4=NO               *  --YES--
                          *                             *          |
                             *         ?             *          *  *  *
                                *                 *          *           *
                                   *           *            *  GO TO 45   *
                                      *     *                *           *
                                         *                      *  *  *
                ________________________|_________________________
                \   WRITE:THREE LINE FEEDS                        /
                 \_______________________________________________/
                                         |
                                     *  *  *
                                   *         *
                                  *    47     *
                                   *         *
                                     *  *  *
       /|                                |
      / |                                |
    / 10 |             I=1,NO            |
  /______|_______________________________|
                ________________________|_________________________
                \   WRITE;"THE SUPPLY AT ORIGIN" I "IS" SO(I)     /
                 \_______________________________________________/
                ________________________|_________________________
                \ WRITE: "IS THIS THE CORRECT VALUE?(Y=YES,N=NO) "/
                 \_______________________________________________/
                ________________________|_________________________
                \ READ:YESNO2                                     /
                 \_______________________________________________/
```


YESNO2=NO
?
--YES--
GO TO 40
GO TO 39
40
WRITE:"WHAT IS THE CORRECT VALUE? (USE A DECIMAL POINT.)"
READ:SO(I)
10
39

```
                              *
                           *     *
                        *           *
                     *                 *
                  *                       *
               *                             *
            *           YESNO5=NO               *  --YES--
               *                             *           |
                  *         ?             *              |
                     *                 *               * * *
                        *           *                *       *
                           *     *                  *  GO TO 53 *
                              *                      *       *
                              |                        * * *
        ______________________|______________________
        \   WRITE:THREE LINE FEEDS                   /
         \__________________________________________/
                              |
                            * * *
                          *       *
                         *   50    *
                          *       *
                            * * *
      /|                      |
     / |                      |
    / 11 |        I=1,ND      |
   /_____|____________________|
        ______________________|______________________
        \ WRITE:"THE DEMAND AT DESTINATION " I "IS" DD(I) /
         \__________________________________________/
        ______________________|______________________
        \ WRITE: "IS THIS THE CORRECT VALUE?(Y=YES,N=NO) "/
         \__________________________________________/
        ______________________|______________________
        \ READ:YESNO3                                /
         \__________________________________________/
                              |
                              *
                           *     *
                        *           *
                     *                 *
                  *                       *
               *                             *
            *           YESNO3=NO               *  --YES--
               *                             *           |
                  *         ?             *              |
                     *                 *               * * *
                        *           *                *       *
                           *     *                  *  GO TO 42 *
                              *                      *       *
                              |                        * * *
                              |
                              |
                              |
                              |
```

```
                         * * *
                       *       *
                      *  GO TO 41 *
                       *       *
                         * * *
                           |
                         * * *
                       *       *
                      *    42    *
                       *       *
                         * * *
                           |
 __________________________|____________________________
 \   WRITE:"WHAT IS THE CORRECT VALUE? (USE A          /
  \  DECIMAL POINT.)"                                  /
   \__________________________________________________/
 __________________________|____________________________
 \   READ:DD(I)                                        /
  \___________________________________________________/
|\                         |
|  \                       |
| 11 \                     |
|______\___________________|
                           |
                         * * *
                       *       *
                      *    41    *
                       *       *
                         * * *
                           |
                           *
                        *     *
                      *         *
                    *             *
                  *                 *
                *                     *
              *       YESNO6=NO         *  --YES--
                *                     *          |
                  *       ?         *            |
                    *             *            * * *
                      *         *            *       *
                        *     *             *  GO TO 52 *
                           *                 *       *
                           |                   * * *
                           |
                         * * *
                       *       *
                      *    45    *
                       *       *
                         * * *
                           |
 __________________________|____________________________
 \   WRITE:"FINAL INPUT CHECK SEQUENCE. COST MATRIX/
  \  ELEMENTS"                                     /
   \______________________________________________/
                           |
                           |
```

```
     /|                                |
    / |                                |
   / 14 |      I=1,NO                  |
  /_____|______________________________|
         ______________________________|______________________
         \   WRITE:I,SO(I)                                   /
          \_________________________________________________/
  |\                                   |
  | \                                  |
  | 14 \                               |
  |_____\______________________________|
         ______________________________|______________________
         \   WRITE:"ARE ALL THESE VALUES CORRECT?            /
          \  (Y=YES,N=NO)."                                 /
           \_______________________________________________/
         ______________________________|______________________
         \   READ:YESNO5                                     /
          \_________________________________________________/
                                       |
                                       *
                                    *     *
                                 *           *
                              *                 *
                           *                       *
                        *                             *
                     *          YESNO5=NO                *  --YES--
                        *                             *          |
                           *        ?              *             |
                              *                 *              * * *
                                 *           *               *       *
                                    *     *                 * GO TO 47 *
                                       *                     *       *
                                       |                       * * *
         ______________________________|______________________
         \   WRITE:THREE LINE FEEDS                          /
          \_________________________________________________/
                                       |
                                     * * *
                                   *       *
                                  *   52    *
                                   *       *
                                     * * *
         ______________________________|______________________
         \   WRITE:"DEMAND AT DESTINATIONS 1 THROUGH" ND     /
          \_________________________________________________/
     /|                                |
    / |                                |
   / 15 |      I=1,ND                  |
  /_____|______________________________|
         ______________________________|______________________
         \   WRITE:I,DD(I)                                   /
          \_________________________________________________/
                                       |
                                       |
                                       |
```

```
|\                                             |
|  \                                           |
| 15 \                                         |
|______\_______________________________________|
                 ______________________________|_________________________
                 \   WRITE:"ARE ALL THESE VALUES CORRECT?               /
                  \  (Y=YES,N=NO)."                                    /
                   \__________________________________________________/
                 ______________________________|_________________________
                 \   READ:YESNO6                                        /
                  \____________________________________________________/
                                               |
                                               *
                                           *       *
                                       *               *
                                   *                       *
                               *                               *
                           *                                       *
                       *               YESNO6=NO                       *  --YES--
                           *                                       *          |
                               *               ?               *              |
                                   *                       *               * * *
                                       *               *                 *       *
                                           *       *                    * GO TO 50 *
                                               *                         *       *
                                               |                           * * *
                        _______________________|__________________________
                       |   K=1                                            |
                       |__________________________________________________|
             /|                                |
           /  |                                |
         / 16 |        I=1,NO                  |
       /______|________________________________|
             /|                                |
           /  |                                |
         / 17 |                                |
       /______|________________________________|
                        _______________________|__________________________
                       |   COSTT(K)=COST(I,J)                             |
                       |   K=K+1                                          |
                       |__________________________________________________|
      |\                                       |
      |  \                                     |
      | 17 \                                   |
      |______\_________________________________|
      |\                                       |
      |  \                                     |
      | 16 \                                   |
      |______\_________________________________|
                                               |
                                               |
```

```
    /|                                 |
   / |                                 |
  / 18 |        I=1,NO                 |
 /_____|_______________________________|
                  _____________________|_______________________
                 | BOTUM(I)=SO(I)                              |
                 |_____________________________________________|
|\                                     |
|  \                                   |
| 18 \                                 |
|______\_______________________________|
                  _____________________|_______________________
                 | M=NO+1                                      |
                 | N=NO+ND                                     |
                 | J=1                                         |
                 |_____________________________________________|
    /|                                 |
   / |                                 |
  / 19 |        I=M,N                  |
 /_____|_______________________________|
                  _____________________|_______________________
                 | BOTUM(I)=DD(J)                              |
                 | J=J+1                                       |
                 |_____________________________________________|
|\                                     |
|  \                                   |
| 19 \                                 |
|______\_______________________________|
                  _____________________|_______________________
                 | K2=NO*ND                                    |
                 |_____________________________________________|
    /|                                 |
   / |                                 |
  / 20 |        I=1,K2                 |
 /_____|_______________________________|
             __________________________|____________________________
             \   WRITE:COSTT(I)                                    /
              \___________________________________________________/
|\                                     |
|  \                                   |
| 20 \                                 |
|______\_______________________________|
                  _____________________|_______________________
                 | ONE=1.0                                     |
                 | ZERO=0.0                                    |
                 | K=NO+1                                      |
                 | L=ND-1                                      |
                 |_____________________________________________|
    /|                                 |
   / |                                 |
  / 21 |        I=1,K                  |
 /_____|_______________________________|
                                       |
                                       |
```

```
        /|                                      |
       / |                                      |
     / 22 |        II=1,ND                      |
    /_____|_________________________________|
          ________________________________|________________________________
          \    WRITE:ONE                                                  /
           \_____________________________________________________________/
|\                                          |
|  \                                        |
| 22 \                                      |
|_____\_____________________________________|
                                            |
        /|                                  |
       / |                                  |
     / 23 |        III=1,NO                 |
    /_____|_________________________________|
                                            |
        /|                                  |
       / |                                  |
     / 24 |        IIII=1,ND                |
    /_____|_________________________________|
          ________________________________|________________________________
          \    WRITE:ZERO                                                 /
           \_____________________________________________________________/
|\                                          |
|  \                                        |
| 23 \                                      |
|_____\_____________________________________|
                                            |
|\                                          |
|  \                                        |
| 24 \                                      |
|_____\_____________________________________|
                                            |
|\                                          |
|  \                                        |
| 21 \                                      |
|_____\_____________________________________|
                                            |
        /|                                  |
       / |                                  |
     / 25 |        I=1,ND                   |
    /_____|_________________________________|
          ________________________________|________________________________
          \    WRITE:ONE                                                  /
           \_____________________________________________________________/
|\                                          |
|  \                                        |
| 25 \                                      |
|_____\_____________________________________|
                                            |
        /|                                  |
       / |                                  |
     / 26 |        J=1,L                    |
    /_____|_________________________________|
```

```
                                                   |
        /|                                         |
       / |                                         |
    / 27 |       I=1,NO                            |
   /_____|_________________________________________|
          _________________________________________|__________________________
          \    WRITE:ONE                                                     /
           \________________________________________________________________/
        /|                                         |
       / |                                         |
    / 28 |       II=1,L                            |
   /_____|_________________________________________|
          _________________________________________|__________________________
          \    WRITE:ZERO                                                    /
           \________________________________________________________________/
   |\                                              |
   | \                                             |
   | 28 \                                          |
   |_____\_________________________________________|
                                                   |
   |\                                              |
   | \                                             |
   | 27 \                                          |
   |_____\_________________________________________|
          _________________________________________|__________________________
          \    WRITE:ZERO                                                    /
           \________________________________________________________________/
   |\                                              |
   | \                                             |
   | 26 \                                          |
   |_____\_________________________________________|
                                                   |
        /|                                         |
       / |                                         |
    / 29 |       I=1,K                             |
   /_____|_________________________________________|
          _________________________________________|__________________________
          \    WRITE:ONE                                                     /
           \________________________________________________________________/
        /|                                         |
       / |                                         |
    / 30 |                                         |
   /_____|_________________________________________|
          _________________________________________|__________________________
          \    WRITE:ZERO                                                    /
           \________________________________________________________________/
   |\                                              |
   | \                                             |
   | 30 \                                          |
   |_____\_________________________________________|
                                                   |
   |\                                              |
   | \                                             |
   | 29 \                                          |
   |_____\_________________________________________|
```

```
             _______________________|________________________
             \   WRITE:ONE                                  /
              \________________________________________/
       /|                           |
      / |                           |
     / 31 |     I=1,N               |
    /_____|_________________________|
             _______________________|________________________
             \   WRITE:BOTUM(I)                             /
              \________________________________________/
    |\                              |
    | \                             |
    | 31 \                          |
    |_____\_________________________|
                                    |
                             * * * * * * *
                            *     STOP    *
                             * * * * * * *
```

```
      PROGRAM MAGEN(TAPE1,TAPE2,TAPE3,TAPE4)
      DIMENSION COST(150,50),BOTUM(7500),
     + SO(150),DD(50),COSTT(7500)
C
      INTEGER OUTPUT
C
C           LABEL           LUN
C           -----           ---
C
C         INPUT            1
C         OUTPUT           4
C         MPOS             2
C         BOUNCE           3
C
C
C          NO=NUMBER OF ORIGINS
C          ND=NUMBER OF DESTINATIONS
C          SCALE=SCALING FACTOR
C          COST(I,J)=COST OF MOVING ONE UNIT FROM I TO J
C          SO(I)=SUPPLY AVAILABLE AT I
C          DD(J)=DEMAND AT J
C          BOTUM(J)= ROW OF CONSTRAINT RIGHTHANDSIDES
      INPUT=1
      MPOS=2
      BOUNCE=3
      OUTPUT=4
C
      DO 333 I=1,50
333   CONTINUE
      WRITE(OUTPUT,1000)
1000  FORMAT(1X,10(/),70('*')/)
C
      WRITE(OUTPUT,1001)
1001  FORMAT(1H1,5X,' WELCOME TO THE RESOURCE ',
     + ' DEVELOPMENT DEPARTMENT '/5X,' TRANSPORTATION COST ',
     + ' LINEAR PROGRAM ',///70('*'),5(/),10X,' HOW MANY ORIGINS ',
     + ' DO YOU  HAVE (MAXIMUM IS 150)? '/10X,' (DON''T USE A ',
     + ' DECIMAL POINT!)'/)
C
      READ(INPUT,1002)NO
1002  FORMAT(I2)
C
      WRITE(OUTPUT,1003)
1003  FORMAT(//10X,' HOW MANY DESTINATIONS DO YOU HAVE (MAXIMUM ',
     + ' IS 50)? '/10X,' (DON''T USE DECIMAL POINT HERE, EITHER)
     + '/)
C
      READ(INPUT,1002)ND
C
      WRITE(OUTPUT,1004)
1004  FORMAT('0',10X,' IF YOU WANT TO USE A SCALING FACTOR, ',
     + ' ENTER IT.  (USE DECIMAL POINT.)'/)
      WRITE(OUTPUT,1026)
1026  FORMAT(1X,' IF NOT, TYPE 1.0 AND TYPE RETURN. '/)
C
      READ(INPUT,1005)SCALE
1005  FORMAT(F60.4)
C
C
C         (SET SCALE=1, IF NO SCALE ENTERED...)
```

```
C
      IF(SCALE.EQ.0.) GO TO 30
      GO TO 31
30    SCALE=1.
31    CONTINUE
C
C
C        (ZERO ARRAYS AND VARIABLES...)
      DO 32 I=1,NO
      SO(I)=0.
      DO 32 J=1,ND
      COST(I,J)=0.
32    CONTINUE
      DO 33 I=1,ND
      DD(I)=0.
33    CONTINUE
      SCALE=0.
      YESNO1=0.
      YESNO2=0.
      YESNO3=0.
      YESNO4=0.
      YESNO5=0.
      YESNO6=0.
C
      WRITE(OUTPUT,1006)
1006  FORMAT('0',5X,' INPUT COST MATRIX STARTING IN UPPER '/5X,
     +' LEFT HAND CORNER.  ENTER ONE ROW AT '/5X,' A TIME ',
     + ' FROM LEFT TO RIGHT.  (TYPE RETURN AFTER ENTERING EACH ',
     + ' ELEMENT.) '/5X,' ( DON''T FORGET TO USE A DECIMAL ',
     + ' POINT!) '/)
C
      KKK=1
      DO 34 I=1,NO
      DO 34 J=1,ND
      WRITE(OUTPUT,396)KKK
396   FORMAT(1X,I5,' =  '/)
      READ(INPUT,1005) COST(I,J)
      KKK=KKK+1
34    CONTINUE
C
      WRITE(OUTPUT,1007)NO
1007  FORMAT(5X,' INPUT SUPPLY AT ORIGINS 1 THROUGH ',I2,' (IN ',
     + ' ORDER) '/5X,' (ENTER ONE SUPPLY VALUE (WITH A DECIMAL ',
     + ' POINT)AND TYPE RETURN.) '/)
      KKK=1
      DO 35 I=1,NO
      WRITE(OUTPUT,396)KKK
      READ(INPUT,1005)SO(I)
      KKK=KKK+1
35    CONTINUE
C
      WRITE(OUTPUT,1008)ND
1008  FORMAT(5X,' INPUT DEMAND AT DESTINATIONS 1 THROUGH ',I2,
     +' (IN ORDER) '/5X,' ENTER ONE DEMAND VALUE (WITH DECIMAL ',
     + ' POINT) AND TYPE RETURN.) '/)
C
      KKK=1
      DO 36 I=1,ND
      WRITE(OUTPUT,396)KKK
      READ(INPUT,1005)DD(I)
```

```
      KKK=KKK+1
36    CONTINUE
C        (END OF INPUT SECTION...)
C ***************************************************************
C
C        (BEGIN INPUT CHECKING SECTION...)
C
      WRITE(4,1010)
1010  FORMAT(1X,' PLEASE CHECK ALL YOUR INPUT CAREFULLY. THE ',
     +' FOLLOWING ARE YOUR COST MATRIX ELEMENTS. '/1X,' VERIFY ',
     + ' OR CORRECT EACH ELEMENT AS IT APPEARS. '/)
C
C        (INPUT CHECK AND CORRECTION PROCEDURE...)
C
44    DO 37 I=1,NO
      DO 37 J=1,ND
      WRITE(4,1009)I,J,COST(I,J)
1009  FORMAT(1X,/' FROM ORIGIN ',I5,' TO DESTINATION ',I5,
     + /,1X,' UNIT TRANSPORT COST IS ',F15.4)
C
      WRITE(4,1011)
1011  FORMAT(1X,' IS THIS THE CORRECT VALUE? (Y=YES,N=NO) '/)
C
      READ(1,1012)YESNO1
1012  FORMAT(1A1)
      IF(YESNO1.EQ.1HN) GO TO 38
      GO TO 37
38    WRITE(4,1013)
1013  FORMAT(1X,' WHAT IS THE CORRECT VALUE? '/1X,' (USE A ',
     + ' DECIMAL POINT.) '/)
C
      READ(1,1005)COST(I,J)
37    CONTINUE
      IF(YESNO4.EQ.1HN) GO TO 45
C
C        (CHECK SUPPLY INPUTS...)
      WRITE(4,3675)
3675  FORMAT(1X,3(/))
C
47    DO 39 I=1,NO
      WRITE(4,1015)I,SO(I)
1015  FORMAT(1X,' THE SUPPLY AT ORIGIN ',I5,' IS ',F15.4)
      WRITE(4,1011)
      READ(1,1012)YESNO2
      IF(YESNO2.EQ.1HN) GO TO 40
      GO TO 39
40    WRITE(4,1013)
      READ(1,1005)SO(I)
39    CONTINUE
      IF(YESNO5.EQ.1HN) GO TO 53
C
C        (CHECK DEMAND INPUTS...)
      WRITE(4,3675)
C
50    DO 41 I=1,ND
      WRITE(4,1016)I,DD(I)
1016  FORMAT(1X,' THE DEMAND AT DESTINATION ',I5,'   IS ',F15.4)
      WRITE(4,1011)
      READ(1,1012)YESNO3
      IF(YESNO3.EQ.1HN) GO TO 42
```

```
      GO TO 41
42    WRITE(4,1013)
      READ(1,1005)DD(I)
41    CONTINUE
      IF(YESNO6.EQ.1HN) GO TO 52
C
C                              (FINAL INPUT CHECK...)
C
45    WRITE(4,1017)
1017  FORMAT('0',1X,' FINAL INPUT CHECK SEQUENCE. '/)
54    WRITE(4,1019)
1019  FORMAT(1X,' COST MATRIX ELEMENTS '/)
C
      DO 43 I=1,NO
      DO 43 J=1,ND
      WRITE(4,1009)I,J,COST(I,J)
43    CONTINUE
C
      WRITE(4,1018)
1018  FORMAT(1X,' ARE ALL THESE VALUES CORRECT? '/1X,
     + ' (Y=YES,N=NO) '/)
C
      READ(1,1012)YESNO4
      IF(YESNO4.EQ.1HN) GO TO 44
C
      WRITE(4,3675)
53    WRITE(4,1020)NO
1020  FORMAT(1X,' SUPPLIES AT ORIGINS 1 THROUGH ',I5)
      DO 46 I=1,NO
      WRITE(4,1015)I,SO(I)
46    CONTINUE
C
      WRITE(4,1018)
      READ(1,1012)YESNO5
      IF(YESNO5.EQ.1HN) GO TO 47
C
C                              (CHECK DEMANDS...)
C
      WRITE(4,3675)
52    WRITE(4,1021) ND
1021  FORMAT(1X,' DEMAND AT DESTINATIONS 1 THROUGH ',I5)
      DO 49 I=1,ND
      WRITE(4,1016)I,DD(I)
49    CONTINUE
      WRITE(4,1018)
      READ(1,1012)YESNO6
      IF(YESNO6.EQ.1HN) GO TO 50
C
C*****************************************************************
C*****************************************************************
C
C                 (WRITE SUPPLIES,DEMANDS, AND COST DATA TO DATFIL
C                  FOR MPOS PROCESSING...)
C                              (CONVERT COST TO A VECTOR...)
      K=1
      DO 55 I=1,NO
      DO 55 J=1,ND
      COSTT(K)=COST(I,J)
      K=K+1
55    CONTINUE
```

```
C                                   (WRITE SUPPY AND DEMAND VECTOR...)
          DO 62 I=1,NO
          BOTUM(I)=SO(I)
 62       CONTINUE
C
          M=NO+1
          N=NO+ND
C
          J=1
          DO 63 I=M,N
          BOTUM(I)=DD(J)
          J=J+1
 63       CONTINUE
C
C                                   (WRITE OBJECTIVE FUNCTION...)
          K2=NO*ND
C
          DO 213 I=1,K2
          WRITE(MPOS,1200) COSTT(I)
 213      CONTINUE
C
          ONE=1.0
          ZERO=0.0
          K=NO-1
          L=ND-1
C       ORIGIN CONSTRAINTS
          DO 20 I=1,K
          DO 730 II=1,ND
          WRITE(2,1200) ONE
 730       CONTINUE
          DO 740 III=1,NO
          DO 750 IIII=1,ND
          WRITE(2,1200) ZERO
 750       CONTINUE
 740       CONTINUE
 20       CONTINUE
C
          DO 60 I=1,ND
          WRITE(2,1200)ONE
 60       CONTINUE
C
C  DEST. CONST.
C
          DO 90 J=1,L
          DO 70 I=1,NO
          WRITE(2,1200) ONE
          DO 80 II=1,L
          WRITE(2,1200) ZERO
 80       CONTINUE
 70       CONTINUE
          WRITE(2,1200) ZERO
 90       CONTINUE
C
          DO 100 I=1,K
          WRITE(2,1200) ONE
          DO 101 II=1,L
          WRITE(2,1200) ZERO
 101      CONTINUE
 100      CONTINUE
          WRITE(2,1200) ONE
```

```
C
1200  FORMAT(1X,F15.4)
      DO 770 I=1,N
      WRITE(MPOS,1200) BOTUM(I)
770   CONTINUE
      END
```

```
C
1200  FORMAT(1X,F15.4)
      DO 770 I=1,N
      WRITE(MPOS,1200) BOTUM(I)
770   CONTINUE
      END
```

MPOS Batch Job Example

The following is a sample of the batch job run on the MSU CYBER 750 from an interactive terminal. It attaches the permanent file KMKII82 (which is the MPOS input file) and runs MPOS from the HAL unsupported library. It then catalogs the output (which is listed beginning on the following page of this appendix) and catalogs the dayfile to trace crashes.

