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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The problem of simultaneous scheduling of multiple projects within the Engineering Division of the St. Paul District, Corps of Engineers, is addressed using a decison-making algorithm in conjunction with a computer softwa e package (IMPSS). This report details the capabilities and limitations of the software, outlines theories used in development and use of IMPSS, and illustrates the IMPSS decision-making algorithm by example.

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INTEGRATED MULTIPLE PROJECT

SCHEDULING SYSTEM

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1 April 1983

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1. Purpose

The purpose of this report is to present the author's solution to the problem of simultaneous scheduling of multiple projects within the Engineering Division of the St. Paul District. This solution involves using a decision-making algorithm in conjunction with a computer software package. The algorithm/software package will hereafter be referred to as the Integrated Multiple Project Scheduling System (IMPSS). This report will do the following:

    a. Detail the capabilities and limitations of the software developed to support IMPSS.

    b. Outline and explain the theories used to develop and use IMPSS.

    c. Illustrate the IMPSS decision-making algorithm by example.

It is important that one point be made and understood at the outset of the report. IMPSS relies heavily on the human element (i.e., the experience and knowledge of executives and managers) to set priorities and allocate resources. The computer will not resource level for all projects. It will show required resource levels at any time and will allow shifting of those levels as management decisions are made.

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2. Background

2.1 Problem Description:

The author was assigned this project by the Chief of the Engineering Division in January 1983. At that time, there was no method for determining actual, total resource requirements without resorting to tedious, time-consuming, manual calculations. The level of detail in the Resource Allocation/Project Management (RA/PM) system not only inundates the manager with a lot of output that requires a great deal of analysis time, but also forces project managers to spend an inordinate amount of time (about one day per week) to keep the data current. Additionally, the development of input for RA/PM requires the same "stubby-pencil" calculations referred to earlier in this paragraph. Consequently, there is no advantage to using RA/PM in its present form.

2.2 Milestone Determinations:

The second part of the problem involves the means by which individual project milestones are determined. Essentially, project managers break down each of their projects into its component activities. Then, through the use of bar charting, critical path method (CPM), and personal estimating techniques, they assign a set of milestones to each project. The project managers are generally operating in a vacuum and assigning milestones without any knowledge of how their projects relate to other projects. This knowledge gap forces projects and project managers to compete for resources. At the functional level, it also causes workload bottlenecks to form which can only be relieved by slipping milestones (a weak and unpopular solution at best). As a result, the amount of crisis management required to meet individual milestones is higher than what would normally be found if project resource interrelationships were known prior to assigning milestones.

2.3 Workload Determination and Contracting-Out:

The last component of the problem is finding a method of accurately determining the total workload in the Engineering Division over the fiscal year. A lead time of 4 to 6 months is required to identify functional area overloads so that they may be relieved by sending the excess work to other districts or by contracting for architect/engineer (A/E) services. Under the current system, branch and section chiefs annually determine their projected workloads, which are then manually assembled to find the total workload of the Division. This not only requires a great deal of time, but it is virtually impossible to manipulate the end product to allow separate courses of action to be developed, analyzed, and the best course selected. In fact, the current procedure is to make policy and priority decisions during the data development and to accept the final product as the best solution.

2.4 Explanation:

It must be noted that the above discussion is not meant to be critical of the individual abilities of managers at any level within the District. Rather, it is meant to point out the pressing need for an automated system of dealing with the minutiae of project management which is currently handcuffing the District's ability to intelligently allocate internal resources. The development of IMPSS or a similar system is indeed necessary.

2.5 Conduct of the Project:

The project was divided into three phases: study, software development, and algorithm development. The study phase consisted of interviews and literature research. The purpose of the interviews was to define the scope and magnitude of the problem and to obtain guidance on the type of output required. Individuals at all levels, from project managers to division chief, were interviewed. The information gathered during those interviews is presented in the preceding paragraphs. Literature research was done to determine which analytical scheduling methods are best suited to the situation. Initially, it appeared that precedence networking would be the best method. However, the cost of obtaining and fielding the required software seemed to be unjustified during the initial stage of the project. The decision was made to modify an existing CPM software package, write a bar charting/ resource load program, and combine the two with an external problem-solving algorithm. The software and algorithm development phases of the project resulted from this decision. These will be explained in detail in the following sections of this report.

3. Software Support Package

3.1 Composition:

The IMPSS software support package consists of the following major components:

    a. "*CPM": a canned program for the Harris 500 which performs critical path method calculations.

    b. "*CPM Option 6": a graphic illustration program for the Techtronix plotter which converts the output from "*CPM" into a Gantt Chart (a bar chart which shows slack by activity) and plots a resource loading histogram based on the Gantt Chart.

If this report is accepted and IMPSS is found to be a satisfactory system, a third component could easily be added which would convert IMPSS final output into RA/PM input. This would relieve project managers of the need to prepare input for two systems.

3.2 Capabilities of "*CPM":

"*CPM" is an interactive, canned program originally developed by Mobile District and modified and improved by St. Paul District. It consists of six subroutines which are used iteratively to compute start, finish, and slack times and to update the input network. "*CPM" will compute the following elements from the network input data (see Appendix A for definition):

    a. Early start date (ES)

    b. Early finish date (EF)

    c. Late start date (LS)

    d. Late finish date (LF)

    e. Total slack (TS)

    f. Remaining slack (RS)

    g. Total project cost

From updated input data, the program can perform the following functions:

    a. Compute total cost to date for each project activity and show total project cost to date.

    b. Show percentage of completion for each project activity.

    c. Replace ES and LS dates with actual start date and alter slack calculations to show how critical the activities are.

d. Replace LF date with milestone date, alter slack calculations, and determine if milestone can be met.

e. If a milestone cannot be met, a warning statement is printed, and TS is shown as a negative number which indicates the number of days that the activity will be late if neither the duration nor the milestone is changed.

The program has the ability to sort the output and list it in several orders. The various sorts and their management uses are as follows:

a. I-J Sort - Activities are listed in numerical order of their I-J (event) numbers. Analysis of this sort allows the logic of the total network to be checked and the level of input accuracy to be quickly determined.

b. Early Start Sort - Activities are listed in chronological order by their ES dates. This sort shows which activities can be started chronologically if resources are available.

c. Early Finish Sort - Activities are listed chronologically by their EF dates. This sort shows how soon activities can be finished if resources are available.

d. Late Start Sort - Activities are listed chronologically by their LS dates. This sort shows when activities must be started to remain on schedule.

e. Late Finish Sort - Activities are listed chronologically by their LF date. This is one of the most important sorts from a management standpoint. It shows which activities must be completed to avoid missing milestones. In the final IMPSS output, the LF dates will be replaced by the activity milestone date. Therefore, this sort could be labeled the milestone sort.

f. Total slack sort - Activities are listed in ascending numerical order by their amounts of total slack. This is the most important management sort because it shows the critical activities and near-critical activities.

g. Project Sort - Activities are listed in the order specified by any of the above five basic sorts for one specific project. This allows project managers to get information on a particular project.

h. Organization Sort - All the activities of a specific organization are listed in the order specified by any of the five basic sorts. This provides specific information on the work schedule of a particular organization to allow evaluation of bottlenecks and analysis of staffing levels.

3.3 Capabilities of "*CPM" Graphics Options:

There are two primary graphics options: a Gantt Chart (Figure 3.3-1) and a resource histogram (Figure 3.3-2). The Gantt Chart is simply a bar chart for all activities which graphically shows available slack. The resource histogram is a graph which shows the total daily cost for each activity scheduled for that day. The resource histogram option has an additional feature which prints out daily totals for both ES and LF schedules (Figure 3.3-3). These numbers correspond to the peak amounts registered on the graph for both the ES and LF plots.

3.4 Limitations of "*CPM":

"*CPM" and its graphics options are limited both by program capacity and the inherent constraints of using critical path method theory. The program capacity limitations follow.

a. The maximum number of activities is 3,000. This includes dummies.

b. Every activity must have a unique I-J (event) number. There-fore, projects with a great number of parallel paths will have a large number of dummies and may reduce the total usable capacity for real activities.

c. The program can only calculate closed networks. Therefore, individual project networks must be linked together at the beginning and end by dummies. This creates false start and stop events and makes output interpretation on a project-by-project basis somewhat tricky. However, some familiarity with the output makes accurate analysis possible. Additionally, use of the project sort can expedite this process.

d. Assembly of a large initial calendar file is required to en-sure that the available "time window" is great enough for the network to occupy. The calendar file can be reduced after the initial run.

e. Strict coding of activity descriptions is required to allow project and organizational sorting.

f. Activity durations must be in calendar days.

g. The amount of output requires a 132-character display. How-ever, a cathode ray tube (CRT) can only display 96 characters. This causes the output to be "wrapped" on the screen, making data interpre-tation somewhat tedious. If totally interactive CRT use is found to be important, additional search and sort subroutines can be added to make the CRT output display less confusing.

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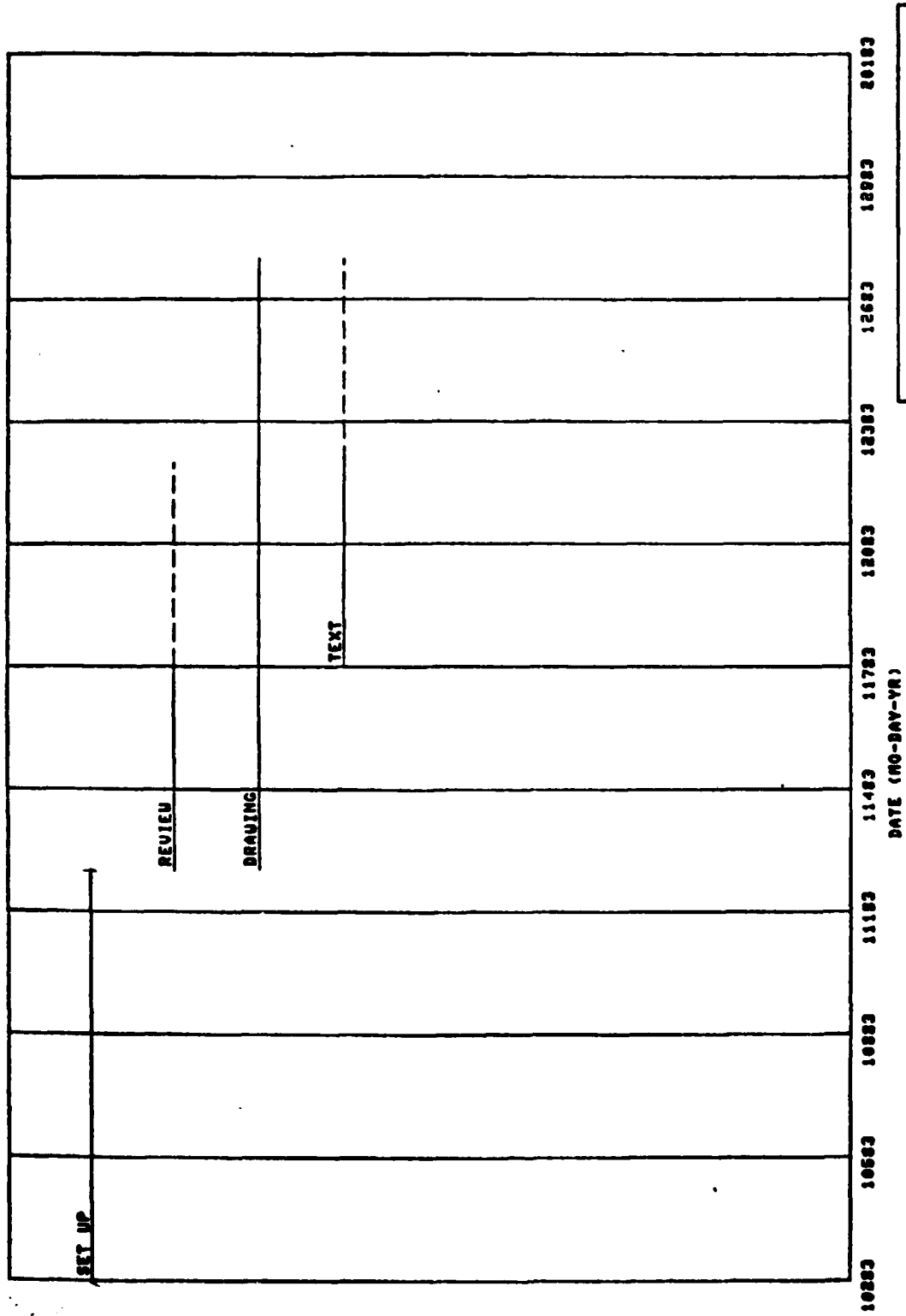
Figure 3.3-1: Sample Gantt Chart
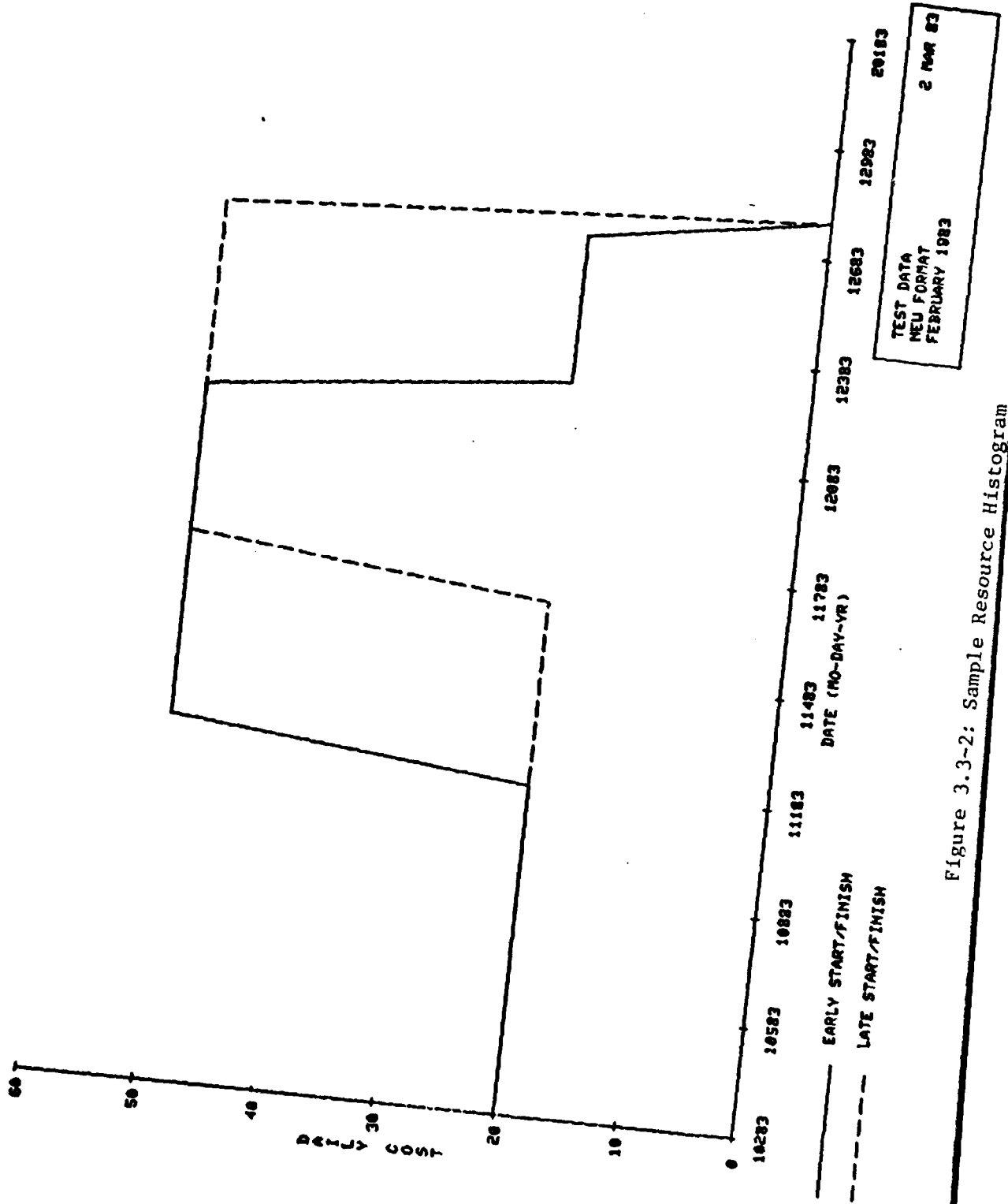
Figure 3.3-2: Sample Resource Histogram