```
1= KYLE,CM370000,JC2500,PN554872,RG3.
2= ATTACH,INP,KMKII02.
3= HAL,L*UNSUP,MPOS,I=INP,O=OUTPUT.
4= CATALOG,OUTPUT,KMKII02OUTPUT,RP=999.
5= EXIT,C,S.
6= DAYFILE.
7= CATALOG,DAYF,KMKII02DAYFILE,RP=999.
```

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

(The following section is the MPOS problem statement.)

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

        TITLE
        I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.
        REGULAR
        VARIABLES
        X1 TO X693
        MINIMIZE
        * OBJECTIVE FUNCTION:
        8.17X1+13.21X2+16.70X3+21.12X4+6.12X5+9.70X6+1.20X7+
        19.96X8+1.66X9+7.85X10+17.36X11+12.91X12+5.38X13+13.86X14+
        11.25X15+8.86X16+14.66X17+20.26X18+4.58X19+7.92X20+6.15X21+
        7.70X22+12.63X23+17.28X24+22.06X25+4.05X26+10.25X27+2.74X28+
        12.43X29+9.33X30+12.40X31+17.14X32+7.82X33+5.36X34+5.53X35+
        23.64X36+8.14X37+1.31X38+14.83X39+17.94X40+5.85X41+16.58X42+
        15.68X43+4.78X44+10.45X45+17.19X46+8.95X47+4.55X48+9.65X49+
        4.56X50+19.59X51+22.62X52+26.75X53+9.68X54+15.80X55+5.22X56+
        4.28X57+18.45X58+21.77X59+25.96X60+8.49X61+14.87X62+4.17X63+
        20.52X64+0.81X65+8.51X66+18.48X67+13.23X68+6.52X69+14.65X70+
        6.94X71+14.25X72+20.77X73+26.15X74+1.60X75+13.96X76+6.98X77+
        2.95X78+17.69X79+21.95X80+26.36X81+6.68X82+14.93X83+4.36X84+
        7.70X85+12.79X86+17.19X87+21.87X88+4.52X89+10.14X90+2.28X91+
        9.41X92+13.43X93+20.91X94+26.87X95+2.74X96+14.45X97+9.29X98+
        14.90X99+6.96X100+10.08X101+15.51X102+9.33X103+3.15X104+8.16X105+
        14.90X106+13.79X107+22.66X108+29.90X109+8.27X110+17.27X111+14.81X112+
        6.06X113+17.19X114+20.00X115+24.14X116+8.48X117+13.19X118+2.79X119+
        11.11X120+15.33X121+23.43X122+29.74X123+5.84X124+17.24X125+12.29X126+
        9.58X127+11.32X128+18.25X129+24.06X130+1.48X131+11.68X132+7.32X133+
        20.13X134+3.39X135+6.36X136+15.74X137+13.53X138+4.07X139+13.65X140+
        14.55X141+5.55X142+12.31X143+19.01X144+7.33X145+6.38X146+9.18X147+
        5.16X148+16.10X149+19.58X150+24.20X151+6.45X152+12.86X153+2.16X154+
        12.86X155+8.66X156+12.02X157+16.96X158+7.83X159+4.99X160+6.09X161+
        21.52X162+1.73X163+7.93X164+18.59X165+14.27X166+6.89X167+15.55X168+
        12.74X169+12.15X170+12.89X171+16.94X172+10.28X173+6.46X174+5.47X175+
        15.54X176+4.57X177+11.93X178+19.13X179+8.15X180+6.49X181+10.24X182+
        14.14X183+6.18X184+11.78X185+17.94X186+7.49X187+5.37X188+8.25X189+
        5.36X190+18.33X191+24.84X192+30.02X193+5.73X194+17.95X195+9.44X196+
        19.21X197+5.10X198+6.06X199+13.89X200+13.19X201+2.16X202+12.41X203+
        9.03X204+11.59X205+15.87X206+20.62X207+4.98X208+8.83X209+2.97X210+
        3.36X211+17.28X212+22.86X213+27.69X214+4.97X215+15.85X216+6.46X217+
        7.40X218+14.78X219+17.80X220+22.05X221+7.15X222+10.89X223+0.56X224+
```

```
17.35X225+2.80X226+10.96X227+19.08X228+9.87X229+6.53X230+11.95X231+
5.00X232+15.12X233+20.40X234+25.23X235+3.49X236+13.38X237+4.40X238+
23.19X239+7.63X240+1.85X241+14.63X242+17.42X243+5.42X244+16.17X245+
16.10X246+5.19X247+9.41X248+15.84X249+9.84X250+3.20X251+9.67X252+
6.48X253+18.38X254+25.23X255+30.58X256+6.01X257+18.42X258+10.36X259+
22.11X260+6.67X261+3.03X262+14.13X263+16.24X264+4.40X265+15.15X266+
14.15X267+6.50X268+14.32X269+21.28X270+6.30X271+8.64X272+9.83X273+
14.97X274+13.54X275+12.24X276+16.29X277+13.10X278+6.99X279+7.90X280+
6.86X281+14.04X282+17.98X283+22.46X284+5.42X285+10.95X286+1.19X287+
8.34X288+11.77X289+17.19X290+22.30X291+2.82X292+10.24X293+4.25X294+
5.55X295+14.55X296+19.74X297+24.57X298+3.33X299+12.72X300+3.93X301+
2.67X302+19.04X303+22.92X304+27.21X305+8.15X306+15.95X307+5.21X308+
23.44X309+8.17X310+1.44X311+14.57X312+17.79X313+5.65X314+16.36X315+
2.79X316+18.30X317+23.89X318+28.69X319+5.80X320+16.87X321+7.28X322+
4.12X323+16.33X324+21.94X325+26.82X326+4.00X327+14.93X328+5.85X329+
5.59X330+15.24X331+21.33X332+26.46X333+2.65X334+14.40X335+6.36X336+
23.40X337+6.91X338+2.39X339+15.41X340+17.34X341+5.76X342+16.49X343+
6.67X344+14.20X345+18.17X346+22.65X347+5.39X348+11.14X349+1.26X350+
18.25X351+9.20X352+7.01X353+11.05X354+13.87X355+2.39X356+10.99X357+
16.13X358+4.05X359+11.86X360+19.39X361+8.62X362+6.77X363+10.91X364+
4.44X365+16.23X366+25.45X367+30.47X368+6.56X369+18.50X370+9.43X371+
13.01X372+7.15X373+12.98X374+18.94X375+6.27X376+6.44X377+7.45X378+
7.98X379+14.87X380+22.01X381+27.68X382+2.97X383+15.36X384+8.95X385+
16.84X386+3.49X387+11.80X388+19.74X389+9.22X390+7.15X391+11.71X392+
14.53X393+13.22X394+22.04X395+29.23X396+7.70X397+16.60X398+14.22X399+
12.01X400+12.53X401+13.61X402+17.67X403+9.82X404+7.09X405+4.75X406+
```



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* PROBLEM NUMBER  1 *
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. N.E. PLANT AT ROSE CITY.

11.80X407+8.32X408+14.69X409+20.61X410+4.61X411+8.15X412+7.06X413+
9.18X414+12.36X415+19.49X416+25.32X417+1.41X418+12.94X419+7.97X420+
7.63X421+14.76X422+17.65X423+21.87X424+7.37X425+10.76X426+0.77X427+
8.74X428+11.88X429+16.15X430+20.88X431+4.90X432+9.11X433+2.74X434+
12.30X435+14.08X436+14.35X437+18.34X438+11.15X439+8.25X440+5.37X441+
6.84X442+17.80X443+20.10X444+24.16X445+9.60X446+13.42X447+3.58X448+
14.63X449+5.48X450+12.38X451+19.15X452+7.35X453+6.51X454+9.32X455+
6.66X456+16.61X457+23.47X458+28.89X459+4.24X460+16.69X461+9.15X462+
18.98X463+7.35X464+5.85X465+11.67X466+13.78X467+1.31X468+11.87X469+
21.34X470+6.47X471+3.69X472+13.57X473+15.54X474+3.62X475+14.37X476+
0.66X477+20.67X478+25.48X479+29.96X480+8.55X481+18.44X482+7.97X483+
6.00X484+14.44X485+20.35X486+25.45X487+2.13X488+13.41X489+5.55X490+
14.02X491+13.69X492+12.98X493+16.98X494+12.38X495+7.36X496+6.99X497+
21.98X498+2.50X499+7.16X500+18.20X501+14.85X502+6.72X503+15.85X504+
2.55X505+18.53X506+24.07X507+28.82X508+6.06X509+17.04X510+7.35X511+
4.52X512+16.93X513+20.64X514+24.95X515+6.97X516+13.67X517+2.92X518+
5.60X519+16.74X520+19.93X521+24.15X522+7.65X523+13.03X524+2.35X525+
5.29X526+17.28X527+20.44X528+24.64X529+8.00X530+13.56X531+2.90X532+
22.26X533+7.09X534+2.73X535+13.95X536+16.50X537+4.49X538+15.25X539+
5.99X540+25.65X541+29.32X542+33.47X543+14.08X544+22.44X545+11.70X546+
```

```
        4.06X547+19.80X548+23.02X549+27.17X550+9.59X551+16.16X552+5.50X553+
        15.89X554+4.25X555+11.05X556+18.21X557+8.75X558+5.57X559+10.23X560+
        5.80X561+14.33X562+19.78X563+24.70X564+2.79X565+12.78X566+4.41X567+
        10.65X568+12.55X569+14.59X570+18.77X571+8.44X572+7.79X573+3.35X574+
        9.96X575+12.77X576+15.18X577+19.41X578+7.86X579+8.31X580+2.66X581+
        11.24X582+9.04X583+15.57X584+21.71X585+3.67X586+9.25X587+7.19X588+
        18.41X589+8.26X590+6.56X591+11.16X592+13.62X593+1.55X594+11.21X595+
        15.76X596+5.19X597+13.63X598+21.24X599+7.87X600+8.60X601+11.31X602+
        2.79X603+19.39X604+23.16X605+27.42X606+8.57X607+16.21X608+5.45X609+
        9.30X610+12.01X611+19.08X612+24.90X613+1.31X614+12.52X615+7.74X616+
        7.52X617+18.04X618+25.19X619+30.72X620+6.00X621+18.48X622+10.96X623+
        8.47X624+16.53X625+23.94X626+29.70X627+5.00X628+17.36X629+10.73X630+
        4.52X631+16.93X632+20.64X633+24.95X634+6.97X635+13.67X636+2.92X637+
        13.07X638+7.19X639+12.71X640+18.59X641+6.52X642+6.09X643+7.30X644+
        5.48X645+15.95X646+22.23X647+27.41X648+3.28X649+15.33X650+7.23X651+
        20.36X652+3.28X653+6.31X654+15.94X655+13.72X656+4.33X657+13.90X658+
        11.31X659+10.09X660+13.53X661+18.23X662+6.93X663+6.49X664+4.49X665+
        16.21X666+5.42X667+9.14X668+15.43X669+10.09X670+2.79X671+9.66X672+
        20.11X673+7.52X674+4.73X675+11.73X676+14.85X677+2.39X678+12.99X679+
        12.49X680+14.28X681+14.38X682+18.36X683+11.44X684+8.37X685+5.62X686+
        10.36X687+13.51X688+15.24X689+19.34X690+8.95X691+8.57X692+3.19X693
        *
(The following are the constraint equations.)
        *
        *
        CONSTRAINTS
        *
     1. X1+X2+X3+X4+X5+X6+X7=11075
     2. X8+X9+X10+X11+X12+X13+X14=14517
     3. X15+X16+X17+X18+X19+X20+X21=16481
     4. X22+X23+X24+X25+X26+X27+X28=18132
     5. X29+X30+X31+X32+X33+X34+X35=14401
     6. X36+X37+X38+X39+X40+X41+X42=9279
     7. X43+X44+X45+X46+X47+X48+X49=21014
     8. X50+X51+X52+X53+X54+X55+X56=5414
     9. X57+X58+X59+X60+X61+X62+X63=3136
    10. X64+X65+X66+X67+X68+X69+X70=15743
    11. X71+X72+X73+X74+X75+X76+X77=10983
    12. X78+X79+X80+X81+X82+X83+X84=21883
    13. X85+X86+X87+X88+X89+X90+X91=10947
    14. X92+X93+X94+X95+X96+X97+X98=18408
    15. X99+X100+X101+X102+X103+X104+X105=6099
    16. X106+X107+X108+X109+X110+X111+X112=20921
    17. X113+X114+X115+X116+X117+X118+X119=14091
    18. X120+X121+X122+X123+X124+X125+X126=2606
    19. X127+X128+X129+X130+X131+X132+X133=7128
    20. X134+X135+X136+X137+X138+X139+X140=19475
    21. X141+X142+X143+X144+X145+X146+X147=7436
    22. X148+X149+X150+X151+X152+X153+X154=21307
    23. X155+X156+X157+X158+X159+X160+X161=10136
    24. X162+X163+X164+X165+X166+X167+X168=20468
    25. X169+X170+X171+X172+X173+X174+X175=15372
T     MPOS VERSION 4.0       NORTHWESTERN UNIVERSITY                    02/24/82   .19.07.38.  PAGE    3

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* PROBLEM NUMBER 1 *
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USING REGULAR
I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

26. X176+X177+X178+X179+X180+X181+X182=14621
27. X183+X184+X185+X186+X187+X188+X189=1301
28. X190+X191+X192+X193+X194+X195+X196=15921
29. X197+X198+X199+X200+X201+X202+X203=19729
30. X204+X205+X206+X207+X208+X209+X210=3405
31. X211+X212+X213+X214+X215+X216+X217=5409
32. X218+X219+X220+X221+X222+X223+X224=4707
33. X225+X226+X227+X228+X229+X230+X231=13013
34. X232+X233+X234+X235+X236+X237+X238=11849
35. X239+X240+X241+X242+X243+X244+X245=9502
36. X246+X247+X248+X249+X250+X251+X252=20677
37. X253+X254+X255+X256+X257+X258+X259=16326
38. X260+X261+X262+X263+X264+X265+X266=18987
39. X267+X268+X269+X270+X271+X272+X273=16185
40. X274+X275+X276+X277+X278+X279+X280=435
41. X281+X282+X283+X284+X285+X286+X287=22248
42. X288+X289+X290+X291+X292+X293+X294=9797
43. X295+X296+X297+X298+X299+X300+X301=13552
44. X302+X303+X304+X305+X306+X307+X308=8283
45. X309+X310+X311+X312+X313+X314+X315=16440
46. X316+X317+X318+X319+X320+X321+X322=21427
47. X323+X324+X325+X326+X327+X328+X329=4751
48. X330+X331+X332+X333+X334+X335+X336=11749
49. X337+X338+X339+X340+X341+X342+X343=21102
50. X344+X345+X346+X347+X348+X349+X350=16008
51. X351+X352+X353+X354+X355+X356+X357=8807
52. X358+X359+X360+X361+X362+X363+X364=16443
53. X365+X366+X367+X368+X369+X370+X371=18848
54. X372+X373+X374+X375+X376+X377+X378=2221
55. X379+X380+X381+X382+X383+X384+X385=7238
56. X386+X387+X388+X389+X390+X391+X392=8816
57. X393+X394+X395+X396+X397+X398+X399=9598
58. X400+X401+X402+X403+X404+X405+X406=13503
59. X407+X408+X409+X410+X411+X412+X413=932
60. X414+X415+X416+X417+X418+X419+X420=12870
61. X421+X422+X423+X424+X425+X426+X427=17890
62. X428+X429+X430+X431+X432+X433+X434=5760
63. X435+X436+X437+X438+X439+X440+X441=15012
64. X442+X443+X444+X445+X446+X447+X448=21029
65. X449+X450+X451+X452+X453+X454+X455=15967
66. X456+X457+X458+X459+X460+X461+X462=1307
67. X463+X464+X465+X466+X467+X468+X469=10946
68. X470+X471+X472+X473+X474+X475+X476=16995
69. X477+X478+X479+X480+X481+X482+X483=21268
70. X484+X485+X486+X487+X488+X489+X490=14334
71. X491+X492+X493+X494+X495+X496+X497=19193
72. X498+X499+X500+X501+X502+X503+X504=3663
73. X505+X506+X507+X508+X509+X510+X511=19091
74. X512+X513+X514+X515+X516+X517+X518=12139

```
 75.  X519+X520+X521+X522+X523+X524+X525=18590
 76.  X526+X527+X528+X529+X530+X531+X532=3541
 77.  X533+X534+X535+X536+X537+X538+X539=9201
 78.  X540+X541+X542+X543+X544+X545+X546=2187
 79.  X547+X548+X549+X550+X551+X552+X553=2757
 80.  X554+X555+X556+X557+X558+X559+X560=8369
 81.  X561+X562+X563+X564+X565+X566+X567=11971
 82.  X568+X569+X570+X571+X572+X573+X574=17547
 83.  X575+X576+X577+X578+X579+X580+X581=20038
 84.  X582+X583+X584+X585+X586+X587+X588=14221
 85.  X589+X590+X591+X592+X593+X594+X595=10957
 86.  X596+X597+X598+X599+X600+X601+X602=10674
 87.  X603+X604+X605+X606+X607+X608+X609=18364
 88.  X610+X611+X612+X613+X614+X615+X616=18469
 89.  X617+X618+X619+X620+X621+X622+X623=10060
 90.  X624+X625+X626+X627+X628+X629+X630=12269
 91.  X631+X632+X633+X634+X635+X636+X637=16819
 92.  X638+X639+X640+X641+X642+X643+X644=12055
 93.  X645+X646+X647+X648+X649+X650+X651=1720
 94.  X652+X653+X654+X655+X656+X657+X658=5080
 95.  X659+X660+X661+X662+X663+X664+X665=2197
 96.  X666+X667+X668+X669+X670+X671+X672=13256
```



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********************
* PROBLEM NUMBER  1 *
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

 97.  X673+X674+X675+X676+X677+X678+X679=893
 98.  X680+X681+X682+X683+X684+X685+X686=6326
 99.  X687+X688+X689+X690+X691+X692+X693=368
      *
      *   DESTINATION 1
100.  X1+X8+X15+X22+X29+X36+X43+X50+X57+X64+X71+X78+X85+X92+X99+X106+X113+
      X120+X127+X134+X141+X148+X155+X162+X169+X176+X183+X190+X197+X204+X211+
      X218+X225+X232+X239+X246+X253+X260+X267+X274+X281+X288+X295+X302+X309+
      X316+X323+X330+X337+X344+X351+X358+X365+X372+X379+X386+X393+X400+X407+
      X414+X421+X428+X435+X442+X449+X456+X463+X470+X477+X484+X491+X498+X505+
      X512+X519+X526+X533+X540+X547+X554+X561+X568+X575+X582+X589+X596+X603+
      X610+X617+X624+X631+X638+X645+X652+X659+X666+X673+X680+X687=
      156950
      *
      *    DESTINATION 2
101.  X2+X9+X16+X23+X30+X37+X44+X51+X58+X65+X72+X79+X86+X93+X100+X107+X114+
      X121+X128+X135+X142+X149+X156+X163+X170+X177+X184+X191+X198+X205+X212+
      X219+X226+X233+X240+X247+X254+X261+X268+X275+X282+X289+X296+X303+X310+
      X317+X324+X331+X338+X345+X352+X359+X366+X373+X380+X387+X394+X401+X408+
      X415+X422+X429+X436+X443+X450+X457+X464+X471+X478+X485+X492+X499+X506+
      X513+X520+X527+X534+X541+X548+X555+X562+X569+X576+X583+X590+X597+X604+
      X611+X618+X625+X632+X639+X646+X653+X660+X667+X674+X681+X688=
      146000
      *
```

```
      *    DESTINATION 3
102.  X3+X10+X17+X24+X31+X38+X45+X52+X59+X66+X73+X80+X87+X94+X101+X108+X115+
      X122+X129+X136+X143+X150+X157+X164+X171+X178+X185+X192+X199+X206+X213+
      X220+X227+X234+X241+X248+X255+X262+X269+X276+X283+X290+X297+X304+X311+
      X318+X325+X332+X339+X346+X353+X360+X367+X374+X381+X388+X395+X402+X409+
      X416+X423+X430+X437+X444+X451+X458+X465+X472+X479+X486+X493+X500+X507+
      X514+X521+X528+X535+X542+X549+X556+X563+X570+X577+X584+X591+X598+X605+
      X612+X619+X626+X633+X640+X647+X654+X661+X668+X675+X682+X689=
      87600
      *
      *    DESTINATION 4
103.  X4+X11+X18+X25+X32+X39+X46+X53+X60+X67+X74+X81+X88+X95+X102+X109+X116+
      X123+X130+X137+X144+X151+X158+X165+X172+X179+X186+X193+X200+X207+X214+
      X221+X228+X235+X242+X249+X256+X263+X270+X277+X284+X291+X298+X305+X312+
      X319+X326+X333+X340+X347+X354+X361+X368+X375+X382+X389+X396+X403+X410+
      X417+X424+X431+X438+X445+X452+X459+X466+X473+X480+X487+X494+X501+X508+
      X515+X522+X529+X536+X543+X550+X557+X564+X571+X578+X585+X592+X599+X606+
      X613+X620+X627+X634+X641+X648+X655+X662+X669+X676+X683+X690=
      82125
      *
      *    DESTINATION 5
104.  X5+X12+X19+X26+X33+X40+X47+X54+X61+X68+X75+X82+X89+X96+X103+X110+X117+
      X124+X131+X138+X145+X152+X159+X166+X173+X180+X187+X194+X201+X208+X215+
      X222+X229+X236+X243+X250+X257+X264+X271+X278+X285+X292+X299+X306+X313+
      X320+X327+X334+X341+X348+X355+X362+X369+X376+X383+X390+X397+X404+X411+
      X418+X425+X432+X439+X446+X453+X460+X467+X474+X481+X488+X495+X502+X509+
      X516+X523+X530+X537+X544+X551+X558+X565+X572+X579+X586+X593+X600+X607+
      X614+X621+X628+X635+X642+X649+X656+X663+X670+X677+X684+X691=
      365000
      *
      *    DESTINATION 6
105.  X6+X13+X20+X27+X34+X41+X48+X55+X62+X69+X76+X83+X90+X97+X104+X111+X118+
      X125+X132+X139+X146+X153+X160+X167+X174+X181+X188+X195+X202+X209+X216+
      X223+X230+X237+X244+X251+X258+X265+X272+X279+X286+X293+X300+X307+X314+
      X321+X328+X335+X342+X349+X356+X363+X370+X377+X384+X391+X398+X405+X412+
      X419+X426+X433+X440+X447+X454+X461+X468+X475+X482+X489+X496+X503+X510+
      X517+X524+X531+X538+X545+X552+X559+X566+X573+X580+X587+X594+X601+X608+
      X615+X622+X629+X636+X643+X650+X657+X664+X671+X678+X685+X692=
      73000
      *
      *
      *    DESTINATION 7
106.  X7+X14+X21+X28+X35+X42+X49+X56+X63+X70+X84+X91+X98+X105+X112+X119+
      X126+X133+X140+X147+X154+X161+X168+X175+X182+X189+X196+X203+X210+
      X217+X224+X231+X238+X245+X252+X259+X266+X273+X280+X287+X294+X301+
      X308+X315+X322+X329+X336+X343+X350+X357+X364+X371+X378+X385+X392+
      X399+X406+X413+X420+X427+X434+X441+X448+X455+X462+X469+X476+X483+
```



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

USING REGULAR
I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.
```

```
X490+X497+X504+X511+X518+X525+X532+X539+X546+X553+X560+X567+X574+
X581+X588+X595+X602+X609+X616+X623+X630+X637+X644+X651+X658+X665+
X672+X679+X686+X693=
285000
*
*
*
BOUNDS
X1 TO X693.GE.0
MAXCM 500000
OPTIMIZE
```



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

(From here to the end of this listing is an example of the MPOS output.)

USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

PROBLEM INPUT SUMMARY

CONSTRAINTS	VARIABLES	NON-ZEROS	PARAMETERS	BOUNDS
EQS= 106	INT= 0	NUMBER= 1385	TOL= .100E-08	
LES= 0	TOTAL= 693	PERCENT= 1.89	EPS=DEFAULT	
GES= 0	NOUB= 0		LIMIT=DEFAULT	
TOTAL= 106	NOLB= 693		RSCALE= .100E+01	

VARIABLE TABLE

1 - X1	2 - X2	3 - X3	4 - X4	5 - X5	6 - X6
7 - X7	8 - X8	9 - X9	10 - X10	11 - X11	12 - X12
13 - X13	14 - X14	15 - X15	16 - X16	17 - X17	18 - X18
19 - X19	20 - X20	21 - X21	22 - X22	23 - X23	24 - X24
25 - X25	26 - X26	27 - X27	28 - X28	29 - X29	30 - X30
31 - X31	32 - X32	33 - X33	34 - X34	35 - X35	36 - X36
37 - X37	38 - X38	39 - X39	40 - X40	41 - X41	42 - X42
43 - X43	44 - X44	45 - X45	46 - X46	47 - X47	48 - X48
49 - X49	50 - X50	51 - X51	52 - X52	53 - X53	54 - X54
55 - X55	56 - X56	57 - X57	58 - X58	59 - X59	60 - X60
61 - X61	62 - X62	63 - X63	64 - X64	65 - X65	66 - X66
67 - X67	68 - X68	69 - X69	70 - X70	71 - X71	72 - X72
73 - X73	74 - X74	75 - X75	76 - X76	77 - X77	78 - X78
79 - X79	80 - X80	81 - X81	82 - X82	83 - X83	84 - X84
85 - X85	86 - X86	87 - X87	88 - X88	89 - X89	90 - X90
91 - X91	92 - X92	93 - X93	94 - X94	95 - X95	96 - X96
97 - X97	98 - X98	99 - X99	100 - X100	101 - X101	102 - X102
103 - X103	104 - X104	105 - X105	106 - X106	107 - X107	108 - X108

109 - X109	110 - X110	111 - X111	112 - X112	113 - X113	114 - X114
115 - X115	116 - X116	117 - X117	118 - X118	119 - X119	120 - X120
121 - X121	122 - X122	123 - X123	124 - X124	125 - X125	126 - X126
127 - X127	128 - X128	129 - X129	130 - X130	131 - X131	132 - X132
133 - X133	134 - X134	135 - X135	136 - X136	137 - X137	138 - X138
139 - X139	140 - X140	141 - X141	142 - X142	143 - X143	144 - X144
145 - X145	146 - X146	147 - X147	148 - X148	149 - X149	150 - X150
151 - X151	152 - X152	153 - X153	154 - X154	155 - X155	156 - X156
157 - X157	158 - X158	159 - X159	160 - X160	161 - X161	162 - X162
163 - X163	164 - X164	165 - X165	166 - X166	167 - X167	168 - X168
169 - X169	170 - X170	171 - X171	172 - X172	173 - X173	174 - X174
175 - X175	176 - X176	177 - X177	178 - X178	179 - X179	180 - X180
181 - X181	182 - X182	183 - X183	184 - X184	185 - X185	186 - X186
187 - X187	188 - X188	189 - X189	190 - X190	191 - X191	192 - X192
193 - X193	194 - X194	195 - X195	196 - X196	197 - X197	198 - X198
199 - X199	200 - X200	201 - X201	202 - X202	203 - X203	204 - X204
205 - X205	206 - X206	207 - X207	208 - X208	209 - X209	210 - X210
211 - X211	212 - X212	213 - X213	214 - X214	215 - X215	216 - X216
217 - X217	218 - X218	219 - X219	220 - X220	221 - X221	222 - X222
223 - X223	224 - X224	225 - X225	226 - X226	227 - X227	228 - X228
229 - X229	230 - X230	231 - X231	232 - X232	233 - X233	234 - X234
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241 - X241	242 - X242	243 - X243	244 - X244	245 - X245	246 - X246
247 - X247	248 - X248	249 - X249	250 - X250	251 - X251	252 - X252
253 - X253	254 - X254	255 - X255	256 - X256	257 - X257	258 - X258
259 - X259	260 - X260	261 - X261	262 - X262	263 - X263	264 - X264
265 - X265	266 - X266	267 - X267	268 - X268	269 - X269	270 - X270
271 - X271	272 - X272	273 - X273	274 - X274	275 - X275	276 - X276
277 - X277	278 - X278	279 - X279	280 - X280	281 - X281	282 - X282
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289 - X289	290 - X290	291 - X291	292 - X292	293 - X293	294 - X294
295 - X295	296 - X296	297 - X297	298 - X298	299 - X299	300 - X300
301 - X301	302 - X302	303 - X303	304 - X304	305 - X305	306 - X306
307 - X307	308 - X308	309 - X309	310 - X310	311 - X311	312 - X312
313 - X313	314 - X314	315 - X315	316 - X316	317 - X317	318 - X318
319 - X319	320 - X320	321 - X321	322 - X322	323 - X323	324 - X324
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337 - X337	338 - X338	339 - X339	340 - X340	341 - X341	342 - X342
343 - X343	344 - X344	345 - X345	346 - X346	347 - X347	348 - X348
349 - X349	350 - X350	351 - X351	352 - X352	353 - X353	354 - X354

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

USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

VARIABLE TABLE

355 - X355	356 - X356	357 - X357	358 - X358	359 - X359	360 - X360

361 - X361	362 - X362	363 - X363	364 - X364	365 - X365	366 - X366
367 - X367	368 - X368	369 - X369	370 - X370	371 - X371	372 - X372
373 - X373	374 - X374	375 - X375	376 - X376	377 - X377	378 - X378
379 - X379	380 - X380	381 - X381	382 - X382	383 - X383	384 - X384
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391 - X391	392 - X392	393 - X393	394 - X394	395 - X395	396 - X396
397 - X397	398 - X398	399 - X399	400 - X400	401 - X401	402 - X402
403 - X403	404 - X404	405 - X405	406 - X406	407 - X407	408 - X408
409 - X409	410 - X410	411 - X411	412 - X412	413 - X413	414 - X414
415 - X415	416 - X416	417 - X417	418 - X418	419 - X419	420 - X420
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427 - X427	428 - X428	429 - X429	430 - X430	431 - X431	432 - X432
433 - X433	434 - X434	435 - X435	436 - X436	437 - X437	438 - X438
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457 - X457	458 - X458	459 - X459	460 - X460	461 - X461	462 - X462
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529 - X529	530 - X530	531 - X531	532 - X532	533 - X533	534 - X534
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601 - X601	602 - X602	603 - X603	604 - X604	605 - X605	606 - X606
607 - X607	608 - X608	609 - X609	610 - X610	611 - X611	612 - X612
613 - X613	614 - X614	615 - X615	616 - X616	617 - X617	618 - X618
619 - X619	620 - X620	621 - X621	622 - X622	623 - X623	624 - X624
625 - X625	626 - X626	627 - X627	628 - X628	629 - X629	630 - X630
631 - X631	632 - X632	633 - X633	634 - X634	635 - X635	636 - X636
637 - X637	638 - X638	639 - X639	640 - X640	641 - X641	642 - X642
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661 - X661	662 - X662	663 - X663	664 - X664	665 - X665	666 - X666
667 - X667	668 - X668	669 - X669	670 - X670	671 - X671	672 - X672
673 - X673	674 - X674	675 - X675	676 - X676	677 - X677	678 - X678
679 - X679	680 - X680	681 - X681	682 - X682	683 - X683	684 - X684
685 - X685	686 - X686	687 - X687	688 - X688	689 - X689	690 - X690

691 - X691 692 - X692 693 - X693

INPUT TRANSLATION TIME = 1.8140 SECONDS

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

USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

```
ITNO.    1 IN VAR-   1  VAR- 800 TO LOWER BOUND  -WMIN=  -2369200.000000
ITNO.    2 IN VAR-   8  VAR- 801 TO LOWER BOUND  -WMIN=  -2340166.000000
ITNO.    3 IN VAR-  15  VAR- 802 TO LOWER BOUND  -WMIN=  -2307204.000000
ITNO.    4 IN VAR-  22  VAR- 803 TO LOWER BOUND  -WMIN=  -2270940.000000
ITNO.    5 IN VAR-  29  VAR- 804 TO LOWER BOUND  -WMIN=  -2242138.000000
ITNO.    6 IN VAR-  36  VAR- 805 TO LOWER BOUND  -WMIN=  -2223580.000000
ITNO.    7 IN VAR-  43  VAR- 806 TO LOWER BOUND  -WMIN=  -2181552.000000
ITNO.    8 IN VAR-  50  VAR- 807 TO LOWER BOUND  -WMIN=  -2170724.000000
ITNO.    9 IN VAR-  57  VAR- 808 TO LOWER BOUND  -WMIN=  -2164452.000000
ITNO.   10 IN VAR-  64  VAR- 809 TO LOWER BOUND  -WMIN=  -2132966.000000
ITNO.   11 IN VAR-  71  VAR- 810 TO LOWER BOUND  -WMIN=  -2111000.000000
ITNO.   12 IN VAR-  78  VAR- 899 TO LOWER BOUND  -WMIN=  -2077450.000000
ITNO.   13 IN VAR-   2  VAR- 811 TO LOWER BOUND  -WMIN=  -2067234.000000
ITNO.   14 IN VAR-  85  VAR-   1 TO LOWER BOUND  -WMIN=  -2055300.000000
ITNO.   15 IN VAR-   9  VAR- 812 TO LOWER BOUND  -WMIN=  -2045340.000000
ITNO.   16 IN VAR-  92  VAR-   8 TO LOWER BOUND  -WMIN=  -2026266.000000
ITNO.   17 IN VAR-  16  VAR- 813 TO LOWER BOUND  -WMIN=  -2008524.000000
ITNO.   18 IN VAR-  99  VAR- 814 TO LOWER BOUND  -WMIN=  -1996326.000000
ITNO.   19 IN VAR- 106  VAR-  15 TO LOWER BOUND  -WMIN=  -1993304.000000
ITNO.   20 IN VAR-  23  VAR-  22 TO LOWER BOUND  -WMIN=  -1957040.000000
ITNO.   21 IN VAR-  30  VAR- 815 TO LOWER BOUND  -WMIN=  -1954484.000000
ITNO.   22 IN VAR- 113  VAR-  29 TO LOWER BOUND  -WMIN=  -1928238.000000
ITNO.   23 IN VAR-  37  VAR- 816 TO LOWER BOUND  -WMIN=  -1926302.000000
ITNO.   24 IN VAR- 120  VAR- 817 TO LOWER BOUND  -WMIN=  -1921090.000000
ITNO.   25 IN VAR- 127  VAR-  36 TO LOWER BOUND  -WMIN=  -1909680.000000
ITNO.   26 IN VAR-  44  VAR- 818 TO LOWER BOUND  -WMIN=  -1906834.000000
ITNO.   27 IN VAR- 134  VAR- 819 TO LOWER BOUND  -WMIN=  -1867884.000000
ITNO.   28 IN VAR- 141  VAR-  43 TO LOWER BOUND  -WMIN=  -1867652.000000
ITNO.   29 IN VAR-  51  VAR-  50 TO LOWER BOUND  -WMIN=  -1856824.000000
ITNO.   30 IN VAR-  58  VAR- 820 TO LOWER BOUND  -WMIN=  -1853012.000000
ITNO.   31 IN VAR- 148  VAR-  57 TO LOWER BOUND  -WMIN=  -1850552.000000
ITNO.   32 IN VAR-  65  VAR-  64 TO LOWER BOUND  -WMIN=  -1819066.000000
ITNO.   33 IN VAR-  72  VAR- 821 TO LOWER BOUND  -WMIN=  -1810398.000000
ITNO.   34 IN VAR- 155  VAR-  71 TO LOWER BOUND  -WMIN=  -1797100.000000
ITNO.   35 IN VAR-  79  VAR- 822 TO LOWER BOUND  -WMIN=  -1790126.000000
ITNO.   36 IN VAR- 162  VAR- 900 TO LOWER BOUND  -WMIN=  -1785450.000000
ITNO.   37 IN VAR-   3  VAR-   2 TO LOWER BOUND  -WMIN=  -1763300.000000
ITNO.   38 IN VAR-  10  VAR-  78 TO LOWER BOUND  -WMIN=  -1753334.000000
ITNO.   39 IN VAR-  86  VAR- 823 TO LOWER BOUND  -WMIN=  -1749190.000000
ITNO.   40 IN VAR- 169  VAR-   9 TO LOWER BOUND  -WMIN=  -1734266.000000
ITNO.   41 IN VAR-  17  VAR-  85 TO LOWER BOUND  -WMIN=  -1731440.000000
ITNO.   42 IN VAR-  93  VAR- 824 TO LOWER BOUND  -WMIN=  -1718446.000000
ITNO.   43 IN VAR- 176  VAR-  16 TO LOWER BOUND  -WMIN=  -1701304.000000
```

```
ITNO.    44 IN VAR-  24  VAR-  92 TO LOWER BOUND  -WMIN=  -1694624.000000
ITNO.    45 IN VAR- 100  VAR- 825 TO LOWER BOUND  -WMIN=  -1689204.000000
ITNO.    46 IN VAR- 183  VAR- 826 TO LOWER BOUND  -WMIN=  -1686602.000000
ITNO.    47 IN VAR- 190  VAR-  99 TO LOWER BOUND  -WMIN=  -1682426.000000
ITNO.    48 IN VAR- 107  VAR-  23 TO LOWER BOUND  -WMIN=  -1665040.000000
ITNO.    49 IN VAR-  31  VAR- 827 TO LOWER BOUND  -WMIN=  -1654760.000000
ITNO.    50 IN VAR- 197  VAR- 106 TO LOWER BOUND  -WMIN=  -1640584.000000
ITNO.    51 IN VAR- 114  VAR-  30 TO LOWER BOUND  -WMIN=  -1636238.000000
ITNO.    52 IN VAR-  38  VAR-  37 TO LOWER BOUND  -WMIN=  -1617680.000000
ITNO.    53 IN VAR-  45  VAR- 828 TO LOWER BOUND  -WMIN=  -1615302.000000
ITNO.    54 IN VAR- 204  VAR- 113 TO LOWER BOUND  -WMIN=  -1612402.000000
ITNO.    55 IN VAR- 121  VAR- 901 TO LOWER BOUND  -WMIN=  -1610250.000000
ITNO.    56 IN VAR-   4  VAR- 829 TO LOWER BOUND  -WMIN=  -1608492.000000
ITNO.    57 IN VAR- 211  VAR- 120 TO LOWER BOUND  -WMIN=  -1607190.000000
ITNO.    58 IN VAR- 128  VAR- 830 TO LOWER BOUND  -WMIN=  -1597674.000000
ITNO.    59 IN VAR- 218  VAR- 127 TO LOWER BOUND  -WMIN=  -1592934.000000
ITNO.    60 IN VAR- 135  VAR- 831 TO LOWER BOUND  -WMIN=  -1588260.000000
ITNO.    61 IN VAR- 225  VAR-   3 TO LOWER BOUND  -WMIN=  -1588100.000000
ITNO.    62 IN VAR-  11  VAR-  44 TO LOWER BOUND  -WMIN=  -1575652.000000
ITNO.    63 IN VAR-  52  VAR-  51 TO LOWER BOUND  -WMIN=  -1564824.000000
ITNO.    64 IN VAR-  59  VAR- 832 TO LOWER BOUND  -WMIN=  -1562234.000000
ITNO.    65 IN VAR- 232  VAR-  10 TO LOWER BOUND  -WMIN=  -1559066.000000
ITNO.    66 IN VAR-  18  VAR-  58 TO LOWER BOUND  -WMIN=  -1558552.000000
ITNO.    67 IN VAR-  66  VAR- 134 TO LOWER BOUND  -WMIN=  -1553984.000000
ITNO.    68 IN VAR- 142  VAR- 141 TO LOWER BOUND  -WMIN=  -1539112.000000
ITNO.    69 IN VAR- 149  VAR- 833 TO LOWER BOUND  -WMIN=  -1538536.000000
ITNO.    70 IN VAR- 239  VAR-  65 TO LOWER BOUND  -WMIN=  -1527066.000000
ITNO.    71 IN VAR-  73  VAR-  17 TO LOWER BOUND  -WMIN=  -1526104.000000
```