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```
TEST DATA                          2 MAR 83
NEW FORMAT
FEBRUARY 1983


            AVERAGE DAILY COST SUMMARY

    DATE        EARLY START/FINISH        LATE START/FINISH
                      COST                      COST

    010283             20.                       20.
    010383             20.                       20.
    010483             20.                       20.
    010583             20.                       20.
    010683             20.                       20.
    010783             20.                       20.
    010883             20.                       20.
    010983             20.                       20.
    011083             20.                       20.
    011183             20.                       20.
    011283             50.                       20.
    011383             50.                       20.
    011483             50.                       20.
    011583             50.                       20.
    011683             50.                       20.
    011783             50.                       50.
    011883             50.                       50.
    011983             50.                       50.
    012083             50.                       50.
    012183             50.                       50.
    012283             20.                       50.
    012383             20.                       50.
    012483             20.                       50.
    012583             20.                       50.
    012683             20.                       50.
    012783              0.                        0.


    MAXIMUM DAILY EARLY START/FINISH COST IS $      50. ON  11283.

    MAXIMUM DAILY LATE START/FINISH COST IS $       50. ON  11783.
EOT..
```

Figure: 3.3-3: Sample Printout of Resource Histogram Totals

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h. Size limitations of the plotter will necessitate some cutting and taping to produce an overall bar chart and resource histogram.

Limitations imposed by the inherent weakness of CPM follow.

a. True project logic is difficult to diagram because CPM does not allow overlapping with preceding activities. This can be partially overcome by using actual start dates and the Gantt Chart option.

b. Converting task activity project networks to organizational activity project networks will require a good deal of thought. A training program for project managers will be necessary.

c. A CPM network must be converted to a Gantt Chart before heuristic resource leveling techniques can be applied.

One final limitation of CPM is the impossibility of mathematically modeling the political climate and the desires, plans, and feelings of the executive group. The computer will not produce an optimal, resource-constrained schedule because to do so would be a waste of time and money. First, the activity durations are estimates, and CPM does not allow use of a mechanism that demonstrates the potential variation of those times within the system. That makes the entire schedule an estimate and degrades the true value of a resource-leveled schedule. Secondly, factors such as flood emergencies and unscheduled resource losses affect the actual schedule and cannot be included in the network input. Most importantly, to use an optimal, resource-constrained schedule as a factor in the decision-making process is to run the risk of letting the computer set the priorities for the corporate body. Therefore, IMPSS is designed only to illustrate total workload requirements in the best and worst possible cases, ensuring that project priorities are set by the appropriate decision makers.

4. The Algorithm and Its Theory

4.1 IMPSS Decision-making Algorithm:

Figure 4.1-1 graphically illustrates the decision-making algorithm, which consists of five stages. The following paragraphs describe each stage and its corresponding theoretical basis. Assumptions will be discussed as they appear within the algorithm.

4.2 Stage I, Network Development:

The first stage consists of assembling the items necessary for the integrated multiple-project network. Individual project networks must first be developed, and this will be the responsibility of individual project managers. Contrary to normal CPM and RA/PM practice, activities will be defined by organization rather than by task. (For purposes of this report, organization is defined as a functional element (within a Branch) such as Interior Drainage, Geotechnical Design, or Estimating). The duration of the activity will be the amount of time required by an organization to complete all the tasks for which it is responsible on a particular project. The total cost of the activity will be the amount of money allocated to the organizations to do those tasks. Restricting activities to established organizational codes is desirable, but organizational codes which represent more than one functional element can be broken down if necessary.

For example, the Structural Section of the Design Branch may have to complete the following three tasks on a certain project: (1) Prepare architectural design concepts, (2) Design structural steel, and (3) Design structural concrete. Each task's duration would take 2 weeks at a budget of $1,000.00, $2,000.00 and $3,000.00, respectively. These tasks would be combined into one activity labeled "Structural Design," with a 6-week duration and a total cost of $6,000.00. (Note: The activity description must receive a coded prefix prior to input).

Once a list of activities with durations and costs is assembled, the individual project network can be constructed using standard CPM theory. At this point, it may be necessary to subdivide certain activities to preserve important precedence relationships within the project. This is allowable, but must be kept to a minimum to avoid unnecessary detail within the output. Additionally, it may be found that a project network consists of nothing but parallel paths. Although this is theoretically possible, it is unlikely, and the logic should be reviewed to determine if a satisfactory technological precedence relationship exists.

The next step is to combine the individual networks into one master network. This is done by first assigning unique I-J numbers for each project (i.e., one project may have numbers starting with 01 while another's numbers may start with 19). There is no theoretical basis for this requirement, but it will be of substantial aid in the analysis and interpretation of the output. The individual projects are now linked together at their initial and final nodes by dummies which emanate from and converge into master start and finish nodes. A comprehensive table of all activities in the master network is then assembled which shows the I-J number, duration, cost, and description for each activity. This

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STAGE I   STAGE II

RELABLE ACTIVITIES TO BE C

NO

BAD   BAD

DEVELOP   INPUT   INITIAL   INITIAL   VERIFY   GOOD INPUT   RUN   VERIFY   GOOD   IS
PROJECT   IN CPM   IN CPM   IN CPM   INPUT   MILESTONES   IN CPM   UPDATE   OUTPUT