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

USING REGULAR
II82. 1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

ITNO.    72 IN VAR-  25  VAR- 834 TO LOWER BOUND  -WMIN=  -1519532.000000
ITNO.    73 IN VAR- 246  VAR-  72 TO LOWER BOUND  -WMIN=  -1505100.000000
ITNO.    74 IN VAR-  80  VAR- 148 TO LOWER BOUND  -WMIN=  -1496498.000000
ITNO.    75 IN VAR- 156  VAR-  24 TO LOWER BOUND  -WMIN=  -1489840.000000
ITNO.    76 IN VAR-  32  VAR- 835 TO LOWER BOUND  -WMIN=  -1478178.000000
ITNO.    77 IN VAR- 253  VAR- 155 TO LOWER BOUND  -WMIN=  -1476226.000000
ITNO.    78 IN VAR- 163  VAR-  79 TO LOWER BOUND  -WMIN=  -1461334.000000
ITNO.    79 IN VAR-  87  VAR-  31 TO LOWER BOUND  -WMIN=  -1461038.000000
ITNO.    80 IN VAR-  39  VAR- 902 TO LOWER BOUND  -WMIN=  -1446000.000000
ITNO.    81 IN VAR-   5  VAR- 836 TO LOWER BOUND  -WMIN=  -1445526.000000
ITNO.    82 IN VAR- 260  VAR-  38 TO LOWER BOUND  -WMIN=  -1442480.000000
ITNO.    83 IN VAR-  46  VAR-  86 TO LOWER BOUND  -WMIN=  -1439440.000000
ITNO.    84 IN VAR-  94  VAR- 162 TO LOWER BOUND  -WMIN=  -1435290.000000
ITNO.    85 IN VAR- 170  VAR-   4 TO LOWER BOUND  -WMIN=  -1423850.000000
ITNO.    86 IN VAR-  12  VAR- 837 TO LOWER BOUND  -WMIN=  -1407552.000000
ITNO.    87 IN VAR- 267  VAR- 169 TO LOWER BOUND  -WMIN=  -1404546.000000
ITNO.    88 IN VAR- 177  VAR-  93 TO LOWER BOUND  -WMIN=  -1402624.000000
ITNO.    89 IN VAR- 101  VAR-  45 TO LOWER BOUND  -WMIN=  -1400452.000000
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ITNO.  90 IN VAR-  53  VAR-  11 TO LOWER BOUND  -WMIN=  -1394816.000000
ITNO.  91 IN VAR-  19  VAR- 100 TO LOWER BOUND  -WMIN=  -1390426.000000
ITNO.  92 IN VAR- 108  VAR-  52 TO LOWER BOUND  -WMIN=  -1389624.000000
ITNO.  93 IN VAR-  60  VAR-  59 TO LOWER BOUND  -WMIN=  -1383352.000000
ITNO.  94 IN VAR-  67  VAR- 176 TO LOWER BOUND  -WMIN=  -1375304.000000
ITNO.  95 IN VAR- 184  VAR- 838 TO LOWER BOUND  -WMIN=  -1375182.000000
ITNO.  96 IN VAR- 274  VAR- 839 TO LOWER BOUND  -WMIN=  -1374312.000000
ITNO.  97 IN VAR- 281  VAR- 183 TO LOWER BOUND  -WMIN=  -1372702.000000
ITNO.  98 IN VAR- 191  VAR-  18 TO LOWER BOUND  -WMIN=  -1361854.000000
ITNO.  99 IN VAR-  26  VAR-  66 TO LOWER BOUND  -WMIN=  -1351866.000000
ITNO. 100 IN VAR-  74  VAR- 107 TO LOWER BOUND  -WMIN=  -1348584.000000
ITNO. 101 IN VAR- 115  VAR- 190 TO LOWER BOUND  -WMIN=  -1340860.000000
ITNO. 102 IN VAR- 198  VAR-  73 TO LOWER BOUND  -WMIN=  -1329900.000000
ITNO. 103 IN VAR-  81  VAR- 840 TO LOWER BOUND  -WMIN=  -1329816.000000
ITNO. 104 IN VAR- 288  VAR-  25 TO LOWER BOUND  -WMIN=  -1325590.000000
ITNO. 105 IN VAR-  33  VAR- 114 TO LOWER BOUND  -WMIN=  -1320402.000000
ITNO. 106 IN VAR- 122  VAR- 121 TO LOWER BOUND  -WMIN=  -1315190.000000
ITNO. 107 IN VAR- 129  VAR- 841 TO LOWER BOUND  -WMIN=  -1310222.000000
ITNO. 108 IN VAR- 295  VAR- 197 TO LOWER BOUND  -WMIN=  -1301402.000000
ITNO. 109 IN VAR- 205  VAR- 128 TO LOWER BOUND  -WMIN=  -1300934.000000
ITNO. 110 IN VAR- 136  VAR-  32 TO LOWER BOUND  -WMIN=  -1296788.000000
ITNO. 111 IN VAR-  40  VAR- 204 TO LOWER BOUND  -WMIN=  -1294592.000000
ITNO. 112 IN VAR- 212  VAR-  80 TO LOWER BOUND  -WMIN=  -1286134.000000
ITNO. 113 IN VAR-  88  VAR- 211 TO LOWER BOUND  -WMIN=  -1283774.000000
ITNO. 114 IN VAR- 219  VAR- 842 TO LOWER BOUND  -WMIN=  -1283118.000000
ITNO. 115 IN VAR- 302  VAR-  39 TO LOWER BOUND  -WMIN=  -1278230.000000
ITNO. 116 IN VAR-  47  VAR- 218 TO LOWER BOUND  -WMIN=  -1274360.000000
ITNO. 117 IN VAR- 226  VAR- 843 TO LOWER BOUND  -WMIN=  -1266552.000000
ITNO. 118 IN VAR- 309  VAR-  87 TO LOWER BOUND  -WMIN=  -1264240.000000
ITNO. 119 IN VAR-  95  VAR- 135 TO LOWER BOUND  -WMIN=  -1261984.000000
ITNO. 120 IN VAR- 143  VAR- 225 TO LOWER BOUND  -WMIN=  -1248334.000000
ITNO. 121 IN VAR- 233  VAR- 142 TO LOWER BOUND  -WMIN=  -1247112.000000
ITNO. 122 IN VAR- 150  VAR-  46 TO LOWER BOUND  -WMIN=  -1236202.000000
ITNO. 123 IN VAR-  54  VAR- 844 TO LOWER BOUND  -WMIN=  -1233672.000000
ITNO. 124 IN VAR- 316  VAR-  94 TO LOWER BOUND  -WMIN=  -1227424.000000
ITNO. 125 IN VAR- 102  VAR-  53 TO LOWER BOUND  -WMIN=  -1225374.000000
ITNO. 126 IN VAR-  61  VAR- 232 TO LOWER BOUND  -WMIN=  -1224636.000000
ITNO. 127 IN VAR- 240  VAR-  60 TO LOWER BOUND  -WMIN=  -1219102.000000
ITNO. 128 IN VAR-  68  VAR- 101 TO LOWER BOUND  -WMIN=  -1215226.000000
ITNO. 129 IN VAR- 109  VAR- 239 TO LOWER BOUND  -WMIN=  -1205632.000000
ITNO. 130 IN VAR- 247  VAR- 149 TO LOWER BOUND  -WMIN=  -1204498.000000
ITNO. 131 IN VAR- 157  VAR- 845 TO LOWER BOUND  -WMIN=  -1190818.000000
ITNO. 132 IN VAR- 323  VAR-  67 TO LOWER BOUND  -WMIN=  -1187616.000000
ITNO. 133 IN VAR-  75  VAR- 156 TO LOWER BOUND  -WMIN=  -1184226.000000
ITNO. 134 IN VAR- 164  VAR- 846 TO LOWER BOUND  -WMIN=  -1181316.000000
ITNO. 135 IN VAR- 330  VAR- 108 TO LOWER BOUND  -WMIN=  -1173384.000000
ITNO. 136 IN VAR- 116  VAR-  74 TO LOWER BOUND  -WMIN=  -1165650.000000
ITNO. 137 IN VAR-  82  VAR- 246 TO LOWER BOUND  -WMIN=  -1164278.000000
ITNO. 138 IN VAR- 254  VAR- 847 TO LOWER BOUND  -WMIN=  -1157818.000000
ITNO. 139 IN VAR- 337  VAR- 115 TO LOWER BOUND  -WMIN=  -1145202.000000
ITNO. 140 IN VAR- 123  VAR- 163 TO LOWER BOUND  -WMIN=  -1143290.000000
ITNO. 141 IN VAR- 171  VAR- 122 TO LOWER BOUND  -WMIN=  -1139990.000000
ITNO. 142 IN VAR- 130  VAR- 253 TO LOWER BOUND  -WMIN=  -1131626.000000
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USING REGULAR
I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

ITNO.  143 IN VAR- 261  VAR- 129 TO LOWER BOUND  -WMIN=  -1125734.000000
ITNO.  144 IN VAR- 137  VAR-  81 TO LOWER BOUND  -WMIN=  -1121884.000000
ITNO.  145 IN VAR-  89  VAR- 848 TO LOWER BOUND  -WMIN=  -1115614.000000
ITNO.  146 IN VAR- 344  VAR- 170 TO LOWER BOUND  -WMIN=  -1112546.000000
ITNO.  147 IN VAR- 178  VAR-  88 TO LOWER BOUND  -WMIN=  -1099990.000000
ITNO.  148 IN VAR-  96  VAR- 260 TO LOWER BOUND  -WMIN=  -1093652.000000
ITNO.  149 IN VAR- 268  VAR- 136 TO LOWER BOUND  -WMIN=  -1086784.000000
ITNO.  150 IN VAR- 144  VAR- 849 TO LOWER BOUND  -WMIN=  -1083598.000000
ITNO.  151 IN VAR- 351  VAR- 177 TO LOWER BOUND  -WMIN=  -1083304.000000
ITNO.  152 IN VAR- 185  VAR- 184 TO LOWER BOUND  -WMIN=  -1080702.000000
ITNO.  153 IN VAR- 192  VAR- 143 TO LOWER BOUND  -WMIN=  -1071912.000000
ITNO.  154 IN VAR- 151  VAR- 850 TO LOWER BOUND  -WMIN=  -1065984.000000
ITNO.  155 IN VAR- 358  VAR-  95 TO LOWER BOUND  -WMIN=  -1063174.000000
ITNO.  156 IN VAR- 103  VAR- 267 TO LOWER BOUND  -WMIN=  -1061282.000000
ITNO.  157 IN VAR- 275  VAR- 274 TO LOWER BOUND  -WMIN=  -1060412.000000
ITNO.  158 IN VAR- 282  VAR- 102 TO LOWER BOUND  -WMIN=  -1050976.000000
ITNO.  159 IN VAR- 110  VAR- 191 TO LOWER BOUND  -WMIN=  -1048860.000000
ITNO.  160 IN VAR- 199  VAR- 851 TO LOWER BOUND  -WMIN=  -1033098.000000
ITNO.  161 IN VAR- 365  VAR- 150 TO LOWER BOUND  -WMIN=  -1029298.000000
ITNO.  162 IN VAR- 158  VAR- 281 TO LOWER BOUND  -WMIN=  -1015916.000000
ITNO.  163 IN VAR- 289  VAR- 198 TO LOWER BOUND  -WMIN=  -1009402.000000
ITNO.  164 IN VAR- 206  VAR- 109 TO LOWER BOUND  -WMIN=  -1009134.000000
ITNO.  165 IN VAR- 117  VAR- 157 TO LOWER BOUND  -WMIN=  -1009026.000000
ITNO.  166 IN VAR- 165  VAR- 205 TO LOWER BOUND  -WMIN=  -1002592.000000
ITNO.  167 IN VAR- 213  VAR- 288 TO LOWER BOUND  -WMIN=   -996322.000000
ITNO.  168 IN VAR- 296  VAR- 852 TO LOWER BOUND  -WMIN=   -995402.000000
ITNO.  169 IN VAR- 372  VAR- 212 TO LOWER BOUND  -WMIN=   -991774.000000
ITNO.  170 IN VAR- 220  VAR- 853 TO LOWER BOUND  -WMIN=   -990960.000000
ITNO.  171 IN VAR- 379  VAR- 219 TO LOWER BOUND  -WMIN=   -982360.000000
ITNO.  172 IN VAR- 227  VAR- 116 TO LOWER BOUND  -WMIN=   -980952.000000
ITNO.  173 IN VAR- 124  VAR- 854 TO LOWER BOUND  -WMIN=   -976484.000000
ITNO.  174 IN VAR- 386  VAR- 123 TO LOWER BOUND  -WMIN=   -975740.000000
ITNO.  175 IN VAR- 131  VAR- 295 TO LOWER BOUND  -WMIN=   -969218.000000
ITNO.  176 IN VAR- 303  VAR- 164 TO LOWER BOUND  -WMIN=   -968090.000000
ITNO.  177 IN VAR- 172  VAR- 130 TO LOWER BOUND  -WMIN=   -961484.000000
ITNO.  178 IN VAR- 138  VAR- 855 TO LOWER BOUND  -WMIN=   -958852.000000
ITNO.  179 IN VAR- 393  VAR- 226 TO LOWER BOUND  -WMIN=   -956334.000000
ITNO.  180 IN VAR- 234  VAR- 302 TO LOWER BOUND  -WMIN=   -952652.000000
ITNO.  181 IN VAR- 310  VAR- 856 TO LOWER BOUND  -WMIN=   -939656.000000
ITNO.  182 IN VAR- 400  VAR- 171 TO LOWER BOUND  -WMIN=   -937346.000000
ITNO.  183 IN VAR- 179  VAR- 233 TO LOWER BOUND  -WMIN=   -932636.000000
ITNO.  184 IN VAR- 241  VAR- 137 TO LOWER BOUND  -WMIN=   -922534.000000
ITNO.  185 IN VAR- 145  VAR- 309 TO LOWER BOUND  -WMIN=   -919772.000000
ITNO.  186 IN VAR- 317  VAR- 240 TO LOWER BOUND  -WMIN=   -913632.000000
ITNO.  187 IN VAR- 248  VAR- 857 TO LOWER BOUND  -WMIN=   -912650.000000
ITNO.  188 IN VAR- 407  VAR- 858 TO LOWER BOUND  -WMIN=   -910786.000000
ITNO.  189 IN VAR- 414  VAR- 178 TO LOWER BOUND  -WMIN=   -908104.000000
ITNO.  190 IN VAR- 186  VAR- 144 TO LOWER BOUND  -WMIN=   -907662.000000
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ITNO.  191 IN VAR- 152  VAR- 185 TO LOWER BOUND  -WMIN=   -905502.000000
ITNO.  192 IN VAR- 193  VAR- 859 TO LOWER BOUND  -WMIN=   -885046.000000
ITNO.  193 IN VAR- 421  VAR- 316 TO LOWER BOUND  -WMIN=   -876918.000000
ITNO.  194 IN VAR- 324  VAR- 192 TO LOWER BOUND  -WMIN=   -873660.000000
ITNO.  195 IN VAR- 200  VAR- 247 TO LOWER BOUND  -WMIN=   -872278.000000
ITNO.  196 IN VAR- 255  VAR- 323 TO LOWER BOUND  -WMIN=   -867416.000000
ITNO.  197 IN VAR- 331  VAR- 151 TO LOWER BOUND  -WMIN=   -865048.000000
ITNO.  198 IN VAR- 159  VAR- 860 TO LOWER BOUND  -WMIN=   -849266.000000
ITNO.  199 IN VAR- 428  VAR- 158 TO LOWER BOUND  -WMIN=   -844776.000000
ITNO.  200 IN VAR- 166  VAR- 330 TO LOWER BOUND  -WMIN=   -843918.000000
ITNO.  201 IN VAR- 338  VAR- 254 TO LOWER BOUND  -WMIN=   -839626.000000
ITNO.  202 IN VAR- 262  VAR- 861 TO LOWER BOUND  -WMIN=   -837746.000000
ITNO.  203 IN VAR- 435  VAR- 199 TO LOWER BOUND  -WMIN=   -834202.000000
ITNO.  204 IN VAR- 207  VAR- 206 TO LOWER BOUND  -WMIN=   -827392.000000
ITNO.  205 IN VAR- 214  VAR- 213 TO LOWER BOUND  -WMIN=   -816574.000000
ITNO.  206 IN VAR- 221  VAR- 862 TO LOWER BOUND  -WMIN=   -807722.000000
ITNO.  207 IN VAR- 442  VAR- 220 TO LOWER BOUND  -WMIN=   -807160.000000
ITNO.  208 IN VAR- 228  VAR- 165 TO LOWER BOUND  -WMIN=   -803840.000000
ITNO.  209 IN VAR- 173  VAR- 337 TO LOWER BOUND  -WMIN=   -801714.000000
ITNO.  210 IN VAR- 345  VAR- 261 TO LOWER BOUND  -WMIN=   -801652.000000
ITNO.  211 IN VAR- 269  VAR- 227 TO LOWER BOUND  -WMIN=   -781134.000000
ITNO.  212 IN VAR- 235  VAR- 172 TO LOWER BOUND  -WMIN=   -773096.000000
ITNO.  213 IN VAR- 180  VAR- 344 TO LOWER BOUND  -WMIN=   -769698.000000
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USING REGULAR
1182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

ITNO.  214 IN VAR- 352  VAR- 268 TO LOWER BOUND  -WMIN=   -769282.000000
ITNO.  215 IN VAR- 276  VAR- 275 TO LOWER BOUND  -WMIN=   -768412.000000
ITNO.  216 IN VAR- 283  VAR- 863 TO LOWER BOUND  -WMIN=   -765664.000000
ITNO.  217 IN VAR- 449  VAR- 234 TO LOWER BOUND  -WMIN=   -757436.000000
ITNO.  218 IN VAR- 242  VAR- 351 TO LOWER BOUND  -WMIN=   -752084.000000
ITNO.  219 IN VAR- 359  VAR- 179 TO LOWER BOUND  -WMIN=   -743854.000000
ITNO.  220 IN VAR- 187  VAR- 186 TO LOWER BOUND  -WMIN=   -741252.000000
ITNO.  221 IN VAR- 194  VAR- 241 TO LOWER BOUND  -WMIN=   -738432.000000
ITNO.  222 IN VAR- 249  VAR- 864 TO LOWER BOUND  -WMIN=   -733730.000000
ITNO.  223 IN VAR- 456  VAR- 865 TO LOWER BOUND  -WMIN=   -731116.000000
ITNO.  224 IN VAR- 463  VAR- 282 TO LOWER BOUND  -WMIN=   -723916.000000
ITNO.  225 IN VAR- 290  VAR- 358 TO LOWER BOUND  -WMIN=   -719198.000000
ITNO.  226 IN VAR- 366  VAR- 903 TO LOWER BOUND  -WMIN=   -716000.000000
ITNO.  227 IN VAR-   6  VAR- 193 TO LOWER BOUND  -WMIN=   -709410.000000
ITNO.  228 IN VAR- 201  VAR- 866 TO LOWER BOUND  -WMIN=   -709224.000000
ITNO.  229 IN VAR- 470  VAR- 289 TO LOWER BOUND  -WMIN=   -704322.000000
ITNO.  230 IN VAR- 297  VAR- 248 TO LOWER BOUND  -WMIN=   -697078.000000
ITNO.  231 IN VAR- 256  VAR-   5 TO LOWER BOUND  -WMIN=   -693850.000000
ITNO.  232 IN VAR-  13  VAR- 365 TO LOWER BOUND  -WMIN=   -681502.000000
ITNO.  233 IN VAR- 373  VAR- 296 TO LOWER BOUND  -WMIN=   -677218.000000
ITNO.  234 IN VAR- 304  VAR- 372 TO LOWER BOUND  -WMIN=   -677060.000000
ITNO.  235 IN VAR- 380  VAR- 867 TO LOWER BOUND  -WMIN=   -675234.000000
ITNO.  236 IN VAR- 477  VAR- 200 TO LOWER BOUND  -WMIN=   -669952.000000
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ITNO.  238 IN VAR-  20  VAR- 255 TO LOWER BOUND  -WMIN=   -664426.000000
ITNO.  239 IN VAR- 263  VAR- 207 TO LOWER BOUND  -WMIN=   -663142.000000
ITNO.  240 IN VAR- 215  VAR- 379 TO LOWER BOUND  -WMIN=   -662584.000000
ITNO.  241 IN VAR- 387  VAR- 303 TO LOWER BOUND  -WMIN=   -660652.000000
ITNO.  242 IN VAR- 311  VAR- 214 TO LOWER BOUND  -WMIN=   -652324.000000
ITNO.  243 IN VAR- 222  VAR- 386 TO LOWER BOUND  -WMIN=   -644952.000000
ITNO.  244 IN VAR- 394  VAR- 221 TO LOWER BOUND  -WMIN=   -642910.000000
ITNO.  245 IN VAR- 229  VAR- 868 TO LOWER BOUND  -WMIN=   -632698.000000
ITNO.  246 IN VAR- 484  VAR-  19 TO LOWER BOUND  -WMIN=   -631854.000000
ITNO.  247 IN VAR-  27  VAR- 310 TO LOWER BOUND  -WMIN=   -627772.000000
ITNO.  248 IN VAR- 318  VAR- 262 TO LOWER BOUND  -WMIN=   -626452.000000
ITNO.  249 IN VAR- 270  VAR- 393 TO LOWER BOUND  -WMIN=   -625756.000000
ITNO.  250 IN VAR- 401  VAR- 228 TO LOWER BOUND  -WMIN=   -616884.000000
ITNO.  251 IN VAR- 236  VAR- 869 TO LOWER BOUND  -WMIN=   -604030.000000
ITNO.  252 IN VAR- 491  VAR- 400 TO LOWER BOUND  -WMIN=   -598750.000000
ITNO.  253 IN VAR- 408  VAR- 407 TO LOWER BOUND  -WMIN=   -596886.000000
ITNO.  254 IN VAR- 415  VAR-  26 TO LOWER BOUND  -WMIN=   -595590.000000
ITNO.  255 IN VAR-  34  VAR- 269 TO LOWER BOUND  -WMIN=   -594082.000000
ITNO.  256 IN VAR- 277  VAR- 276 TO LOWER BOUND  -WMIN=   -593212.000000
ITNO.  257 IN VAR- 284  VAR- 235 TO LOWER BOUND  -WMIN=   -593186.000000
ITNO.  258 IN VAR- 243  VAR- 317 TO LOWER BOUND  -WMIN=   -584918.000000
ITNO.  259 IN VAR- 325  VAR- 324 TO LOWER BOUND  -WMIN=   -575416.000000
ITNO.  260 IN VAR- 332  VAR- 242 TO LOWER BOUND  -WMIN=   -574182.000000
ITNO.  261 IN VAR- 250  VAR- 414 TO LOWER BOUND  -WMIN=   -571146.000000
ITNO.  262 IN VAR- 422  VAR- 904 TO LOWER BOUND  -WMIN=   -570000.000000
ITNO.  263 IN VAR-   7  VAR-  33 TO LOWER BOUND  -WMIN=   -566788.000000
ITNO.  264 IN VAR-  41  VAR- 870 TO LOWER BOUND  -WMIN=   -565644.000000
ITNO.  265 IN VAR- 498  VAR- 871 TO LOWER BOUND  -WMIN=   -558318.000000
ITNO.  266 IN VAR- 505  VAR- 331 TO LOWER BOUND  -WMIN=   -551918.000000
ITNO.  267 IN VAR- 339  VAR- 283 TO LOWER BOUND  -WMIN=   -548716.000000
ITNO.  268 IN VAR- 291  VAR-  40 TO LOWER BOUND  -WMIN=   -548230.000000
ITNO.  269 IN VAR-  48  VAR-   6 TO LOWER BOUND  -WMIN=   -547850.000000
ITNO.  270 IN VAR-  14  VAR- 421 TO LOWER BOUND  -WMIN=   -535366.000000
ITNO.  271 IN VAR- 429  VAR- 249 TO LOWER BOUND  -WMIN=   -532828.000000
ITNO.  272 IN VAR- 257  VAR- 290 TO LOWER BOUND  -WMIN=   -529122.000000
ITNO.  273 IN VAR- 298  VAR- 428 TO LOWER BOUND  -WMIN=   -523846.000000
ITNO.  274 IN VAR- 436  VAR- 872 TO LOWER BOUND  -WMIN=   -520136.000000
ITNO.  275 IN VAR- 512  VAR-  13 TO LOWER BOUND  -WMIN=   -518816.000000
ITNO.  276 IN VAR-  21  VAR- 338 TO LOWER BOUND  -WMIN=   -509714.000000
ITNO.  277 IN VAR- 346  VAR-  47 TO LOWER BOUND  -WMIN=   -506202.000000
ITNO.  278 IN VAR-  55  VAR- 297 TO LOWER BOUND  -WMIN=   -502018.000000
ITNO.  279 IN VAR- 305  VAR- 256 TO LOWER BOUND  -WMIN=   -500176.000000
ITNO.  280 IN VAR- 264  VAR- 873 TO LOWER BOUND  -WMIN=   -495858.000000
ITNO.  281 IN VAR- 519  VAR-  54 TO LOWER BOUND  -WMIN=   -495374.000000
ITNO.  282 IN VAR-  62  VAR- 435 TO LOWER BOUND  -WMIN=   -493822.000000
ITNO.  283 IN VAR- 443  VAR-  61 TO LOWER BOUND  -WMIN=   -489102.000000
ITNO.  284 IN VAR-  69  VAR-  20 TO LOWER BOUND  -WMIN=   -485854.000000
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1182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