NETWORKS &   RUN   OUTPUT   ACCURACY   & ACTUAL   UPDATE   INPUT   REALISTIC
DURATIONS   START   ACCURACY   ?
START   IS CPM
                                                                         & CHANGES

PREFORM RESOURCE LEVELING BY RESCHEDULING NON-C
USING ACTUAL START DATE OR CHANGING DURATIONS

FIGURE 4.1-1:

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ES TO BE CONTRACTED OUT & REMOVE FROM NETWORK   YES

NO

OVERRUN CONTRACT OUT ? NO

IS OUTPUT REALISTIC ? YES GENERATE GRAPHICS BAR CHART & RESOURCE - ES & LF COMPARE CHART TO RESOURCED OK IDENTIFY RESOURCE OVER 3 OTHER RUNS FINAL RESOURCE CURVE & BAR CHART CORPORATE SATISFACTION ? YES RUN ORGANIZATION & PROJECT SCHEDULES & CURVES PUBLISH CURRENT MILESTONES

NOT O.K.

UNDERRUN ADD MORE SMALL PROJECTS ? NO

ULING NON-CRITICAL ACTIVITIES
DURATIONS

YES
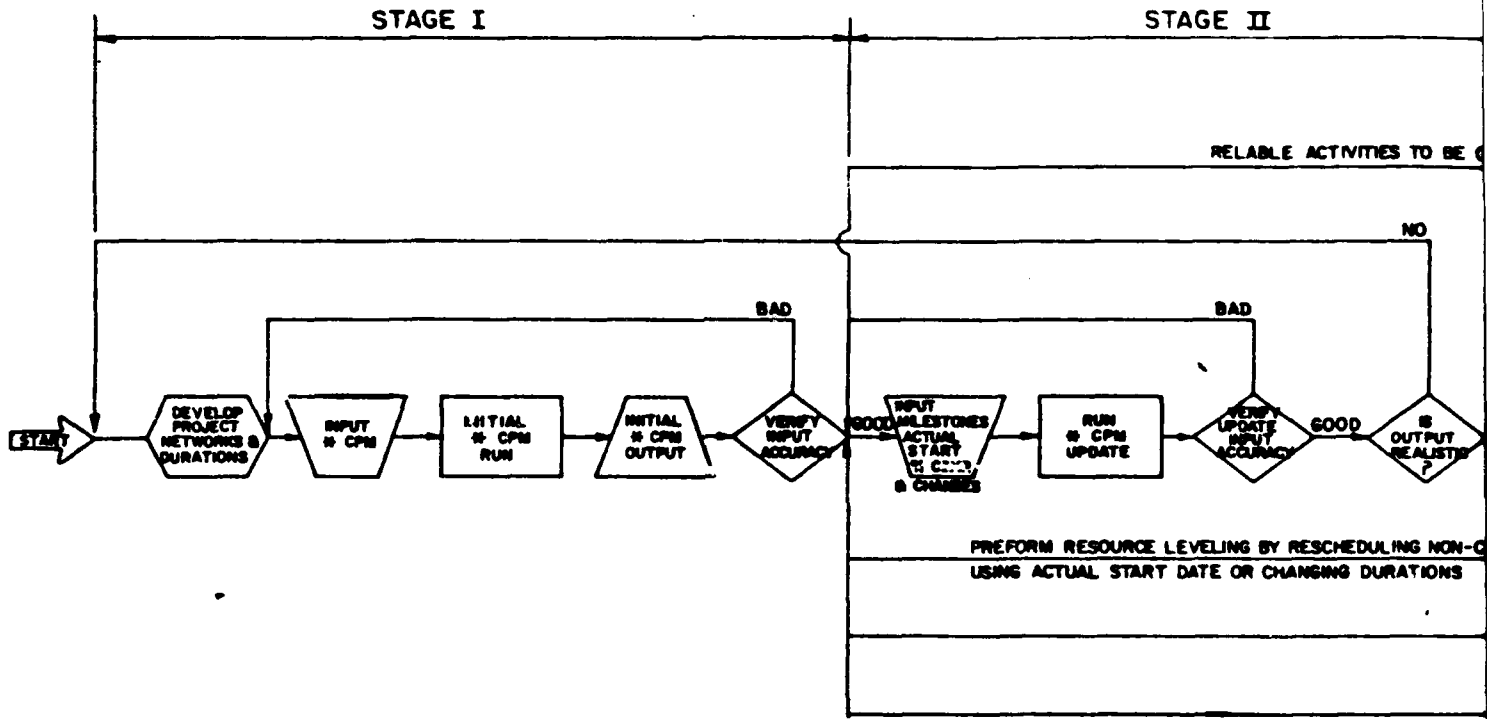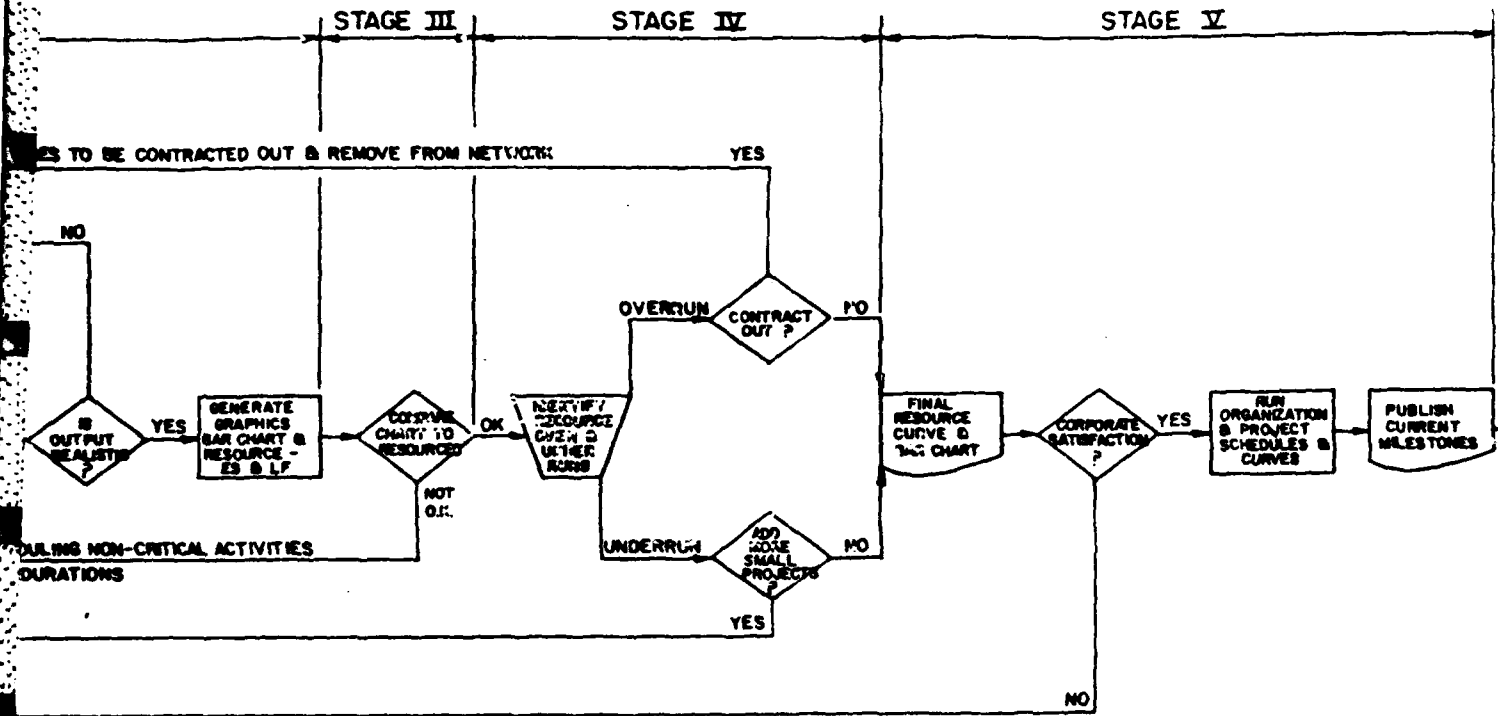
NO

RE 4.1-1: IMPSS ALGORITHM FLOW CHART

table becomes the initial input to "*CPM". Finally, an initial run of "*CPM" is made, and its output used to check the accuracy of the input. Once the above steps have been completed satisfactorily, the user can move to Stage II of IMPSS.

4.3 Stage II, Project Constraints:

The second stage involves constraining the theoretical network built in Stage I with actual milestones, start dates, and percentages of completion. This is done by using the update option of "*CPM". The information required is provided by project managers as a part of their initial input. After this information has been entered, a second computer run can be made and the output checked for accuracy. Next, it must be determined if the output is realistic. If it is not, the entire system must be reviewed and the fallacies in the logic identified and corrected before going on. If everything is in order, the graphics options of "*CPM" should be run, generating the following output:

    a. ES bar chart.

    b. LF (milestone) bar chart.

    c. ES resource histogram.

    d. LF resource histogram.

    e. TS sort for master network.

The above information and the output generated by Step 1 should provide all the information required for Stage III.

4.4. Stage III, Resource Leveling:

The goal of Stage III is to distribute the total workload as evenly as possible across the selected period of time. This is done by comparing the ES and LF resource histograms with the ES bar chart. Before this operation can be explained in detail, the comparison criteria must be understood. The resource requirement is measured in dollars per day and is determined for an individual activity by dividing the activity's total cost (the organization's project budget) by its duration. This operation assumes that the money allocated for a single activity is uniformly expended throughout its duration. Consequently, the total resource require-ment for any one day will be the sum of the individual activity resource requirements that are scheduled for that day. That sum can then be compared to the maximum amount of dollars that the parent organization can expend on any given day to determine if the parent organization will be over or under committed on that particular day. For purposes of this report, parent organization is defined as the aggregate of functional elements over which it has control. This theory can be reduced to the following equations:

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$$r_x = \frac{c_x}{d_x} \quad \ldots \ldots \quad \text{Equation 1}$$

$$R_i = \sum_{x=1}^{n} r_x(i) \ldots \quad \text{Equation 2}$$

Where: r_x = Resource requirement for activity "x" ($/day)

c_x = Total cost for activity "x" ($)

d_x = Duration of activity "x" (Days)

And: R_i = Total resource requirement on day "i" ($)

i = Day

R_{max} = Maximum daily resource capacity for parent organization

Therefore:

If: $R_{max} < R_i$ . . . . Equation 3

Then: The parent organization is over committed

If: $R_{max} = R_i$ . . . . .Equation 4

Then: The parent organization is fully committed

If: $R_{max} > R_i$. . . . . Equation 5

Then: The parent organization is under committed

Resource leveling can now begin, using this theory and the updating option of "*CPM". A simple heuristic program is used iteratively until a satisfactory solution is reached. The program is based on four rules (heuristics):

    a. Allocate resources serially in time (i.e., start with ES schedule).

    b. Give preference to activities with the least slack.

    c. Reschedule non-critical activities to free resources for critical activities.

    d. Schedule activities by project priority as determined by executive group.

The heuristic program is applied using the following sequence of events:

    a. Locate times in which $R_i > R_{max}$ on ES resource histogram.

    b. Check corresponding times on ES Gantt Chart to determine which activities have slack and which activities do not (i.e., critical activities).

    c. Add the resource requirement for those activities with no slack. If this amount is greater than R_{max}, the parent organization will be over committed unless a means to shorten the duration of critical activities can be found.

    d. Attempt to schedule activities with slack at a point between their ES and LS date where $R_i < R_{max}$. Call these dates tentative actual start dates.

    e. Using the LF Gantt Chart, LF resource histogram and the TS sort, identify which milestones are most heavily limiting the overall system. Select tentative new milestones, if possible, for super-critical activities. A super-critical activity is defined as one which cannot meet its milestone.

    f. Update the master file with newly determined tentative actual start dates, tentative new milestones, revised durations, and other changes.

    g. Run newest update. Analyze that output and repeat the process until a satisfactory solution is reached.

It is doubtful that a level resource histogram can be derived. Therefore, the best possible solution will contain times when the parent organization is both over committed and under committed. This is dealt with in Stage IV.

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4.5 Stage IV, Project Assignment:

The fourth stage of IMPSS involves a number of crucial management decisions. These include:

    a. Which projects and activities will be done internally.

    b. Which projects and activities should be sent to other districts.

    c. Which projects and activities should be contracted out.

    d. If there are small projects and other activities not included in the master file which could fill the times when the parent organization is under committed.

    e. If personnel staffing levels should change.

    f. How much overtime should be authorized and where it should occur.

These decisions can be made with the aid of additional iterations of "*CPM" as described below.

    a. Identify times where $R_i > R_{max}$ and the activities that occur during those times.

    b. Determine which activities will be done internally and which will be done externally (contracted or sent out).

    c. Remove the activities which will be done by an external agency. (Note: The I-J numbers and new logic of the modified master file should be checked to ensure that no system limitations are exceeded).