ITNO.  285 IN VAR-  28  VAR- 304 TO LOWER BOUND  -WMIN=   -485452.000000
ITNO.  286 IN VAR- 312  VAR- 345 TO LOWER BOUND  -WMIN=   -477698.000000
ITNO.  287 IN VAR- 353  VAR- 263 TO LOWER BOUND  -WMIN=   -462202.000000
ITNO.  288 IN VAR- 271  VAR- 352 TO LOWER BOUND  -WMIN=   -460084.000000
ITNO.  289 IN VAR- 360  VAR- 874 TO LOWER BOUND  -WMIN=   -458678.000000
ITNO.  290 IN VAR- 526  VAR-  68 TO LOWER BOUND  -WMIN=   -457616.000000
ITNO.  291 IN VAR-  76  VAR- 311 TO LOWER BOUND  -WMIN=   -452572.000000
ITNO.  292 IN VAR- 319  VAR- 442 TO LOWER BOUND  -WMIN=   -451764.000000
ITNO.  293 IN VAR- 450  VAR- 875 TO LOWER BOUND  -WMIN=   -451596.000000
ITNO.  294 IN VAR- 533  VAR-  27 TO LOWER BOUND  -WMIN=   -449590.000000
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ITNO.  299 IN VAR- 285  VAR- 877 TO LOWER BOUND  -WMIN=   -428820.000000
ITNO.  300 IN VAR- 547  VAR- 359 TO LOWER BOUND  -WMIN=   -427198.000000
ITNO.  301 IN VAR- 367  VAR- 878 TO LOWER BOUND  -WMIN=   -423306.000000
ITNO.  302 IN VAR- 554  VAR-  34 TO LOWER BOUND  -WMIN=   -420788.000000
ITNO.  303 IN VAR-  42  VAR- 449 TO LOWER BOUND  -WMIN=   -419830.000000
ITNO.  304 IN VAR- 457  VAR- 456 TO LOWER BOUND  -WMIN=   -417216.000000
ITNO.  305 IN VAR- 464  VAR- 318 TO LOWER BOUND  -WMIN=   -409718.000000
ITNO.  306 IN VAR- 326  VAR- 879 TO LOWER BOUND  -WMIN=   -406568.000000
ITNO.  307 IN VAR- 561  VAR-  41 TO LOWER BOUND  -WMIN=   -402230.000000
ITNO.  308 IN VAR-  49  VAR- 325 TO LOWER BOUND  -WMIN=   -400216.000000
ITNO.  309 IN VAR- 333  VAR- 463 TO LOWER BOUND  -WMIN=   -395324.000000
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ITNO.  311 IN VAR-  90  VAR- 366 TO LOWER BOUND  -WMIN=   -389502.000000
ITNO.  312 IN VAR- 374  VAR- 373 TO LOWER BOUND  -WMIN=   -385060.000000
ITNO.  313 IN VAR- 381  VAR- 284 TO LOWER BOUND  -WMIN=   -384466.000000
ITNO.  314 IN VAR- 292  VAR- 880 TO LOWER BOUND  -WMIN=   -382626.000000
ITNO.  315 IN VAR- 568  VAR- 332 TO LOWER BOUND  -WMIN=   -376718.000000
ITNO.  316 IN VAR- 340  VAR- 380 TO LOWER BOUND  -WMIN=   -370584.000000
ITNO.  317 IN VAR- 388  VAR-  89 TO LOWER BOUND  -WMIN=   -369990.000000
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ITNO.  323 IN VAR-  63  VAR- 881 TO LOWER BOUND  -WMIN=   -347532.000000
ITNO.  324 IN VAR- 575  VAR-  62 TO LOWER BOUND  -WMIN=   -343102.000000
ITNO.  325 IN VAR-  70  VAR- 298 TO LOWER BOUND  -WMIN=   -337768.000000
ITNO.  326 IN VAR- 306  VAR- 339 TO LOWER BOUND  -WMIN=   -334514.000000
ITNO.  327 IN VAR- 347  VAR- 394 TO LOWER BOUND  -WMIN=   -333756.000000
ITNO.  328 IN VAR- 402  VAR-  96 TO LOWER BOUND  -WMIN=   -333174.000000
ITNO.  329 IN VAR- 104  VAR- 305 TO LOWER BOUND  -WMIN=   -321202.000000
ITNO.  330 IN VAR- 313  VAR- 103 TO LOWER BOUND  -WMIN=   -320976.000000
ITNO.  331 IN VAR- 111  VAR- 477 TO LOWER BOUND  -WMIN=   -318798.000000
ITNO.  332 IN VAR- 485  VAR-  69 TO LOWER BOUND  -WMIN=   -311616.000000
ITNO.  333 IN VAR-  84  VAR- 882 TO LOWER BOUND  -WMIN=   -307456.000000
ITNO.  334 IN VAR- 582  VAR- 401 TO LOWER BOUND  -WMIN=   -306750.000000
ITNO.  335 IN VAR- 409  VAR- 408 TO LOWER BOUND  -WMIN=   -304886.000000
ITNO.  336 IN VAR- 416  VAR- 346 TO LOWER BOUND  -WMIN=   -302498.000000
ITNO.  337 IN VAR- 354  VAR- 484 TO LOWER BOUND  -WMIN=   -290130.000000
```

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ITNO.  338 IN VAR- 492  VAR- 312 TO LOWER BOUND  -WMIN=   -288322.000000
ITNO.  339 IN VAR- 320  VAR- 353 TO LOWER BOUND  -WMIN=   -284884.000000
ITNO.  340 IN VAR- 361  VAR- 415 TO LOWER BOUND  -WMIN=   -279146.000000
ITNO.  341 IN VAR- 423  VAR- 110 TO LOWER BOUND  -WMIN=   -279134.000000
ITNO.  342 IN VAR- 118  VAR- 883 TO LOWER BOUND  -WMIN=   -279014.000000
ITNO.  343 IN VAR- 589  VAR-  83 TO LOWER BOUND  -WMIN=   -267850.000000
ITNO.  344 IN VAR-  91  VAR- 884 TO LOWER BOUND  -WMIN=   -257100.000000
ITNO.  345 IN VAR- 596  VAR- 360 TO LOWER BOUND  -WMIN=   -251998.000000
ITNO.  346 IN VAR- 368  VAR- 491 TO LOWER BOUND  -WMIN=   -251744.000000
ITNO.  347 IN VAR- 499  VAR- 117 TO LOWER BOUND  -WMIN=   -250952.000000
ITNO.  348 IN VAR- 125  VAR-  90 TO LOWER BOUND  -WMIN=   -245956.000000
ITNO.  349 IN VAR-  98  VAR- 124 TO LOWER BOUND  -WMIN=   -245740.000000
ITNO.  350 IN VAR- 132  VAR- 319 TO LOWER BOUND  -WMIN=   -245468.000000
ITNO.  351 IN VAR- 327  VAR- 498 TO LOWER BOUND  -WMIN=   -244418.000000
ITNO.  352 IN VAR- 506  VAR- 422 TO LOWER BOUND  -WMIN=   -243366.000000
ITNO.  353 IN VAR- 430  VAR- 326 TO LOWER BOUND  -WMIN=   -235966.000000
ITNO.  354 IN VAR- 334  VAR- 885 TO LOWER BOUND  -WMIN=   -235752.000000
ITNO.  355 IN VAR- 603  VAR- 429 TO LOWER BOUND  -WMIN=   -231846.000000
```


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* PROBLEM NUMBER  1 *
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USING REGULAR
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ITNO.  356 IN VAR- 437  VAR- 131 TO LOWER BOUND  -WMIN=   -231484.000000
ITNO.  357 IN VAR- 139  VAR- 367 TO LOWER BOUND  -WMIN=   -214302.000000
ITNO.  358 IN VAR- 375  VAR- 333 TO LOWER BOUND  -WMIN=   -212468.000000
ITNO.  359 IN VAR- 341  VAR- 374 TO LOWER BOUND  -WMIN=   -209860.000000
ITNO.  360 IN VAR- 382  VAR-  97 TO LOWER BOUND  -WMIN=   -209140.000000
ITNO.  361 IN VAR- 105  VAR- 505 TO LOWER BOUND  -WMIN=   -206236.000000
ITNO.  362 IN VAR- 513  VAR- 436 TO LOWER BOUND  -WMIN=   -201822.000000
ITNO.  363 IN VAR- 444  VAR- 886 TO LOWER BOUND  -WMIN=   -199024.000000
ITNO.  364 IN VAR- 610  VAR- 104 TO LOWER BOUND  -WMIN=   -196942.000000
ITNO.  365 IN VAR- 112  VAR- 381 TO LOWER BOUND  -WMIN=   -195384.000000
ITNO.  366 IN VAR- 389  VAR- 138 TO LOWER BOUND  -WMIN=   -192534.000000
ITNO.  367 IN VAR- 146  VAR- 512 TO LOWER BOUND  -WMIN=   -181958.000000
ITNO.  368 IN VAR- 520  VAR- 388 TO LOWER BOUND  -WMIN=   -177752.000000
ITNO.  369 IN VAR- 396  VAR- 145 TO LOWER BOUND  -WMIN=   -177662.000000
ITNO.  370 IN VAR- 153  VAR- 340 TO LOWER BOUND  -WMIN=   -170264.000000
ITNO.  371 IN VAR- 348  VAR- 887 TO LOWER BOUND  -WMIN=   -162086.000000
ITNO.  372 IN VAR- 617  VAR- 443 TO LOWER BOUND  -WMIN=   -159764.000000
ITNO.  373 IN VAR- 451  VAR- 395 TO LOWER BOUND  -WMIN=   -158556.000000
ITNO.  374 IN VAR- 403  VAR- 111 TO LOWER BOUND  -WMIN=   -155100.000000
ITNO.  375 IN VAR- 119  VAR- 519 TO LOWER BOUND  -WMIN=   -144778.000000
ITNO.  376 IN VAR- 527  VAR- 888 TO LOWER BOUND  -WMIN=   -141966.000000
ITNO.  377 IN VAR- 624  VAR- 347 TO LOWER BOUND  -WMIN=   -138248.000000
ITNO.  378 IN VAR- 355  VAR- 526 TO LOWER BOUND  -WMIN=   -137696.000000
ITNO.  379 IN VAR- 534  VAR- 152 TO LOWER BOUND  -WMIN=   -135048.000000
ITNO.  380 IN VAR- 160  VAR- 402 TO LOWER BOUND  -WMIN=   -131550.000000
ITNO.  381 IN VAR- 410  VAR- 409 TO LOWER BOUND  -WMIN=   -129686.000000
ITNO.  382 IN VAR- 417  VAR- 450 TO LOWER BOUND  -WMIN=   -127830.000000
ITNO.  383 IN VAR- 458  VAR- 118 TO LOWER BOUND  -WMIN=   -126918.000000
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ITNO.  384 IN VAR- 126  VAR- 457 TO LOWER BOUND  -WMIN=   -125216.000000
ITNO.  385 IN VAR- 465  VAR- 125 TO LOWER BOUND  -WMIN=   -121706.000000
ITNO.  386 IN VAR- 133  VAR- 354 TO LOWER BOUND  -WMIN=   -120634.000000
ITNO.  387 IN VAR- 362  VAR- 533 TO LOWER BOUND  -WMIN=   -119294.000000
ITNO.  388 IN VAR- 541  VAR- 889 TO LOWER BOUND  -WMIN=   -117428.000000
ITNO.  389 IN VAR- 631  VAR- 540 TO LOWER BOUND  -WMIN=   -114920.000000
ITNO.  390 IN VAR- 548  VAR- 159 TO LOWER BOUND  -WMIN=   -114776.000000
ITNO.  391 IN VAR- 167  VAR- 547 TO LOWER BOUND  -WMIN=   -109406.000000
ITNO.  392 IN VAR- 555  VAR- 132 TO LOWER BOUND  -WMIN=   -107450.000000
ITNO.  393 IN VAR- 140  VAR- 416 TO LOWER BOUND  -WMIN=   -103946.000000
ITNO.  394 IN VAR- 424  VAR- 464 TO LOWER BOUND  -WMIN=   -103324.000000
ITNO.  395 IN VAR- 472  VAR- 554 TO LOWER BOUND  -WMIN=    -92668.000000
ITNO.  396 IN VAR- 562  VAR- 361 TO LOWER BOUND  -WMIN=    -87748.000000
ITNO.  397 IN VAR- 369  VAR- 890 TO LOWER BOUND  -WMIN=    -83790.000000
ITNO.  398 IN VAR- 638  VAR- 166 TO LOWER BOUND  -WMIN=    -73840.000000
ITNO.  399 IN VAR- 174  VAR- 471 TO LOWER BOUND  -WMIN=    -69334.000000
ITNO.  400 IN VAR- 479  VAR- 561 TO LOWER BOUND  -WMIN=    -68726.000000
ITNO.  401 IN VAR- 569  VAR- 139 TO LOWER BOUND  -WMIN=    -68500.000000
ITNO.  402 IN VAR- 147  VAR- 423 TO LOWER BOUND  -WMIN=    -68166.000000
ITNO.  403 IN VAR- 431  VAR- 891 TO LOWER BOUND  -WMIN=    -59680.000000
ITNO.  404 IN VAR- 645  VAR- 430 TO LOWER BOUND  -WMIN=    -56646.000000
ITNO.  405 IN VAR- 438  VAR- 892 TO LOWER BOUND  -WMIN=    -56240.000000
ITNO.  406 IN VAR- 652  VAR- 146 TO LOWER BOUND  -WMIN=    -53628.000000
ITNO.  407 IN VAR- 154  VAR- 368 TO LOWER BOUND  -WMIN=    -50052.000000
ITNO.  408 IN VAR- 376  VAR- 893 TO LOWER BOUND  -WMIN=    -46080.000000
ITNO.  409 IN VAR- 659  VAR- 375 TO LOWER BOUND  -WMIN=    -45610.000000
ITNO.  410 IN VAR- 383  VAR- 173 TO LOWER BOUND  -WMIN=    -43096.000000
ITNO.  411 IN VAR- 181  VAR- 894 TO LOWER BOUND  -WMIN=    -41686.000000
ITNO.  412 IN VAR- 666  VAR- 568 TO LOWER BOUND  -WMIN=    -33632.000000
ITNO.  413 IN VAR- 576  VAR- 382 TO LOWER BOUND  -WMIN=    -31134.000000
ITNO.  414 IN VAR- 390  VAR- 478 TO LOWER BOUND  -WMIN=    -26798.000000
ITNO.  415 IN VAR- 486  VAR- 437 TO LOWER BOUND  -WMIN=    -26622.000000
ITNO.  416 IN VAR- 445  VAR- 895 TO LOWER BOUND  -WMIN=    -15174.000000
ITNO.  417 IN VAR- 673  VAR- 180 TO LOWER BOUND  -WMIN=    -13854.000000
ITNO.  418 IN VAR- 188  VAR- 389 TO LOWER BOUND  -WMIN=    -13502.000000
ITNO.  419 IN VAR- 397  VAR- 896 TO LOWER BOUND  -WMIN=    -13388.000000
ITNO.  420 IN VAR- 680  VAR- 187 TO LOWER BOUND  -WMIN=    -11252.000000
ITNO.  421 IN VAR- 195  VAR- 153 TO LOWER BOUND  -WMIN=    -11014.000000
ITNO.  422 IN VAR- 161  VAR- 897 TO LOWER BOUND  -WMIN=      -736.000000
ITNO.  423 IN VAR- 687  VAR- 898 TO LOWER BOUND  -WMIN=         0.000000