    d. Run "*CPM" and analyze output to determine if R_i is still greater than R_{max}. Make necessary decisions and iterate until $R_i < R_{max}$ in all cases.

    e. Identify times when $R_i < R_{max}$.

    f. Add additional small projects to master file during those times if necessary.

    g. Run "*CPM", analyze output, and make any necessary changes. Iterate until satisfied with output.

    h. Relabel activities to be done by external sources and put them back into the network.

    i. Run final output.

The final output should consist of the graphics and sorts that are most useful to managers.

4.6 Stage V, Output Utilization:

Stage V is an optional stage and is described here only as the author's opinion of how "*CPM" output might be used after all decisions have been made. Once the final output is generated, it should be reviewed to ensure that the corporate body is satisfied with the decisions which the output illustrates. If they are not, then "its back to the old drawing board." Assuming that the final output is satisfactory, the following things can be done to enhance its value as a communications vehicle:

    a. Using a special search option of "*CPM", a Gantt Chart and resource histogram can be drawn for each separate organization. Organizational managers (branch and section chiefs) could use these diagrams to aid them in their daily work scheduling and to remind them of critical activities.

    b. The same search option will produce like diagrams on an individual project basis for use by project managers.

    c. The LF sort could be used as the base document for publishing a consolidated list of milestones.

There are probably a number of other uses for the output. It is specifically designed to allow the interrelationships between projects to be shown in both tabular and graphical form.

5. Example of IMPSS Use

This section consists of an example of how the IMPSS algorithm is used in conjunction with "*CPM". For simplicity, only three projects are used, and decisions will be made about their interrelationships. The computer output for each point in the algorithm is shown to illustrate the information that can be gleaned from it by proper analysis.

5.1 Stage I Example:

The three projects have each been given a three-digit code as required by the "*CPM" search option, and they will be referred to by that code throughout this example. Figures 5.1-1, 5.1-2, and 5.1-3 are the networks associated with each project. Figure 5.1-4 illustrates how the three are integrated by joining them at the start and finish points with dummies and common nodes. The projects have been further identified by assigning each node a four-digit number in which the first two digits are unique throughout the network for each project. Table 5.1-1 is a list of the three-digit activity codes which have been assigned to each functional area within the Engineering Division. Thus, individual activities can be identified by combining their project code and functional area activity code.

Table 5.1-1 Functional Area Activity Codes

Functional Area	Activity Code
G & H Branch:	
Geology & Surveys	EGS
Field Survey Party	EGF
Boring Crew	EGB
Geotechnical Design	EGD
Hydraulics	EHA
Hydrology	EHO
Design Branch:	
General Engineering	EGE
Drafting	EDD
Specifications & Estimating	ESP
Structural Design	EDS
Non-structural Design	EDN
Estimating	EDE
Project Management	EPM