ENTERING PHASE II

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

USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

ITNO.  424 IN VAR- 311  VAR- 396 TO LOWER BOUND  -ZMIN= -12757064.819991
ITNO.  425 IN VAR- 678  VAR- 673 TO LOWER BOUND  -ZMIN= -12707940.889991
ITNO.  426 IN VAR- 594  VAR- 195 TO LOWER BOUND  -ZMIN= -12451648.939991
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ITNO.  427 IN VAR-  75  VAR- 589 TO LOWER BOUND  -ZMIN= -12113747.979991
ITNO.  428 IN VAR- 657  VAR- 486 TO LOWER BOUND  -ZMIN= -12030938.439991
ITNO.  429 IN VAR- 477  VAR- 313 TO LOWER BOUND  -ZMIN= -12017443.799990
ITNO.  430 IN VAR- 241  VAR-  76 TO LOWER BOUND  -ZMIN= -11810003.319990
ITNO.  431 IN VAR-  96  VAR- 652 TO LOWER BOUND  -ZMIN= -11790143.049990
ITNO.  432 IN VAR- 671  VAR- 160 TO LOWER BOUND  -ZMIN= -11534850.969990
ITNO.  433 IN VAR- 175  VAR- 243 TO LOWER BOUND  -ZMIN= -11420924.019990
ITNO.  434 IN VAR- 339  VAR- 666 TO LOWER BOUND  -ZMIN= -10990287.589990
ITNO.  435 IN VAR- 525  VAR- 479 TO LOWER BOUND  -ZMIN= -10730837.689990
ITNO.  436 IN VAR- 456  VAR-  98 TO LOWER BOUND  -ZMIN= -10713376.189990
ITNO.  437 IN VAR- 110  VAR- 458 TO LOWER BOUND  -ZMIN= -10665641.029990
ITNO.  438 IN VAR- 442  VAR- 444 TO LOWER BOUND  -ZMIN= -10439967.599990
ITNO.  439 IN VAR- 466  VAR- 341 TO LOWER BOUND  -ZMIN= -10290568.959990
ITNO.  440 IN VAR- 262  VAR- 575 TO LOWER BOUND  -ZMIN= -10178782.659990
ITNO.  441 IN VAR- 597  VAR- 520 TO LOWER BOUND  -ZMIN= -10068105.169990
ITNO.  442 IN VAR- 532  VAR- 465 TO LOWER BOUND  -ZMIN=  -9898662.169990
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ITNO.  443 IN VAR- 452  VAR- 527 TO LOWER BOUND  -ZMIN=  -9869600.669990
ITNO.  444 IN VAR- 553  VAR- 548 TO LOWER BOUND  -ZMIN=  -9717496.979990
ITNO.  445 IN VAR- 518  VAR- 112 TO LOWER BOUND  -ZMIN=  -9670080.659990
ITNO.  446 IN VAR- 124  VAR- 445 TO LOWER BOUND  -ZMIN=  -9611729.309990
ITNO.  447 IN VAR- 414  VAR- 596 TO LOWER BOUND  -ZMIN=  -9586103.729990
ITNO.  448 IN VAR- 639  VAR- 126 TO LOWER BOUND  -ZMIN=  -9534101.769990
ITNO.  449 IN VAR- 131  VAR- 264 TO LOWER BOUND  -ZMIN=  -9309943.369990
ITNO.  450 IN VAR- 354  VAR- 133 TO LOWER BOUND  -ZMIN=  -9198754.649990
ITNO.  451 IN VAR-  38  VAR- 513 TO LOWER BOUND  -ZMIN=  -9130133.919990
ITNO.  452 IN VAR- 546  VAR- 541 TO LOWER BOUND  -ZMIN=  -9032878.029990
ITNO.  453 IN VAR- 511  VAR- 638 TO LOWER BOUND  -ZMIN=  -9027206.829990
ITNO.  454 IN VAR- 583  VAR- 417 TO LOWER BOUND  -ZMIN=  -9014394.089990
ITNO.  455 IN VAR- 421  VAR- 451 TO LOWER BOUND  -ZMIN=  -9000921.329990
ITNO.  456 IN VAR- 474  VAR-  42 TO LOWER BOUND  -ZMIN=  -8841610.029990
ITNO.  457 IN VAR- 145  VAR- 355 TO LOWER BOUND  -ZMIN=  -8789493.969990
ITNO.  458 IN VAR- 473  VAR- 474 TO LOWER BOUND  -ZMIN=  -8641568.769990
ITNO.  459 IN VAR- 200  VAR- 147 TO LOWER BOUND  -ZMIN=  -8609432.679990
ITNO.  460 IN VAR-  19  VAR- 582 TO LOWER BOUND  -ZMIN=  -8570401.379990
ITNO.  461 IN VAR- 660  VAR- 659 TO LOWER BOUND  -ZMIN=  -8509961.909990
ITNO.  462 IN VAR- 450  VAR- 506 TO LOWER BOUND  -ZMIN=  -8444710.269990
ITNO.  463 IN VAR- 488  VAR- 201 TO LOWER BOUND  -ZMIN=  -8128508.029990
ITNO.  464 IN VAR-  65  VAR- 485 TO LOWER BOUND  -ZMIN=  -8083624.949990
ITNO.  465 IN VAR- 581  VAR-  70 TO LOWER BOUND  -ZMIN=  -7750312.799990
ITNO.  466 IN VAR-   9  VAR- 576 TO LOWER BOUND  -ZMIN=  -7613753.289990
ITNO.  467 IN VAR- 565  VAR-  19 TO LOWER BOUND  -ZMIN=  -7518910.029989
ITNO.  468 IN VAR- 251  VAR-  14 TO LOWER BOUND  -ZMIN=  -7389728.369989
ITNO.  469 IN VAR- 137  VAR- 452 TO LOWER BOUND  -ZMIN=  -7361376.869989
ITNO.  470 IN VAR- 681  VAR- 174 TO LOWER BOUND  -ZMIN=  -7320507.349989
ITNO.  471 IN VAR- 224  VAR- 424 TO LOWER BOUND  -ZMIN=  -7308399.099989
ITNO.  472 IN VAR- 135  VAR- 562 TO LOWER BOUND  -ZMIN=  -7284437.939989
ITNO.  473 IN VAR- 614  VAR- 681 TO LOWER BOUND  -ZMIN=  -7236264.269989
ITNO.  474 IN VAR- 568  VAR- 222 TO LOWER BOUND  -ZMIN=  -7192704.809989
ITNO.  475 IN VAR- 280  VAR- 278 TO LOWER BOUND  -ZMIN=  -7181677.559989
ITNO.  476 IN VAR- 287  VAR- 140 TO LOWER BOUND  -ZMIN=  -6888459.299989
ITNO.  477 IN VAR- 163  VAR- 610 TO LOWER BOUND  -ZMIN=  -6832737.689989
ITNO.  478 IN VAR- 418  VAR- 569 TO LOWER BOUND  -ZMIN=  -6813693.799989
ITNO.  479 IN VAR- 428  VAR- 431 TO LOWER BOUND  -ZMIN=  -6702180.199989
ITNO.  480 IN VAR- 491  VAR- 250 TO LOWER BOUND  -ZMIN=  -6605268.319989
ITNO.  481 IN VAR-  48  VAR- 414 TO LOWER BOUND  -ZMIN=  -6579259.339989
ITNO.  482 IN VAR- 586  VAR- 167 TO LOWER BOUND  -ZMIN=  -6479383.399989
ITNO.  483 IN VAR- 676  VAR- 678 TO LOWER BOUND  -ZMIN=  -6463568.369989
ITNO.  484 IN VAR- 592  VAR- 285 TO LOWER BOUND  -ZMIN=  -6409277.649989
ITNO.  485 IN VAR- 350  VAR- 137 TO LOWER BOUND  -ZMIN=  -6331507.749989
ITNO.  486 IN VAR- 408  VAR- 583 TO LOWER BOUND  -ZMIN=  -6319394.469989
ITNO.  487 IN VAR- 411  VAR- 410 TO LOWER BOUND  -ZMIN=  -6315786.249989
ITNO.  488 IN VAR- 177  VAR- 408 TO LOWER BOUND  -ZMIN=  -6305369.389989
ITNO.  489 IN VAR- 432  VAR-  49 TO LOWER BOUND  -ZMIN=  -6236833.889989
ITNO.  490 IN VAR- 104  VAR- 428 TO LOWER BOUND  -ZMIN=  -6221025.439989
ITNO.  491 IN VAR- 663  VAR- 660 TO LOWER BOUND  -ZMIN=  -6189784.099989
ITNO.  492 IN VAR- 628  VAR- 348 TO LOWER BOUND  -ZMIN=  -6162335.499989
ITNO.  493 IN VAR- 574  VAR- 105 TO LOWER BOUND  -ZMIN=  -6150047.899989
ITNO.  494 IN VAR- 540  VAR- 546 TO LOWER BOUND  -ZMIN=  -6121595.029989
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USING REGULAR
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```
ITNO.  495 IN VAR- 505  VAR- 568 TO LOWER BOUND  -ZMIN=  -5946435.429989
ITNO.  496 IN VAR- 693  VAR- 687 TO LOWER BOUND  -ZMIN=  -5942030.469989
ITNO.  497 IN VAR- 497  VAR- 511 TO LOWER BOUND  -ZMIN=  -5891788.459989
ITNO.  498 IN VAR- 226  VAR- 492 TO LOWER BOUND  -ZMIN=  -5846935.929989
ITNO.  499 IN VAR- 302  VAR- 624 TO LOWER BOUND  -ZMIN=  -5793746.079989
ITNO.  500 IN VAR-  19  VAR- 306 TO LOWER BOUND  -ZMIN=  -5760798.879989
ITNO.  501 IN VAR- 316  VAR- 491 TO LOWER BOUND  -ZMIN=  -5614443.219989
ITNO.  502 IN VAR- 686  VAR-  21 TO LOWER BOUND  -ZMIN=  -5596867.469989
ITNO.  503 IN VAR-  26  VAR- 680 TO LOWER BOUND  -ZMIN=  -5555808.599989
ITNO.  504 IN VAR- 427  VAR- 320 TO LOWER BOUND  -ZMIN=  -5534451.399989
ITNO.  505 IN VAR- 547  VAR- 553 TO LOWER BOUND  -ZMIN=  -5511568.299989
ITNO.  506 IN VAR-  78  VAR- 421 TO LOWER BOUND  -ZMIN=  -5407052.039989
ITNO.  507 IN VAR- 642  VAR- 229 TO LOWER BOUND  -ZMIN=  -5340333.239989
ITNO.  508 IN VAR- 387  VAR- 639 TO LOWER BOUND  -ZMIN=  -5318349.239989
ITNO.  509 IN VAR- 535  VAR- 181 TO LOWER BOUND  -ZMIN=  -5299441.779989
ITNO.  510 IN VAR- 441  VAR- 390 TO LOWER BOUND  -ZMIN=  -5235569.309989
ITNO.  511 IN VAR- 359  VAR- 534 TO LOWER BOUND  -ZMIN=  -5228350.769989
ITNO.  512 IN VAR- 139  VAR-  28 TO LOWER BOUND  -ZMIN=  -5199892.229989
ITNO.  513 IN VAR- 460  VAR- 594 TO LOWER BOUND  -ZMIN=  -5191227.669989
ITNO.  514 IN VAR- 655  VAR- 456 TO LOWER BOUND  -ZMIN=  -5186460.669989
ITNO.  515 IN VAR- 649  VAR- 645 TO LOWER BOUND  -ZMIN=  -5171221.469989
ITNO.  516 IN VAR- 621  VAR- 438 TO LOWER BOUND  -ZMIN=  -5161904.449989
ITNO.  517 IN VAR- 406  VAR- 657 TO LOWER BOUND  -ZMIN=  -5148115.969989
ITNO.  518 IN VAR- 137  VAR-  84 TO LOWER BOUND  -ZMIN=  -5120815.159989
ITNO.  519 IN VAR-  50  VAR- 362 TO LOWER BOUND  -ZMIN=  -5108129.599989
ITNO.  520 IN VAR- 665  VAR- 617 TO LOWER BOUND  -ZMIN=  -5098386.019989
ITNO.  521 IN VAR- 277  VAR- 280 TO LOWER BOUND  -ZMIN=  -5096415.469989
ITNO.  522 IN VAR- 448  VAR-  56 TO LOWER BOUND  -ZMIN=  -5090253.229989
ITNO.  523 IN VAR-  57  VAR-  63 TO LOWER BOUND  -ZMIN=  -5080374.829989
ITNO.  524 IN VAR- 365  VAR- 665 TO LOWER BOUND  -ZMIN=  -5074174.369989
ITNO.  525 IN VAR- 159  VAR- 161 TO LOWER BOUND  -ZMIN=  -5037279.329989
ITNO.  526 IN VAR-  89  VAR- 442 TO LOWER BOUND  -ZMIN=  -5024480.689989
ITNO.  527 IN VAR- 494  VAR- 403 TO LOWER BOUND  -ZMIN=  -5006150.609989
ITNO.  528 IN VAR- 453  VAR-  89 TO LOWER BOUND  -ZMIN=  -4995023.129989
ITNO.  529 IN VAR- 637  VAR- 137 TO LOWER BOUND  -ZMIN=  -4990644.729989
ITNO.  530 IN VAR- 653  VAR- 369 TO LOWER BOUND  -ZMIN=  -4983923.489989
ITNO.  531 IN VAR- 211  VAR- 655 TO LOWER BOUND  -ZMIN=  -4969874.859989
ITNO.  532 IN VAR- 202  VAR- 215 TO LOWER BOUND  -ZMIN=  -4963228.299989
ITNO.  533 IN VAR- 665  VAR- 497 TO LOWER BOUND  -ZMIN=  -4960462.549989
ITNO.  534 IN VAR- 160  VAR- 450 TO LOWER BOUND  -ZMIN=  -4955463.049989
ITNO.  535 IN VAR- 600  VAR- 139 TO LOWER BOUND  -ZMIN=  -4951362.169989
ITNO.  536 IN VAR- 187  VAR- 188 TO LOWER BOUND  -ZMIN=  -4950425.449989
ITNO.  537 IN VAR-  89  VAR- 663 TO LOWER BOUND  -ZMIN=  -4950171.049989
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
1	X1	--	LB	0.0000000	-5.3700000	0.0000	INF
2	X2	--	LB	0.0000000	-12.4500000	0.0000	INF
3	X3	--	LB	0.0000000	-14.2500000	0.0000	INF
4	X4	--	LB	0.0000000	-8.7900000	0.0000	INF
5	X5	--	LB	0.0000000	-2.6800000	0.0000	INF
6	X6	--	LB	0.0000000	-9.1000000	0.0000	INF
7	X7	--	B	11075.0000000	0.0000000	0.0000	INF
8	X8	--	LB	0.0000000	-16.2600000	0.0000	INF
9	X9	--	B	14517.0000000	0.0000000	0.0000	INF
10	X10	--	LB	0.0000000	-4.5000000	0.0000	INF
11	X11	--	LB	0.0000000	-4.1300000	0.0000	INF
12	X12	--	LB	0.0000000	-8.5700000	0.0000	INF
13	X13	--	LB	0.0000000	-3.8800000	0.0000	INF
14	X14	--	LB	0.0000000	-11.7600000	0.0000	INF
15	X15	--	LB	0.0000000	-7.3100000	0.0000	INF
16	X16	--	LB	0.0000000	-6.9600000	0.0000	INF
17	X17	--	LB	0.0000000	-11.0700000	0.0000	INF
18	X18	--	LB	0.0000000	-6.7900000	0.0000	INF
19	X19	--	B	16481.0000000	0.0000000	0.0000	INF
20	X20	--	LB	0.0000000	-6.1800000	0.0000	INF
21	X21	--	LB	0.0000000	-3.8100000	0.0000	INF
22	X22	--	LB	0.0000000	-4.2900000	0.0000	INF
23	X23	--	LB	0.0000000	-11.2600000	0.0000	INF
24	X24	--	LB	0.0000000	-14.2200000	0.0000	INF
25	X25	--	LB	0.0000000	-9.1200000	0.0000	INF
26	X26	--	B	18132.0000000	0.0000000	0.0000	INF
27	X27	--	LB	0.0000000	-9.0400000	0.0000	INF
28	X28	--	LB	0.0000000	-.9300000	0.0000	INF
29	X29	--	LB	0.0000000	-5.3000000	0.0000	INF
30	X30	--	LB	0.0000000	-4.2400000	0.0000	INF
31	X31	--	LB	0.0000000	-5.6200000	0.0000	INF
32	X32	--	LB	0.0000000	-.4800000	0.0000	INF
33	X33	--	LB	0.0000000	-.0500000	0.0000	INF
34	X34	--	LB	0.0000000	-.4300000	0.0000	INF
35	X35	--	B	14401.0000000	0.0000000	0.0000	INF
36	X36	--	LB	0.0000000	-21.9800000	0.0000	INF
37	X37	--	LB	0.0000000	-8.5200000	0.0000	INF
38	X38	--	B	9279.0000000	0.0000000	0.0000	INF
39	X39	--	LB	0.0000000	-3.6400000	0.0000	INF
40	X40	--	LB	0.0000000	-15.6400000	0.0000	INF
41	X41	--	LB	0.0000000	-6.3900000	0.0000	INF
42	X42	--	LB	0.0000000	-16.5200000	0.0000	INF
43	X43	--	LB	0.0000000	-8.9300000	0.0000	INF
44	X44	--	LB	0.0000000	-.0700000	0.0000	INF
45	X45	--	LB	0.0000000	-4.0500000	0.0000	INF
46	X46	--	LB	0.0000000	-.9100000	0.0000	INF
47	X47	--	LB	0.0000000	-1.5600000	0.0000	INF

48	X48	--	B	21014.0000000	0.0000000	0.0000	INF
49	X49	--	LB	0.0000000	-4.5000000	0.0000	INF
50	X50	--	B	5414.0000000	0.0000000	0.0000	INF
51	X51	--	LB	0.0000000	-17.0700000	0.0000	INF
52	X52	--	LB	0.0000000	-18.4100000	0.0000	INF
53	X53	--	LB	0.0000000	-12.6600000	0.0000	INF
54	X54	--	LB	0.0000000	-4.4800000	0.0000	INF
55	X55	--	LB	0.0000000	-13.4400000	0.0000	INF
56	X56	--	LB	0.0000000	-2.2600000	0.0000	INF
57	X57	--	B	3136.0000000	0.0000000	0.0000	INF
58	X58	--	LB	0.0000000	-16.2100000	0.0000	INF
59	X59	--	LB	0.0000000	-17.8400000	0.0000	INF
60	X60	--	LB	0.0000000	-12.1500000	0.0000	INF
61	X61	--	LB	0.0000000	-3.5700000	0.0000	INF
62	X62	--	LB	0.0000000	-12.7900000	0.0000	INF
63	X63	--	LB	0.0000000	-1.4900000	0.0000	INF
64	X64	--	LB	0.0000000	-17.6700000	0.0000	INF
65	X65	--	B	15743.0000000	0.0000000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
66	X66	--	LB	0.0000000	-6.0100000	0.0000	INF
67	X67	--	LB	0.0000000	-6.1000000	0.0000	INF
68	X68	--	LB	0.0000000	-9.7400000	0.0000	INF
69	X69	--	LB	0.0000000	-5.8700000	0.0000	INF
70	X70	--	LB	0.0000000	-13.4000000	0.0000	INF
71	X71	--	LB	0.0000000	-5.9800000	0.0000	INF
72	X72	--	LB	0.0000000	-15.3300000	0.0000	INF
73	X73	--	LB	0.0000000	-20.1600000	0.0000	INF
74	X74	--	LB	0.0000000	-15.6600000	0.0000	INF
75	X75	--	B	10983.0000000	0.0000000	0.0000	INF
76	X76	--	LB	0.0000000	-15.2000000	0.0000	INF
77	X77	--	LB	0.0000000	-7.6200000	0.0000	INF
78	X78	--	B	21883.0000000	0.0000000	0.0000	INF
79	X79	--	LB	0.0000000	-16.7800000	0.0000	INF
80	X80	--	LB	0.0000000	-19.3500000	0.0000	INF
81	X81	--	LB	0.0000000	-13.8800000	0.0000	INF
82	X82	--	LB	0.0000000	-3.0900000	0.0000	INF
83	X83	--	LB	0.0000000	-14.1800000	0.0000	INF
84	X84	--	LB	0.0000000	-3.0100000	0.0000	INF
85	X85	--	LB	0.0000000	-3.8200000	0.0000	INF
86	X86	--	LB	0.0000000	-10.9500000	0.0000	INF
87	X87	--	LB	0.0000000	-13.6600000	0.0000	INF
88	X88	--	LB	0.0000000	-8.4600000	0.0000	INF

89	X89	--	B	1272.0000000	0.0000000	0.0000	INF
90	X90	--	LB	0.0000000	-8.4600000	0.0000	INF
91	X91	--	B	9675.0000000	0.0000000	0.0000	INF
92	X92	--	LB	0.0000000	-7.3100000	0.0000	INF
93	X93	--	LB	0.0000000	-13.3700000	0.0000	INF
94	X94	--	LB	0.0000000	-19.1600000	0.0000	INF
95	X95	--	LB	0.0000000	-15.2400000	0.0000	INF
96	X96	--	B	18408.0000000	0.0000000	0.0000	INF
97	X97	--	LB	0.0000000	-14.5500000	0.0000	INF
98	X98	--	LB	0.0000000	-8.7900000	0.0000	INF
99	X99	--	LB	0.0000000	-9.5500000	0.0000	INF
100	X100	--	LB	0.0000000	-3.6500000	0.0000	INF
101	X101	--	LB	0.0000000	-5.0800000	0.0000	INF
102	X102	--	LB	0.0000000	-.6300000	0.0000	INF
103	X103	--	LB	0.0000000	-3.3400000	0.0000	INF
104	X104	--	B	6099.0000000	0.0000000	0.0000	INF
105	X105	--	LB	0.0000000	-4.4100000	0.0000	INF
106	X106	--	LB	0.0000000	-7.2700000	0.0000	INF
107	X107	--	LB	0.0000000	-8.2000000	0.0000	INF
108	X108	--	LB	0.0000000	-15.3800000	0.0000	INF
109	X109	--	LB	0.0000000	-12.7400000	0.0000	INF
110	X110	--	B	20921.0000000	0.0000000	0.0000	INF
111	X111	--	LB	0.0000000	-11.8400000	0.0000	INF
112	X112	--	LB	0.0000000	-8.7800000	0.0000	INF
113	X113	--	LB	0.0000000	-1.6700000	0.0000	INF
114	X114	--	LB	0.0000000	-14.8400000	0.0000	INF
115	X115	--	LB	0.0000000	-15.9600000	0.0000	INF
116	X116	--	LB	0.0000000	-10.2200000	0.0000	INF
117	X117	--	LB	0.0000000	-3.4500000	0.0000	INF
118	X118	--	LB	0.0000000	-11.0000000	0.0000	INF
119	X119	--	B	14091.0000000	0.0000000	0.0000	INF
120	X120	--	LB	0.0000000	-5.9100000	0.0000	INF
121	X121	--	LB	0.0000000	-12.1700000	0.0000	INF
122	X122	--	LB	0.0000000	-18.5800000	0.0000	INF
123	X123	--	LB	0.0000000	-15.0100000	0.0000	INF
124	X124	--	B	2606.0000000	0.0000000	0.0000	INF
125	X125	--	LB	0.0000000	-14.2400000	0.0000	INF
126	X126	--	LB	0.0000000	-8.6900000	0.0000	INF
127	X127	--	LB	0.0000000	-8.7400000	0.0000	INF
128	X128	--	LB	0.0000000	-12.5200000	0.0000	INF
129	X129	--	LB	0.0000000	-17.7600000	0.0000	INF
130	X130	--	LB	0.0000000	-13.6900000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR VAR ROW STATUS ACTIVITY OPPORTUNITY LOWER UPPER

NO	NAME	NO		LEVEL	COST	BOUND	BOUND
131	X131	--	B	7128.0000000	0.0000000	0.0000	INF
132	X132	--	LB	0.0000000	-13.0400000	0.0000	INF
133	X133	--	LB	0.0000000	-8.0800000	0.0000	INF
134	X134	--	LB	0.0000000	-14.7000000	0.0000	INF
135	X135	--	B	19475.0000000	0.0000000	0.0000	INF
136	X136	--	LB	0.0000000	-1.2800000	0.0000	INF
137	X137	--	LB	0.0000000	-.7800000	0.0000	INF
138	X138	--	LB	0.0000000	-7.4600000	0.0000	INF
139	X139	--	LB	0.0000000	-.8400000	0.0000	INF
140	X140	--	LB	0.0000000	-9.8200000	0.0000	INF
141	X141	--	LB	0.0000000	-7.8600000	0.0000	INF
142	X142	--	LB	0.0000000	-.9000000	0.0000	INF
143	X143	--	LB	0.0000000	-5.9700000	0.0000	INF
144	X144	--	LB	0.0000000	-2.7900000	0.0000	INF
145	X145	--	B	7436.0000000	0.0000000	0.0000	INF
146	X146	--	LB	0.0000000	-1.8900000	0.0000	INF
147	X147	--	LB	0.0000000	-4.0900000	0.0000	INF
148	X148	--	LB	0.0000000	-1.4000000	0.0000	INF
149	X149	--	LB	0.0000000	-14.3800000	0.0000	INF
150	X150	--	LB	0.0000000	-16.1700000	0.0000	INF
151	X151	--	LB	0.0000000	-10.9100000	0.0000	INF
152	X152	--	LB	0.0000000	-2.0500000	0.0000	INF
153	X153	--	LB	0.0000000	-11.3000000	0.0000	INF
154	X154	--	B	21307.0000000	0.0000000	0.0000	INF
155	X155	--	LB	0.0000000	-5.6700000	0.0000	INF
156	X156	--	LB	0.0000000	-3.5100000	0.0000	INF
157	X157	--	LB	0.0000000	-5.1800000	0.0000	INF
158	X158	--	LB	0.0000000	-.2400000	0.0000	INF
159	X159	--	B	923.0000000	0.0000000	0.0000	INF
160	X160	--	B	9213.0000000	0.0000000	0.0000	INF
161	X161	--	LB	0.0000000	-.5000000	0.0000	INF
162	X162	--	LB	0.0000000	-17.7500000	0.0000	INF
163	X163	--	B	20468.0000000	0.0000000	0.0000	INF
164	X164	--	LB	0.0000000	-4.5100000	0.0000	INF
165	X165	--	LB	0.0000000	-5.2900000	0.0000	INF
166	X166	--	LB	0.0000000	-9.8600000	0.0000	INF
167	X167	--	LB	0.0000000	-5.3200000	0.0000	INF
168	X168	--	LB	0.0000000	-13.3800000	0.0000	INF
169	X169	--	LB	0.0000000	-5.6700000	0.0000	INF
170	X170	--	LB	0.0000000	-7.1200000	0.0000	INF
171	X171	--	LB	0.0000000	-6.1700000	0.0000	INF
172	X172	--	LB	0.0000000	-.3400000	0.0000	INF
173	X173	--	LB	0.0000000	-2.5700000	0.0000	INF
174	X174	--	LB	0.0000000	-1.5900000	0.0000	INF
175	X175	--	B	15372.0000000	0.0000000	0.0000	INF
176	X176	--	LB	0.0000000	-8.9300000	0.0000	INF
177	X177	--	B	14621.0000000	0.0000000	0.0000	INF
178	X178	--	LB	0.0000000	-5.6700000	0.0000	INF
179	X179	--	LB	0.0000000	-2.9900000	0.0000	INF
180	X180	--	LB	0.0000000	-.9000000	0.0000	INF
181	X181	--	LB	0.0000000	-2.0800000	0.0000	INF
182	X182	--	LB	0.0000000	-5.2300000	0.0000	INF
183	X183	--	LB	0.0000000	-7.2900000	0.0000	INF
184	X184	--	LB	0.0000000	-1.3700000	0.0000	INF

185	X185	--	LB	0.0000000	-5.2800000	0.0000	INF
186	X186	--	LB	0.0000000	-1.5600000	0.0000	INF
187	X187	--	B	1301.0000000	0.0000000	0.0000	INF
188	X188	--	LB	0.0000000	-.7200000	0.0000	INF
189	X189	--	LB	0.0000000	-3.0000000	0.0000	INF
190	X190	--	LB	0.0000000	-.2700000	0.0000	INF
191	X191	--	LB	0.0000000	-15.2800000	0.0000	INF
192	X192	--	LB	0.0000000	-20.1000000	0.0000	INF
193	X193	--	LB	0.0000000	-15.4000000	0.0000	INF
194	X194	--	B	15921.0000000	0.0000000	0.0000	INF
195	X195	--	LB	0.0000000	-15.0600000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
196	X196	--	LB	0.0000000	-5.9500000	0.0000	INF
197	X197	--	LB	0.0000000	-14.8500000	0.0000	INF
198	X198	--	LB	0.0000000	-2.7800000	0.0000	INF
199	X199	--	LB	0.0000000	-2.0500000	0.0000	INF
200	X200	--	B	16988.0000000	0.0000000	0.0000	INF
201	X201	--	LB	0.0000000	-8.1900000	0.0000	INF
202	X202	--	B	2741.0000000	0.0000000	0.0000	INF
203	X203	--	LB	0.0000000	-9.6500000	0.0000	INF
204	X204	--	LB	0.0000000	-4.6900000	0.0000	INF
205	X205	--	LB	0.0000000	-9.2900000	0.0000	INF
206	X206	--	LB	0.0000000	-11.8800000	0.0000	INF
207	X207	--	LB	0.0000000	-6.7500000	0.0000	INF
208	X208	--	B	3405.0000000	0.0000000	0.0000	INF
209	X209	--	LB	0.0000000	-6.6900000	0.0000	INF
210	X210	--	LB	0.0000000	-.2300000	0.0000	INF
211	X211	--	B	5409.0000000	0.0000000	0.0000	INF
212	X212	--	LB	0.0000000	-15.9600000	0.0000	INF
213	X213	--	LB	0.0000000	-19.8500000	0.0000	INF
214	X214	--	LB	0.0000000	-14.8000000	0.0000	INF
215	X215	--	LB	0.0000000	-.8700000	0.0000	INF
216	X216	--	LB	0.0000000	-14.6900000	0.0000	INF
217	X217	--	LB	0.0000000	-4.7000000	0.0000	INF
218	X218	--	LB	0.0000000	-5.2400000	0.0000	INF
219	X219	--	LB	0.0000000	-14.6600000	0.0000	INF
220	X220	--	LB	0.0000000	-15.9900000	0.0000	INF
221	X221	--	LB	0.0000000	-10.3600000	0.0000	INF
222	X222	--	LB	0.0000000	-4.3500000	0.0000	INF
223	X223	--	LB	0.0000000	-10.9300000	0.0000	INF
224	X224	--	B	4707.0000000	0.0000000	0.0000	INF
225	X225	--	LB	0.0000000	-12.5100000	0.0000	INF

226	X226	--	B	13013.0000000	0.0000000	0.0000	INF
227	X227	--	LB	0.0000000	-6.4700000	0.0000	INF
228	X228	--	LB	0.0000000	-4.7100000	0.0000	INF
229	X229	--	LB	0.0000000	-4.3900000	0.0000	INF
230	X230	--	LB	0.0000000	-3.8900000	0.0000	INF
231	X231	--	LB	0.0000000	-8.7100000	0.0000	INF
232	X232	--	LB	0.0000000	-2.1500000	0.0000	INF
233	X233	--	LB	0.0000000	-14.3100000	0.0000	INF
234	X234	--	LB	0.0000000	-17.9000000	0.0000	INF
235	X235	--	LB	0.0000000	-12.8500000	0.0000	INF
236	X236	--	B	11849.0000000	0.0000000	0.0000	INF
237	X237	--	LB	0.0000000	-12.7300000	0.0000	INF
238	X238	--	LB	0.0000000	-3.1500000	0.0000	INF
239	X239	--	LB	0.0000000	-20.9900000	0.0000	INF
240	X240	--	LB	0.0000000	-7.4700000	0.0000	INF
241	X241	--	B	9502.0000000	0.0000000	0.0000	INF
242	X242	--	LB	0.0000000	-2.9000000	0.0000	INF
243	X243	--	LB	0.0000000	-14.5800000	0.0000	INF
244	X244	--	LB	0.0000000	-5.4200000	0.0000	INF
245	X245	--	LB	0.0000000	-15.5700000	0.0000	INF
246	X246	--	LB	0.0000000	-10.7000000	0.0000	INF
247	X247	--	LB	0.0000000	-1.8300000	0.0000	INF
248	X248	--	LB	0.0000000	-4.3600000	0.0000	INF
249	X249	--	LB	0.0000000	-.9100000	0.0000	INF
250	X250	--	LB	0.0000000	-3.8000000	0.0000	INF
251	X251	--	B	20677.0000000	0.0000000	0.0000	INF
252	X252	--	LB	0.0000000	-5.8700000	0.0000	INF
253	X253	--	LB	0.0000000	-1.1100000	0.0000	INF
254	X254	--	LB	0.0000000	-15.0500000	0.0000	INF
255	X255	--	LB	0.0000000	-20.2100000	0.0000	INF
256	X256	--	LB	0.0000000	-15.6800000	0.0000	INF
257	X257	--	B	16326.0000000	0.0000000	0.0000	INF
258	X258	--	LB	0.0000000	-15.2500000	0.0000	INF
259	X259	--	LB	0.0000000	-6.5900000	0.0000	INF
260	X260	--	LB	0.0000000	-18.7300000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
261	X261	--	LB	0.0000000	-5.3300000	0.0000	INF
262	X262	--	B	18987.0000000	0.0000000	0.0000	INF
263	X263	--	LB	0.0000000	-1.2200000	0.0000	INF
264	X264	--	LB	0.0000000	-12.2200000	0.0000	INF
265	X265	--	LB	0.0000000	-3.2200000	0.0000	INF
266	X266	--	LB	0.0000000	-13.3700000	0.0000	INF

267	X267	--	LB	0.0000000	-8.4900000	0.0000	INF
268	X268	--	LB	0.0000000	-2.8800000	0.0000	INF
269	X269	--	LB	0.0000000	-9.0100000	0.0000	INF
270	X270	--	LB	0.0000000	-6.0900000	0.0000	INF
271	X271	--	B	16185.0000000	0.0000000	0.0000	INF
272	X272	--	LB	0.0000000	-5.1800000	0.0000	INF
273	X273	--	LB	0.0000000	-5.7700000	0.0000	INF
274	X274	--	LB	0.0000000	-8.2100000	0.0000	INF
275	X275	--	LB	0.0000000	-8.8200000	0.0000	INF
276	X276	--	LB	0.0000000	-5.8300000	0.0000	INF
277	X277	--	B	435.0000000	0.0000000	0.0000	INF
278	X278	--	LB	0.0000000	-5.7000000	0.0000	INF
279	X279	--	LB	0.0000000	-2.4300000	0.0000	INF
280	X280	--	LB	0.0000000	-2.7400000	0.0000	INF
281	X281	--	LB	0.0000000	-4.0700000	0.0000	INF
282	X282	--	LB	0.0000000	-13.2900000	0.0000	INF
283	X283	--	LB	0.0000000	-15.5400000	0.0000	INF
284	X284	--	LB	0.0000000	-10.1400000	0.0000	INF
285	X285	--	LB	0.0000000	-1.9900000	0.0000	INF
286	X286	--	LB	0.0000000	-10.3600000	0.0000	INF
287	X287	--	B	22248.0000000	0.0000000	0.0000	INF
288	X288	--	LB	0.0000000	-6.1600000	0.0000	INF
289	X289	--	LB	0.0000000	-11.6300000	0.0000	INF
290	X290	--	LB	0.0000000	-15.3600000	0.0000	INF
291	X291	--	LB	0.0000000	-10.5900000	0.0000	INF
292	X292	--	B	9797.0000000	0.0000000	0.0000	INF
293	X293	--	LB	0.0000000	-10.2600000	0.0000	INF
294	X294	--	LB	0.0000000	-3.6700000	0.0000	INF
295	X295	--	LB	0.0000000	-2.8600000	0.0000	INF
296	X296	--	LB	0.0000000	-13.9000000	0.0000	INF
297	X297	--	LB	0.0000000	-17.4000000	0.0000	INF
298	X298	--	LB	0.0000000	-12.3500000	0.0000	INF
299	X299	--	B	13552.0000000	0.0000000	0.0000	INF
300	X300	--	LB	0.0000000	-12.2300000	0.0000	INF
301	X301	--	LB	0.0000000	-2.8400000	0.0000	INF
302	X302	--	B	8283.0000000	0.0000000	0.0000	INF
303	X303	--	LB	0.0000000	-18.4100000	0.0000	INF
304	X304	--	LB	0.0000000	-20.6000000	0.0000	INF
305	X305	--	LB	0.0000000	-15.0100000	0.0000	INF
306	X306	--	LB	0.0000000	-4.8400000	0.0000	INF
307	X307	--	LB	0.0000000	-15.4800000	0.0000	INF
308	X308	--	LB	0.0000000	-4.1400000	0.0000	INF
309	X309	--	LB	0.0000000	-21.6500000	0.0000	INF
310	X310	--	LB	0.0000000	-8.4200000	0.0000	INF
311	X311	--	B	16440.0000000	0.0000000	0.0000	INF
312	X312	--	LB	0.0000000	-3.2500000	0.0000	INF
313	X313	--	LB	0.0000000	-15.3600000	0.0000	INF
314	X314	--	LB	0.0000000	-6.0600000	0.0000	INF
315	X315	--	LB	0.0000000	-16.1700000	0.0000	INF
316	X316	--	B	21427.0000000	0.0000000	0.0000	INF
317	X317	--	LB	0.0000000	-17.5500000	0.0000	INF
318	X318	--	LB	0.0000000	-21.4500000	0.0000	INF
319	X319	--	LB	0.0000000	-16.3700000	0.0000	INF
320	X320	--	LB	0.0000000	-2.3700000	0.0000	INF
321	X321	--	LB	0.0000000	-16.2800000	0.0000	INF

322	X322	--	LB	0.0000000	-6.0900000	0.0000	INF
323	X323	--	LB	0.0000000	-.7600000	0.0000	INF
324	X324	--	LB	0.0000000	-15.0100000	0.0000	INF
325	X325	--	LB	0.0000000	-18.9300000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
326	X326	--	LB	0.0000000	-13.9300000	0.0000	INF
327	X327	--	B	4751.0000000	0.0000000	0.0000	INF
328	X328	--	LB	0.0000000	-13.7700000	0.0000	INF
329	X329	--	LB	0.0000000	-4.0900000	0.0000	INF
330	X330	--	LB	0.0000000	-3.5800000	0.0000	INF
331	X331	--	LB	0.0000000	-15.2700000	0.0000	INF
332	X332	--	LB	0.0000000	-19.6700000	0.0000	INF
333	X333	--	LB	0.0000000	-14.9200000	0.0000	INF
334	X334	--	B	11749.0000000	0.0000000	0.0000	INF
335	X335	--	LB	0.0000000	-14.5900000	0.0000	INF
336	X336	--	LB	0.0000000	-5.9500000	0.0000	INF
337	X337	--	LB	0.0000000	-20.6600000	0.0000	INF
338	X338	--	LB	0.0000000	-6.2100000	0.0000	INF
339	X339	--	B	21102.0000000	0.0000000	0.0000	INF
340	X340	--	LB	0.0000000	-3.1400000	0.0000	INF
341	X341	--	LB	0.0000000	-13.9600000	0.0000	INF
342	X342	--	LB	0.0000000	-5.2200000	0.0000	INF
343	X343	--	LB	0.0000000	-15.3500000	0.0000	INF
344	X344	--	LB	0.0000000	-3.8100000	0.0000	INF
345	X345	--	LB	0.0000000	-13.3800000	0.0000	INF
346	X346	--	LB	0.0000000	-15.6600000	0.0000	INF
347	X347	--	LB	0.0000000	-10.2600000	0.0000	INF
348	X348	--	LB	0.0000000	-1.8900000	0.0000	INF
349	X349	--	LB	0.0000000	-10.4800000	0.0000	INF
350	X350	--	B	16008.0000000	0.0000000	0.0000	INF
351	X351	--	LB	0.0000000	-16.7300000	0.0000	INF
352	X352	--	LB	0.0000000	-9.7200000	0.0000	INF
353	X353	--	LB	0.0000000	-5.8400000	0.0000	INF
354	X354	--	B	8807.0000000	0.0000000	0.0000	INF
355	X355	--	LB	0.0000000	-11.7100000	0.0000	INF
356	X356	--	LB	0.0000000	-3.0700000	0.0000	INF
357	X357	--	LB	0.0000000	-11.0700000	0.0000	INF
358	X358	--	LB	0.0000000	-10.0400000	0.0000	INF
359	X359	--	B	16443.0000000	0.0000000	0.0000	INF
360	X360	--	LB	0.0000000	-6.1200000	0.0000	INF
361	X361	--	LB	0.0000000	-3.7700000	0.0000	INF
362	X362	--	LB	0.0000000	-1.8900000	0.0000	INF

363	X363	--	LB	0.0000000	-2.8800000	0.0000	INF
364	X364	--	LB	0.0000000	-6.4200000	0.0000	INF
365	X365	--	B	18848.0000000	0.0000000	0.0000	INF
366	X366	--	LB	0.0000000	-13.8300000	0.0000	INF
367	X367	--	LB	0.0000000	-21.3600000	0.0000	INF
368	X368	--	LB	0.0000000	-16.5000000	0.0000	INF
369	X369	--	LB	0.0000000	-1.4800000	0.0000	INF
370	X370	--	LB	0.0000000	-16.2600000	0.0000	INF
371	X371	--	LB	0.0000000	-6.5900000	0.0000	INF
372	X372	--	LB	0.0000000	-7.3800000	0.0000	INF
373	X373	--	LB	0.0000000	-3.5600000	0.0000	INF
374	X374	--	LB	0.0000000	-7.7000000	0.0000	INF
375	X375	--	LB	0.0000000	-3.7800000	0.0000	INF
376	X376	--	B	2221.0000000	0.0000000	0.0000	INF
377	X377	--	LB	0.0000000	-3.0100000	0.0000	INF
378	X378	--	LB	0.0000000	-3.4200000	0.0000	INF
379	X379	--	LB	0.0000000	-5.6500000	0.0000	INF
380	X380	--	LB	0.0000000	-14.5800000	0.0000	INF
381	X381	--	LB	0.0000000	-20.0300000	0.0000	INF
382	X382	--	LB	0.0000000	-15.8200000	0.0000	INF
383	X383	--	B	7238.0000000	0.0000000	0.0000	INF
384	X384	--	LB	0.0000000	-15.2300000	0.0000	INF
385	X385	--	LB	0.0000000	-8.2200000	0.0000	INF
386	X386	--	LB	0.0000000	-11.3100000	0.0000	INF
387	X387	--	B	8816.0000000	0.0000000	0.0000	INF
388	X388	--	LB	0.0000000	-6.6200000	0.0000	INF
389	X389	--	LB	0.0000000	-4.6800000	0.0000	INF
390	X390	--	LB	0.0000000	-3.0500000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
391	X391	--	LB	0.0000000	-3.8200000	0.0000	INF
392	X392	--	LB	0.0000000	-7.7800000	0.0000	INF
393	X393	--	LB	0.0000000	-7.4700000	0.0000	INF
394	X394	--	LB	0.0000000	-8.2000000	0.0000	INF
395	X395	--	LB	0.0000000	-15.3300000	0.0000	INF
396	X396	--	LB	0.0000000	-12.6400000	0.0000	INF
397	X397	--	B	9598.0000000	0.0000000	0.0000	INF
398	X398	--	LB	0.0000000	-11.7400000	0.0000	INF
399	X399	--	LB	0.0000000	-8.7600000	0.0000	INF
400	X400	--	LB	0.0000000	-5.6600000	0.0000	INF
401	X401	--	LB	0.0000000	-8.2200000	0.0000	INF
402	X402	--	LB	0.0000000	-7.6100000	0.0000	INF
403	X403	--	LB	0.0000000	-1.7900000	0.0000	INF

404	X404	--	LB	0.0000000	-2.8300000	0.0000	INF
405	X405	--	LB	0.0000000	-2.9400000	0.0000	INF
406	X406	--	B	13503.0000000	0.0000000	0.0000	INF
407	X407	--	LB	0.0000000	-7.8300000	0.0000	INF
408	X408	--	LB	0.0000000	-6.3900000	0.0000	INF
409	X409	--	LB	0.0000000	-11.0700000	0.0000	INF
410	X410	--	LB	0.0000000	-7.1100000	0.0000	INF
411	X411	--	B	932.0000000	0.0000000	0.0000	INF
412	X412	--	LB	0.0000000	-6.3800000	0.0000	INF
413	X413	--	LB	0.0000000	-4.6900000	0.0000	INF
414	X414	--	LB	0.0000000	-8.4100000	0.0000	INF
415	X415	--	LB	0.0000000	-13.6300000	0.0000	INF
416	X416	--	LB	0.0000000	-19.0700000	0.0000	INF
417	X417	--	LB	0.0000000	-15.0200000	0.0000	INF
418	X418	--	B	12870.0000000	0.0000000	0.0000	INF
419	X419	--	LB	0.0000000	-14.3700000	0.0000	INF
420	X420	--	LB	0.0000000	-8.8000000	0.0000	INF
421	X421	--	LB	0.0000000	-5.2600000	0.0000	INF
422	X422	--	LB	0.0000000	-14.4300000	0.0000	INF
423	X423	--	LB	0.0000000	-15.6300000	0.0000	INF
424	X424	--	LB	0.0000000	-9.9700000	0.0000	INF
425	X425	--	LB	0.0000000	-4.3600000	0.0000	INF
426	X426	--	LB	0.0000000	-10.5900000	0.0000	INF
427	X427	--	B	17890.0000000	0.0000000	0.0000	INF
428	X428	--	LB	0.0000000	-4.4800000	0.0000	INF
429	X429	--	LB	0.0000000	-9.6600000	0.0000	INF
430	X430	--	LB	0.0000000	-12.2400000	0.0000	INF
431	X431	--	LB	0.0000000	-7.0900000	0.0000	INF
432	X432	--	B	5760.0000000	0.0000000	0.0000	INF
433	X433	--	LB	0.0000000	-7.0500000	0.0000	INF
434	X434	--	LB	0.0000000	-.0800000	0.0000	INF
435	X435	--	LB	0.0000000	-5.3300000	0.0000	INF
436	X436	--	LB	0.0000000	-9.1500000	0.0000	INF
437	X437	--	LB	0.0000000	-7.7300000	0.0000	INF
438	X438	--	LB	0.0000000	-1.8400000	0.0000	INF
439	X439	--	LB	0.0000000	-3.5400000	0.0000	INF
440	X440	--	LB	0.0000000	-3.4800000	0.0000	INF
441	X441	--	B	15012.0000000	0.0000000	0.0000	INF
442	X442	--	LB	0.0000000	-1.6600000	0.0000	INF
443	X443	--	LB	0.0000000	-14.6600000	0.0000	INF
444	X444	--	LB	0.0000000	-15.2700000	0.0000	INF
445	X445	--	LB	0.0000000	-9.4500000	0.0000	INF
446	X446	--	LB	0.0000000	-3.7800000	0.0000	INF
447	X447	--	LB	0.0000000	-10.4400000	0.0000	INF
448	X448	--	B	21029.0000000	0.0000000	0.0000	INF
449	X449	--	LB	0.0000000	-7.9200000	0.0000	INF
450	X450	--	LB	0.0000000	-.8100000	0.0000	INF
451	X451	--	LB	0.0000000	-6.0200000	0.0000	INF
452	X452	--	LB	0.0000000	-2.9100000	0.0000	INF
453	X453	--	B	15967.0000000	0.0000000	0.0000	INF
454	X454	--	LB	0.0000000	-2.0000000	0.0000	INF
455	X455	--	LB	0.0000000	-4.2100000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
456	X456	--	LB	0.0000000	-3.0600000	0.0000	INF
457	X457	--	LB	0.0000000	-15.0500000	0.0000	INF
458	X458	--	LB	0.0000000	-20.2200000	0.0000	INF
459	X459	--	LB	0.0000000	-15.7600000	0.0000	INF
460	X460	--	B	1307.0000000	0.0000000	0.0000	INF
461	X461	--	LB	0.0000000	-15.2900000	0.0000	INF
462	X462	--	LB	0.0000000	-7.1500000	0.0000	INF
463	X463	--	LB	0.0000000	-16.8400000	0.0000	INF
464	X464	--	LB	0.0000000	-7.2500000	0.0000	INF
465	X465	--	LB	0.0000000	-4.0600000	0.0000	INF
466	X466	--	B	10946.0000000	0.0000000	0.0000	INF
467	X467	--	LB	0.0000000	-11.0000000	0.0000	INF
468	X468	--	LB	0.0000000	-1.3700000	0.0000	INF
469	X469	--	LB	0.0000000	-11.3300000	0.0000	INF
470	X470	--	LB	0.0000000	-17.3000000	0.0000	INF
471	X471	--	LB	0.0000000	-4.4700000	0.0000	INF
472	X472	--	B	3089.0000000	0.0000000	0.0000	INF
473	X473	--	B	13906.0000000	0.0000000	0.0000	INF
474	X474	--	LB	0.0000000	-10.8600000	0.0000	INF
475	X475	--	LB	0.0000000	-1.7800000	0.0000	INF
476	X476	--	LB	0.0000000	-11.9300000	0.0000	INF
477	X477	--	B	21268.0000000	0.0000000	0.0000	INF
478	X478	--	LB	0.0000000	-22.0500000	0.0000	INF
479	X479	--	LB	0.0000000	-25.1700000	0.0000	INF
480	X480	--	LB	0.0000000	-19.7700000	0.0000	INF
481	X481	--	LB	0.0000000	-7.2500000	0.0000	INF
482	X482	--	LB	0.0000000	-19.9800000	0.0000	INF
483	X483	--	LB	0.0000000	-8.9100000	0.0000	INF
484	X484	--	LB	0.0000000	-4.5100000	0.0000	INF
485	X485	--	LB	0.0000000	-14.9900000	0.0000	INF
486	X486	--	LB	0.0000000	-19.2100000	0.0000	INF
487	X487	--	LB	0.0000000	-14.4300000	0.0000	INF
488	X488	--	B	14334.0000000	0.0000000	0.0000	INF
489	X489	--	LB	0.0000000	-14.1200000	0.0000	INF
490	X490	--	LB	0.0000000	-5.6600000	0.0000	INF
491	X491	--	LB	0.0000000	-6.5700000	0.0000	INF
492	X492	--	LB	0.0000000	-8.2800000	0.0000	INF
493	X493	--	LB	0.0000000	-5.8800000	0.0000	INF
494	X494	--	B	19193.0000000	0.0000000	0.0000	INF
495	X495	--	LB	0.0000000	-4.2900000	0.0000	INF
496	X496	--	LB	0.0000000	-2.1100000	0.0000	INF
497	X497	--	LB	0.0000000	-1.1400000	0.0000	INF
498	X498	--	LB	0.0000000	-17.4400000	0.0000	INF
499	X499	--	B	3663.0000000	0.0000000	0.0000	INF

500	X500	--	LB	0.0000000	-2.9700000	0.0000	INF
501	X501	--	LB	0.0000000	-4.1300000	0.0000	INF
502	X502	--	LB	0.0000000	-9.6700000	0.0000	INF
503	X503	--	LB	0.0000000	-4.3800000	0.0000	INF
504	X504	--	LB	0.0000000	-12.9100000	0.0000	INF
505	X505	--	B	19091.0000000	0.0000000	0.0000	INF
506	X506	--	LB	0.0000000	-18.0200000	0.0000	INF
507	X507	--	LB	0.0000000	-21.8700000	0.0000	INF
508	X508	--	LB	0.0000000	-16.7400000	0.0000	INF
509	X509	--	LB	0.0000000	-2.8700000	0.0000	INF
510	X510	--	LB	0.0000000	-16.6900000	0.0000	INF
511	X511	--	LB	0.0000000	-6.4000000	0.0000	INF
512	X512	--	LB	0.0000000	0.0000000	0.0000	INF
513	X513	--	LB	0.0000000	-14.4500000	0.0000	INF
514	X514	--	LB	0.0000000	-16.4700000	0.0000	INF
515	X515	--	LB	0.0000000	-10.9000000	0.0000	INF
516	X516	--	LB	0.0000000	-1.8100000	0.0000	INF
517	X517	--	LB	0.0000000	-11.3500000	0.0000	INF
518	X518	--	B	12139.0000000	0.0000000	0.0000	INF
519	X519	--	LB	0.0000000	-1.6500000	0.0000	INF
520	X520	--	LB	0.0000000	-14.8300000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
I182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
521	X521	--	LB	0.0000000	-16.3300000	0.0000	INF
522	X522	--	LB	0.0000000	-10.6700000	0.0000	INF
523	X523	--	LB	0.0000000	-3.0600000	0.0000	INF
524	X524	--	LB	0.0000000	-11.2800000	0.0000	INF
525	X525	--	B	18590.0000000	0.0000000	0.0000	INF
526	X526	--	LB	0.0000000	-.7900000	0.0000	INF
527	X527	--	LB	0.0000000	-14.8200000	0.0000	INF
528	X528	--	LB	0.0000000	-16.2900000	0.0000	INF
529	X529	--	LB	0.0000000	-10.6100000	0.0000	INF
530	X530	--	LB	0.0000000	-2.8600000	0.0000	INF
531	X531	--	LB	0.0000000	-11.2600000	0.0000	INF
532	X532	--	B	3541.0000000	0.0000000	0.0000	INF
533	X533	--	LB	0.0000000	-19.1800000	0.0000	INF
534	X534	--	LB	0.0000000	-6.0500000	0.0000	INF
535	X535	--	B	9201.0000000	0.0000000	0.0000	INF
536	X536	--	LB	0.0000000	-1.3400000	0.0000	INF
537	X537	--	LB	0.0000000	-12.7800000	0.0000	INF
538	X538	--	LB	0.0000000	-3.6100000	0.0000	INF
539	X539	--	LB	0.0000000	-13.7700000	0.0000	INF
540	X540	--	B	2187.0000000	0.0000000	0.0000	INF

541	X541	--	LB	0.0000000	-21.7000000	0.0000	INF
542	X542	--	LB	0.0000000	-23.6800000	0.0000	INF
543	X543	--	LB	0.0000000	-17.9500000	0.0000	INF
544	X544	--	LB	0.0000000	-7.4500000	0.0000	INF
545	X545	--	LB	0.0000000	-18.6500000	0.0000	INF
546	X546	--	LB	0.0000000	-7.3100000	0.0000	INF
547	X547	--	B	2757.0000000	0.0000000	0.0000	INF
548	X548	--	LB	0.0000000	-17.7800000	0.0000	INF
549	X549	--	LB	0.0000000	-19.3100000	0.0000	INF
550	X550	--	LB	0.0000000	-13.5800000	0.0000	INF
551	X551	--	LB	0.0000000	-4.8900000	0.0000	INF
552	X552	--	LB	0.0000000	-14.3000000	0.0000	INF
553	X553	--	LB	0.0000000	-3.0400000	0.0000	INF
554	X554	--	LB	0.0000000	-9.6000000	0.0000	INF
555	X555	--	B	8369.0000000	0.0000000	0.0000	INF
556	X556	--	LB	0.0000000	-5.1100000	0.0000	INF
557	X557	--	LB	0.0000000	-2.3900000	0.0000	INF
558	X558	--	LB	0.0000000	-1.8200000	0.0000	INF
559	X559	--	LB	0.0000000	-1.4800000	0.0000	INF
560	X560	--	LB	0.0000000	-5.5400000	0.0000	INF
561	X561	--	LB	0.0000000	-3.6500000	0.0000	INF
562	X562	--	LB	0.0000000	-14.2200000	0.0000	INF
563	X563	--	LB	0.0000000	-17.9800000	0.0000	INF
564	X564	--	LB	0.0000000	-13.0200000	0.0000	INF
565	X565	--	B	11971.0000000	0.0000000	0.0000	INF
566	X566	--	LB	0.0000000	-12.8300000	0.0000	INF
567	X567	--	LB	0.0000000	-3.8600000	0.0000	INF
568	X568	--	LB	0.0000000	-5.7000000	0.0000	INF
569	X569	--	LB	0.0000000	-9.6400000	0.0000	INF
570	X570	--	LB	0.0000000	-9.9900000	0.0000	INF
571	X571	--	LB	0.0000000	-4.2900000	0.0000	INF
572	X572	--	LB	0.0000000	-2.8500000	0.0000	INF
573	X573	--	LB	0.0000000	-5.0400000	0.0000	INF
574	X574	--	B	17547.0000000	0.0000000	0.0000	INF
575	X575	--	LB	0.0000000	-5.7000000	0.0000	INF
576	X576	--	LB	0.0000000	-10.5500000	0.0000	INF
577	X577	--	LB	0.0000000	-11.2700000	0.0000	INF
578	X578	--	LB	0.0000000	-5.6200000	0.0000	INF
579	X579	--	LB	0.0000000	-2.9600000	0.0000	INF
580	X580	--	LB	0.0000000	-6.2500000	0.0000	INF
581	X581	--	B	20038.0000000	0.0000000	0.0000	INF
582	X582	--	LB	0.0000000	-8.2100000	0.0000	INF
583	X583	--	LB	0.0000000	-8.0500000	0.0000	INF
584	X584	--	LB	0.0000000	-12.8900000	0.0000	INF
585	X585	--	LB	0.0000000	-9.1500000	0.0000	INF

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

USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
586	X586	--	B	14221.0000000	0.0000000	0.0000	INF
587	X587	--	LB	0.0000000	-8.4200000	0.0000	INF
588	X588	--	LB	0.0000000	-5.7600000	0.0000	INF
589	X589	--	LB	0.0000000	-16.7800000	0.0000	INF
590	X590	--	LB	0.0000000	-8.6700000	0.0000	INF
591	X591	--	LB	0.0000000	-5.2800000	0.0000	INF
592	X592	--	B	10957.0000000	0.0000000	0.0000	INF
593	X593	--	LB	0.0000000	-11.3500000	0.0000	INF
594	X594	--	LB	0.0000000	-2.1200000	0.0000	INF
595	X595	--	LB	0.0000000	-11.1800000	0.0000	INF
596	X596	--	LB	0.0000000	-8.5300000	0.0000	INF
597	X597	--	B	5792.0000000	0.0000000	0.0000	INF
598	X598	--	LB	0.0000000	-6.7500000	0.0000	INF
599	X599	--	LB	0.0000000	-4.4800000	0.0000	INF
600	X600	--	B	4882.0000000	0.0000000	0.0000	INF
601	X601	--	LB	0.0000000	-3.5700000	0.0000	INF
602	X602	--	LB	0.0000000	-5.6800000	0.0000	INF
603	X603	--	B	18364.0000000	0.0000000	0.0000	INF
604	X604	--	LB	0.0000000	-18.6400000	0.0000	INF
605	X605	--	LB	0.0000000	-20.7200000	0.0000	INF
606	X606	--	LB	0.0000000	-15.1000000	0.0000	INF
607	X607	--	LB	0.0000000	-5.1400000	0.0000	INF
608	X608	--	LB	0.0000000	-15.6200000	0.0000	INF
609	X609	--	LB	0.0000000	-4.2600000	0.0000	INF
610	X610	--	LB	0.0000000	-8.6300000	0.0000	INF
611	X611	--	LB	0.0000000	-13.3800000	0.0000	INF
612	X612	--	LB	0.0000000	-18.7600000	0.0000	INF
613	X613	--	LB	0.0000000	-14.7000000	0.0000	INF
614	X614	--	B	18469.0000000	0.0000000	0.0000	INF
615	X615	--	LB	0.0000000	-14.0500000	0.0000	INF
616	X616	--	LB	0.0000000	-8.6700000	0.0000	INF
617	X617	--	LB	0.0000000	-2.1600000	0.0000	INF
618	X618	--	LB	0.0000000	-14.7200000	0.0000	INF
619	X619	--	LB	0.0000000	-20.1800000	0.0000	INF
620	X620	--	LB	0.0000000	-15.8300000	0.0000	INF
621	X621	--	B	10060.0000000	0.0000000	0.0000	INF
622	X622	--	LB	0.0000000	-15.3200000	0.0000	INF
623	X623	--	LB	0.0000000	-7.2000000	0.0000	INF
624	X624	--	LB	0.0000000	-4.1100000	0.0000	INF
625	X625	--	LB	0.0000000	-14.2100000	0.0000	INF
626	X626	--	LB	0.0000000	-19.9300000	0.0000	INF
627	X627	--	LB	0.0000000	-15.8100000	0.0000	INF
628	X628	--	B	12269.0000000	0.0000000	0.0000	INF
629	X629	--	LB	0.0000000	-15.2000000	0.0000	INF
630	X630	--	LB	0.0000000	-7.9700000	0.0000	INF
631	X631	--	B	8883.0000000	0.0000000	0.0000	INF
632	X632	--	LB	0.0000000	-14.4500000	0.0000	INF
633	X633	--	LB	0.0000000	-16.4700000	0.0000	INF
634	X634	--	LB	0.0000000	-10.9000000	0.0000	INF
635	X635	--	LB	0.0000000	-1.8100000	0.0000	INF
636	X636	--	LB	0.0000000	-11.3500000	0.0000	INF

637	X637	--	B	7936.0000000	0.0000000	0.0000	INF
638	X638	--	LB	0.0000000	-7.1900000	0.0000	INF
639	X639	--	LB	0.0000000	-3.3500000	0.0000	INF
640	X640	--	LB	0.0000000	-7.1800000	0.0000	INF
641	X641	--	LB	0.0000000	-3.1800000	0.0000	INF
642	X642	--	B	12055.0000000	0.0000000	0.0000	INF
643	X643	--	LB	0.0000000	-2.4100000	0.0000	INF
644	X644	--	LB	0.0000000	-3.0200000	0.0000	INF
645	X645	--	LB	0.0000000	-2.8400000	0.0000	INF
646	X646	--	LB	0.0000000	-15.3500000	0.0000	INF
647	X647	--	LB	0.0000000	-19.9400000	0.0000	INF
648	X648	--	LB	0.0000000	-15.2400000	0.0000	INF
649	X649	--	B	1720.0000000	0.0000000	0.0000	INF
650	X650	--	LB	0.0000000	-14.8900000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
1182.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
651	X651	--	LB	0.0000000	-6.1900000	0.0000	INF
652	X652	--	LB	0.0000000	-15.0400000	0.0000	INF
653	X653	--	B	5080.0000000	0.0000000	0.0000	INF
654	X654	--	LB	0.0000000	-1.3400000	0.0000	INF
655	X655	--	LB	0.0000000	-1.0900000	0.0000	INF
656	X656	--	LB	0.0000000	-7.7600000	0.0000	INF
657	X657	--	LB	0.0000000	-1.2100000	0.0000	INF
658	X658	--	LB	0.0000000	-10.1800000	0.0000	INF
659	X659	--	LB	0.0000000	-5.2200000	0.0000	INF
660	X660	--	LB	0.0000000	-6.0400000	0.0000	INF
661	X661	--	LB	0.0000000	-7.7900000	0.0000	INF
662	X662	--	LB	0.0000000	-2.6100000	0.0000	INF
663	X663	--	LB	0.0000000	-.2000000	0.0000	INF
664	X664	--	LB	0.0000000	-2.6000000	0.0000	INF
665	X665	--	B	2197.0000000	0.0000000	0.0000	INF
666	X666	--	LB	0.0000000	-11.2200000	0.0000	INF
667	X667	--	LB	0.0000000	-2.4700000	0.0000	INF
668	X668	--	LB	0.0000000	-4.5000000	0.0000	INF
669	X669	--	LB	0.0000000	-.9100000	0.0000	INF
670	X670	--	LB	0.0000000	-4.4600000	0.0000	INF
671	X671	--	B	13256.0000000	0.0000000	0.0000	INF
672	X672	--	LB	0.0000000	-6.2700000	0.0000	INF
673	X673	--	LB	0.0000000	-17.9100000	0.0000	INF
674	X674	--	LB	0.0000000	-7.3600000	0.0000	INF
675	X675	--	LB	0.0000000	-2.8800000	0.0000	INF
676	X676	--	B	893.0000000	0.0000000	0.0000	INF
677	X677	--	LB	0.0000000	-12.0100000	0.0000	INF

678	X678	--	LB	0.0000000	-2.3900000	0.0000	INF
679	X679	--	LB	0.0000000	-12.3900000	0.0000	INF
680	X680	--	LB	0.0000000	-5.2700000	0.0000	INF
681	X681	--	LB	0.0000000	-9.1000000	0.0000	INF
682	X682	--	LB	0.0000000	-7.5100000	0.0000	INF
683	X683	--	LB	0.0000000	-1.6100000	0.0000	INF
684	X684	--	LB	0.0000000	-3.5800000	0.0000	INF
685	X685	--	LB	0.0000000	-3.3500000	0.0000	INF
686	X686	--	B	6326.0000000	0.0000000	0.0000	INF
687	X687	--	LB	0.0000000	-5.5700000	0.0000	INF
688	X688	--	LB	0.0000000	-10.7600000	0.0000	INF
689	X689	--	LB	0.0000000	-10.8000000	0.0000	INF
690	X690	--	LB	0.0000000	-5.0200000	0.0000	INF
691	X691	--	LB	0.0000000	-3.5200000	0.0000	INF
692	X692	--	LB	0.0000000	-5.9800000	0.0000	INF
693	X693	--	B	368.0000000	0.0000000	0.0000	INF
694	ARTIF-- D-	1	LB	0.0000000	1.2000000	0.0000	INF
695	ARTIF-- D-	2	LB	0.0000000	2.1000000	0.0000	INF
696	ARTIF-- D-	3	LB	0.0000000	2.3400000	0.0000	INF
697	ARTIF-- D-	4	LB	0.0000000	1.8100000	0.0000	INF
698	ARTIF-- D-	5	LB	0.0000000	5.5300000	0.0000	INF
699	ARTIF-- D-	6	LB	0.0000000	.0600000	0.0000	INF
700	ARTIF-- D-	7	LB	0.0000000	5.1500000	0.0000	INF
701	ARTIF-- D-	8	LB	0.0000000	2.9600000	0.0000	INF
702	ARTIF-- D-	9	LB	0.0000000	2.6800000	0.0000	INF
703	ARTIF-- D-	10	LB	0.0000000	1.2500000	0.0000	INF
704	ARTIF-- D-	11	LB	0.0000000	-.6400000	0.0000	INF
705	ARTIF-- D-	12	LB	0.0000000	1.3500000	0.0000	INF
706	ARTIF-- D-	13	LB	0.0000000	2.2800000	0.0000	INF
707	ARTIF-- D-	14	LB	0.0000000	.5000000	0.0000	INF
708	ARTIF-- D-	15	LB	0.0000000	3.7500000	0.0000	INF
709	ARTIF-- D-	16	LB	0.0000000	6.0300000	0.0000	INF
710	ARTIF-- D-	17	LB	0.0000000	2.7900000	0.0000	INF
711	ARTIF-- D-	18	LB	0.0000000	3.6000000	0.0000	INF
712	ARTIF-- D-	19	LB	0.0000000	-.7600000	0.0000	INF
713	ARTIF-- D-	20	LB	0.0000000	3.8300000	0.0000	INF
714	ARTIF-- D-	21	LB	0.0000000	5.0900000	0.0000	INF
715	ARTIF-- D-	22	LB	0.0000000	2.1600000	0.0000	INF

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PROBLEM NUMBER 1
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
716	ARTIF-- D-	23	LB	0.0000000	5.5900000	0.0000	INF
717	ARTIF-- D-	24	LB	0.0000000	2.1700000	0.0000	INF
718	ARTIF-- D-	25	LB	0.0000000	5.4700000	0.0000	INF

719	ARTIF-- D-	26	LB	0.0000000	5.0100000	0.0000	INF
720	ARTIF-- D-	27	LB	0.0000000	5.2500000	0.0000	INF
721	ARTIF-- D-	28	LB	0.0000000	3.4900000	0.0000	INF
722	ARTIF-- D-	29	LB	0.0000000	2.7600000	0.0000	INF
723	ARTIF-- D-	30	LB	0.0000000	2.7400000	0.0000	INF
724	ARTIF-- D-	31	LB	0.0000000	1.7600000	0.0000	INF
725	ARTIF-- D-	32	LB	0.0000000	.5600000	0.0000	INF
726	ARTIF-- D-	33	LB	0.0000000	3.2400000	0.0000	INF
727	ARTIF-- D-	34	LB	0.0000000	1.2500000	0.0000	INF
728	ARTIF-- D-	35	LB	0.0000000	.6000000	0.0000	INF
729	ARTIF-- D-	36	LB	0.0000000	3.8000000	0.0000	INF
730	ARTIF-- D-	37	LB	0.0000000	3.7700000	0.0000	INF
731	ARTIF-- D-	38	LB	0.0000000	1.7800000	0.0000	INF
732	ARTIF-- D-	39	LB	0.0000000	4.0600000	0.0000	INF
733	ARTIF-- D-	40	LB	0.0000000	5.1600000	0.0000	INF
734	ARTIF-- D-	41	LB	0.0000000	1.1900000	0.0000	INF
735	ARTIF-- D-	42	LB	0.0000000	.5800000	0.0000	INF
736	ARTIF-- D-	43	LB	0.0000000	1.0900000	0.0000	INF
737	ARTIF-- D-	44	LB	0.0000000	1.0700000	0.0000	INF
738	ARTIF-- D-	45	LB	0.0000000	.1900000	0.0000	INF
739	ARTIF-- D-	46	LB	0.0000000	1.1900000	0.0000	INF
740	ARTIF-- D-	47	LB	0.0000000	1.7600000	0.0000	INF
741	ARTIF-- D-	48	LB	0.0000000	.4100000	0.0000	INF
742	ARTIF-- D-	49	LB	0.0000000	1.1400000	0.0000	INF
743	ARTIF-- D-	50	LB	0.0000000	1.2600000	0.0000	INF
744	ARTIF-- D-	51	LB	0.0000000	-.0800000	0.0000	INF
745	ARTIF-- D-	52	LB	0.0000000	4.4900000	0.0000	INF
746	ARTIF-- D-	53	LB	0.0000000	2.8400000	0.0000	INF
747	ARTIF-- D-	54	LB	0.0000000	4.0300000	0.0000	INF
748	ARTIF-- D-	55	LB	0.0000000	.7300000	0.0000	INF
749	ARTIF-- D-	56	LB	0.0000000	3.9300000	0.0000	INF
750	ARTIF-- D-	57	LB	0.0000000	5.4600000	0.0000	INF
751	ARTIF-- D-	58	LB	0.0000000	4.7500000	0.0000	INF
752	ARTIF-- D-	59	LB	0.0000000	2.3700000	0.0000	INF
753	ARTIF-- D-	60	LB	0.0000000	-.8300000	0.0000	INF
754	ARTIF-- D-	61	LB	0.0000000	.7700000	0.0000	INF
755	ARTIF-- D-	62	LB	0.0000000	2.6600000	0.0000	INF
756	ARTIF-- D-	63	LB	0.0000000	5.3700000	0.0000	INF
757	ARTIF-- D-	64	LB	0.0000000	3.5800000	0.0000	INF
758	ARTIF-- D-	65	LB	0.0000000	5.1100000	0.0000	INF
759	ARTIF-- D-	66	LB	0.0000000	2.0000000	0.0000	INF
760	ARTIF-- D-	67	LB	0.0000000	.5400000	0.0000	INF
761	ARTIF-- D-	68	LB	0.0000000	2.4400000	0.0000	INF
762	ARTIF-- D-	69	LB	0.0000000	-.9400000	0.0000	INF
763	ARTIF-- D-	70	LB	0.0000000	-.1100000	0.0000	INF
764	ARTIF-- D-	71	LB	0.0000000	5.8500000	0.0000	INF
765	ARTIF-- D-	72	LB	0.0000000	2.9400000	0.0000	INF
766	ARTIF-- D-	73	LB	0.0000000	.9500000	0.0000	INF
767	ARTIF-- D-	74	LB	0.0000000	2.9200000	0.0000	INF
768	ARTIF-- D-	75	LB	0.0000000	2.3500000	0.0000	INF
769	ARTIF-- D-	76	LB	0.0000000	2.9000000	0.0000	INF
770	ARTIF-- D-	77	LB	0.0000000	1.4800000	0.0000	INF
771	ARTIF-- D-	78	LB	0.0000000	4.3900000	0.0000	INF
772	ARTIF-- D-	79	LB	0.0000000	2.4600000	0.0000	INF
773	ARTIF-- D-	80	LB	0.0000000	4.6900000	0.0000	INF

774	ARTIF-- D- 81	LB	0.0000000	.5500000	0.0000	INF
775	ARTIF-- D- 82	LB	0.0000000	3.3500000	0.0000	INF
776	ARTIF-- D- 83	LB	0.0000000	2.6600000	0.0000	INF
777	ARTIF-- D- 84	LB	0.0000000	1.4300000	0.0000	INF
778	ARTIF-- D- 85	LB	0.0000000	.0300000	0.0000	INF
779	ARTIF-- D- 86	LB	0.0000000	5.6300000	0.0000	INF
780	ARTIF-- D- 87	LB	0.0000000	1.1900000	0.0000	INF

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* PROBLEM NUMBER 1 *
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USING REGULAR
II82.1982.99 ORIGINS,693 ELE. W.E. PLANT AT ROSE CITY.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
781	ARTIF-- D-	88	LB	0.0000000	-.9300000	0.0000	INF
782	ARTIF-- D-	89	LB	0.0000000	3.7600000	0.0000	INF
783	ARTIF-- D-	90	LB	0.0000000	2.7600000	0.0000	INF
784	ARTIF-- D-	91	LB	0.0000000	2.9200000	0.0000	INF
785	ARTIF-- D-	92	LB	0.0000000	4.2800000	0.0000	INF
786	ARTIF-- D-	93	LB	0.0000000	1.0400000	0.0000	INF
787	ARTIF-- D-	94	LB	0.0000000	3.7200000	0.0000	INF
788	ARTIF-- D-	95	LB	0.0000000	4.4900000	0.0000	INF
789	ARTIF-- D-	96	LB	0.0000000	3.3900000	0.0000	INF
790	ARTIF-- D-	97	LB	0.0000000	.6000000	0.0000	INF
791	ARTIF-- D-	98	LB	0.0000000	5.6200000	0.0000	INF
792	ARTIF-- D-	99	LB	0.0000000	3.1900000	0.0000	INF
793	ARTIF-- D-	100	LB	0.0000000	1.6000000	0.0000	INF
794	ARTIF-- D-	101	LB	0.0000000	-.4400000	0.0000	INF
795	ARTIF-- D-	102	LB	0.0000000	1.2500000	0.0000	INF
796	ARTIF-- D-	103	LB	0.0000000	11.1300000	0.0000	INF
797	ARTIF-- D-	104	LB	0.0000000	2.2400000	0.0000	INF
798	ARTIF-- D-	105	LB	0.0000000	-.6000000	0.0000	INF
905	ARTIF-- D-	106	B	0.0000000	0.0000000	0.0000	INF

MINIMUM VALUE OF THE OBJECTIVE FUNCTION = 4950171.049989

CALCULATION TIME WAS 9.3640 SECONDS FOR 538 ITERATIONS.

DATA STORAGE MEMORY =254054(OCTAL) TOTAL MEMORY = 306100(OCTAL)
2TOTAL TIME FOR THIS PROBLEM WAS 12.261 SECONDS

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