Once the above information has been entered into "*CPM", an initial run can be made and the output can be checked for accuracy before starting Stage II. Figure 5.1-5 illustrates the initial output.
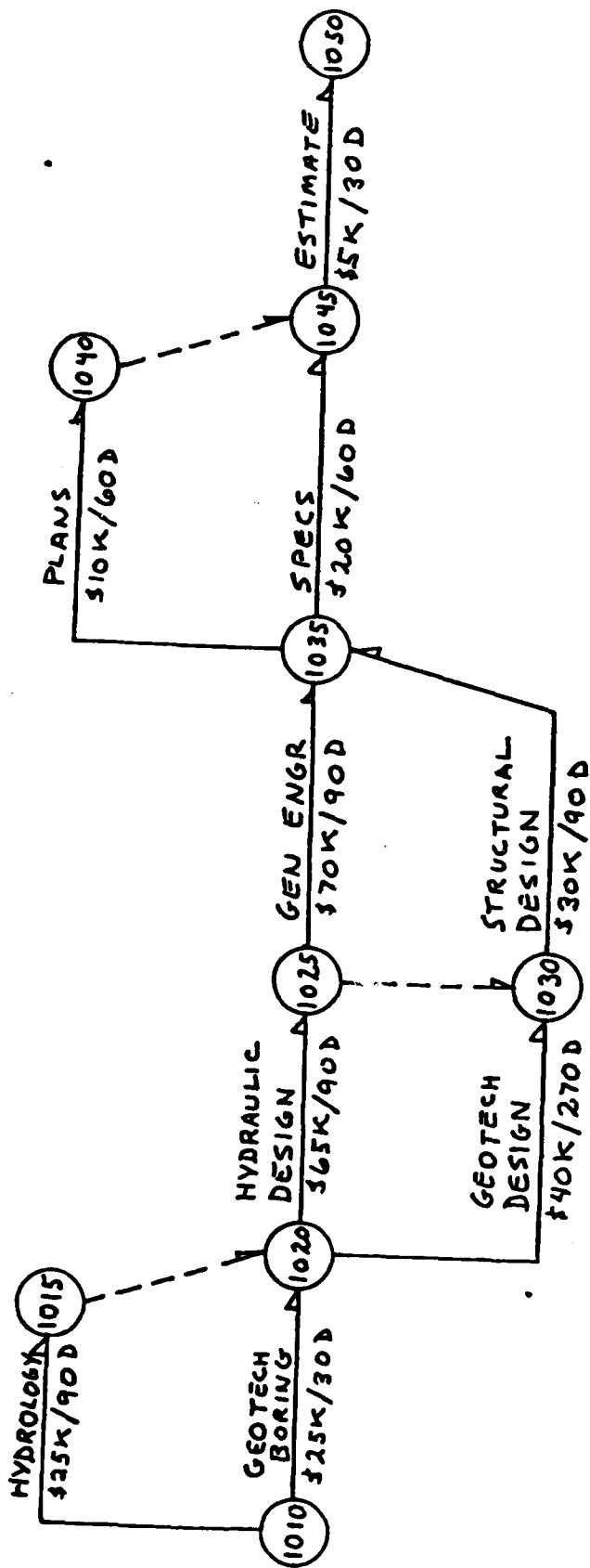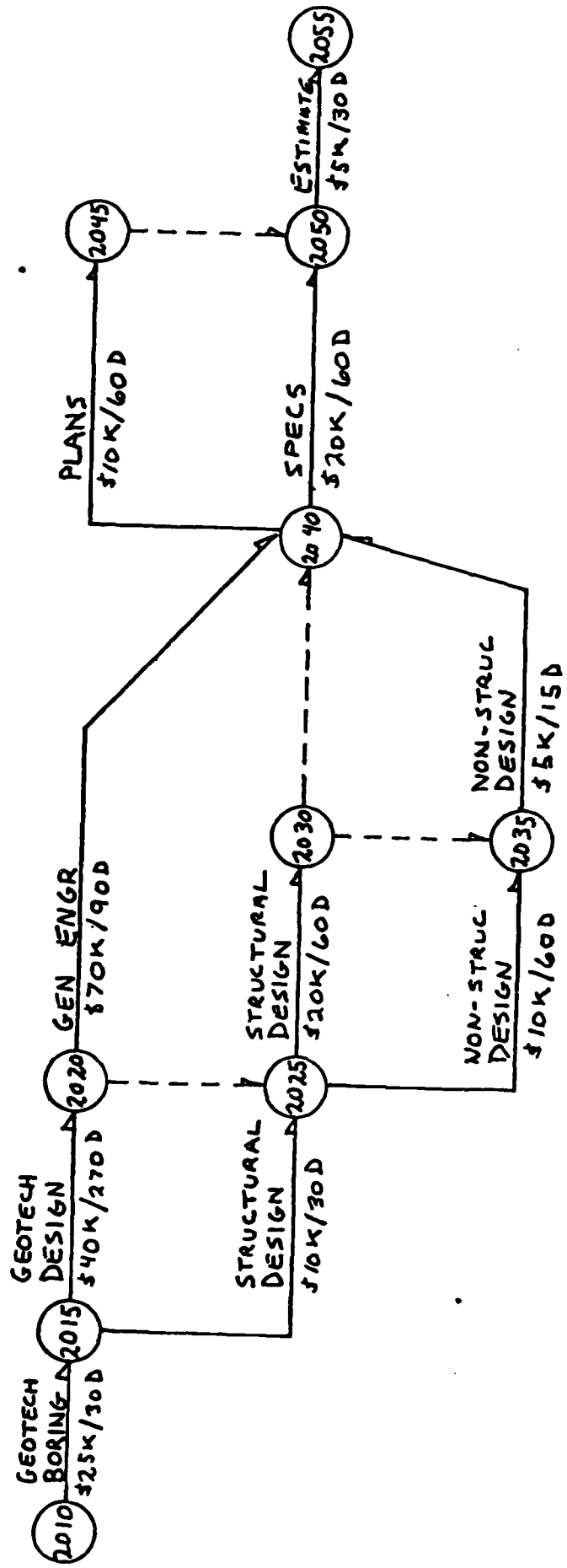
Figure 5.1-1 Network for Project AAA

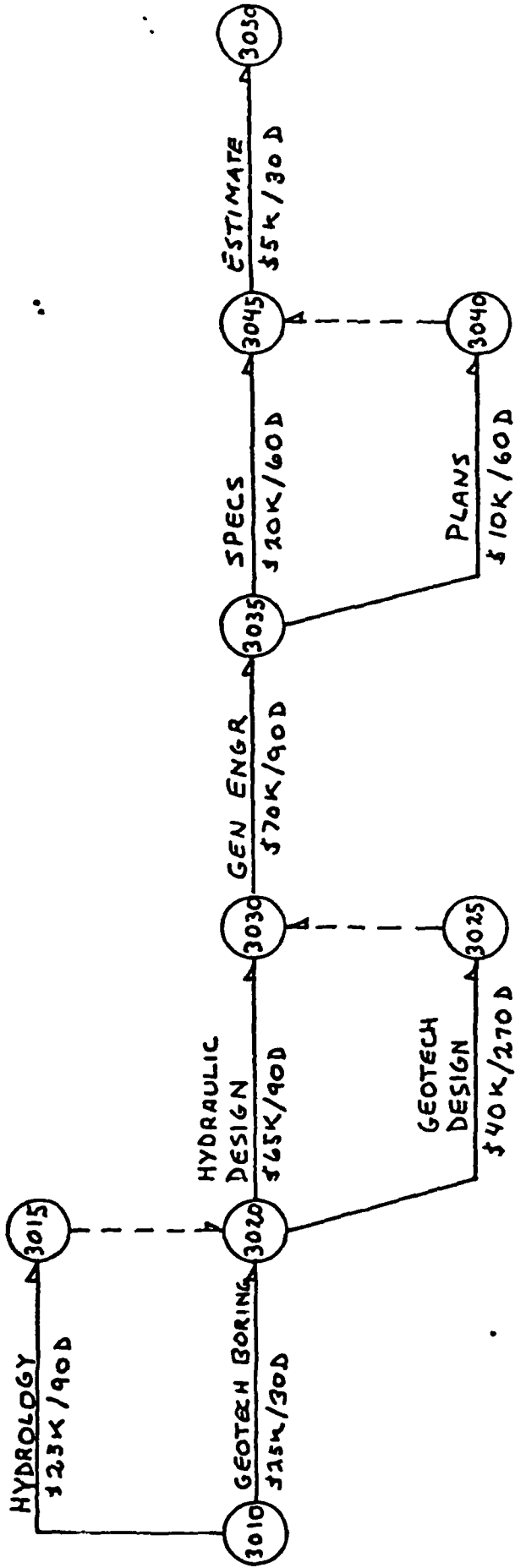19

Figure 5.1-2 Network for Project BBB

Figure 5.1-3 Network for Project CCC
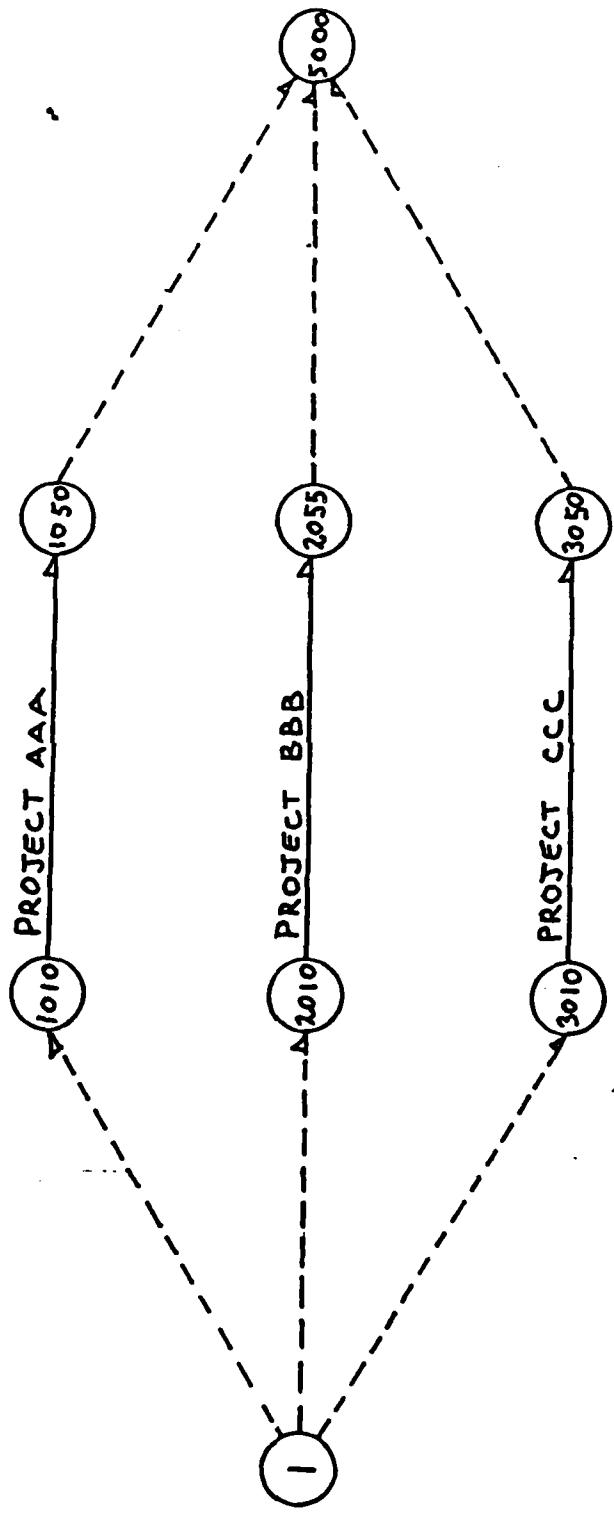
Figure 5.1-4 Master Network for All Projects

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REPORT EXAMPLE OUTPUT   11 MAR 83

THREE HYPOTHETICAL PROJECTS
ILLUSTRATES USE OF IMPSS ALGORITHM AND SAMPLE OUTPUTS

3   I-J SORT

EVENT I	J	DUR ATION	ACTIVITY DESCRIPTION	TOTAL COST	CURRENT COST	PCT COMP	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	SLACK	TOT REM
1	1010	0	D	0	0	0	1OCT83	1OCT83	1OCT83	1OCT83	0	0
1	2010	0	D	0	0	0	1OCT83	1OCT83	30NOV83	30NOV83	60	60
1	3010	0	D	0	0	0	1OCT83	1OCT83	1OCT83	1OCT83	0	0
1010	1015	90	AAA-EHO,HYDROLOGY	25000	0	0	1OCT83	30DEC83	1OCT83	30DEC83	0	0
1010	1020	30	AAA-EGB,GEOTECH BORING	25000	0	0	1OCT83	31OCT83	30NOV83	30DEC83	60	60
1015	1020	0	D	0	0	0	30DEC83	30DEC83	30DEC83	30DEC83	0	0
1020	1025	90	AAA-EHA,HYDRAULIC DESIGN	65000	0	0	30DEC83	29MAR84	27JUN84	25SEP84	180	180
1020	1030	270	AAA-EGD,GEOTECH DESIGN	40000	0	0	30DEC83	25SEP84	30DEC83	25SEP84	0	0
1025	1030	0	D	0	0	0	29MAR84	29MAR84	25SEP84	25SEP84	180	180
1025	1035	90	AAA-EGE,GENERAL ENGR	70000	0	0	29MAR84	27JUN84	25SEP84	24DEC84	180	180
1030	1035	90	AAA-EDS,STRUCTURAL DESIGN	30000	0	0	25SEP84	24DEC84	25SEP84	24DEC84	0	0
1035	1040	60	AAA-EDD,DRAFTING PLANS	10000	0	0	24DEC84	22FEB85	24DEC84	22FEB85	0	0
1035	1045	60	AAA-ESP,SPECS	20000	0	0	24DEC84	22FEB85	24DEC84	22FEB85	0	0
1040	1045	0	D	0	0	0	22FEB85	22FEB85	22FEB85	22FEB85	0	0
1045	1050	30	AAA-EDE,ESTIMATE	5000	0	0	22FEB85	24MAR85	22FEB85	24MAR85	0	0
1050	5000	0	D	0	0	0	24MAR85	24MAR85	24MAR85	24MAR85	0	0
2010	2015	30	BBB-EGB,GEOTECH BORING	25000	0	0	1OCT83	31OCT83	30NOV83	30DEC83	60	60
2015	2020	270	BBB-EGD,GEOTECH DESIGN	40000	0	0	31OCT83	27JUL84	30DEC83	25SEP84	60	60
2015	2025	30	BBB-EDS,STRUCTURAL DESIGN	10000	0	0	31OCT83	30NOV83	10SEP84	10OCT84	315	315
2020	2025	0	D	0	0	0	27JUL84	27JUL84	10OCT84	10OCT84	75	75
2020	2040	90	BBB-EGE,GENERAL ENGR	70000	0	0	27JUL84	25OCT84	25SEP84	24DEC84	60	60
2025	2030	60	BBB-EDS,STRUCTURAL DESIGN	20000	0	0	27JUL84	25SEP84	10OCT84	9DEC84	75	75
2025	2035	60	BBB-EDN,NONSTRUCTURAL DESIGN	10000	0	0	27JUL84	25SEP84	10OCT84	9DEC84	75	75
2030	2035	0	D	0	0	0	25SEP84	25SEP84	9DEC84	9DEC84	75	75
2030	2040	0	D	0	0	0	25SEP84	25SEP84	9DEC84	9DEC84	75	75
2035	2040	15	BBB-EDN,NONSTRUCTURAL DESIGN	5000	0	0	25SEP84	10OCT84	9DEC84	24DEC84	90	90
2040	2045	60	BBB-EDD,DRAFTING PLANS	10000	0	0	25OCT84	24DEC84	24DEC84	22FEB85	60	60
2040	2050	60	BBB-ESP,SPECS	20000	0	0	25OCT84	24DEC84	24DEC84	22FEB85	60	60
2045	2050	0	D	0	0	0	24DEC84	24DEC84	22FEB85	22FEB85	60	60
2050	2055	30	BBB-EDE,ESTIMATE	5000	0	0	24DEC84	23JAN85	22FEB85	24MAR85	60	60
2055	5000	0	D	0	0	0	23JAN85	23JAN85	24MAR85	24MAR85	60	60
3010	3015	90	CCC-EHO,HYDROLOGY	25000	0	0	1OCT83	30DEC83	1OCT83	30DEC83	0	0
3010	3020	30	CCC-EGB,GEOTECH BORING	25000	0	0	1OCT83	31OCT83	30NOV83	30DEC83	60	60
3015	3020	0	D	0	0	0	30DEC83	30DEC83	30DEC83	30DEC83	0	0
3020	3025	270	CCC-EGD,GEOTECH DESIGN	40000	0	0	30DEC83	25SEP84	30DEC83	25SEP84	0	0
3020	3030	90	CCC-EHA,HYDRAULIC DESIGN	65000	0	0	30DEC83	29MAR84	27JUN84	25SEP84	180	180
3025	3030	0	D	0	0	0	29MAR84	29MAR84	25SEP84	25SEP84	180	180
3030	3035	90	CCC-EGE,GENERAL ENGR	70000	0	0	25SEP84	24DEC84	25SEP84	24DEC84	0	0
3035	3040	60	CCC-EDD,DRAFTING PLANS	10000	0	0	24DEC84	22FEB85	24DEC84	22FEB85	0	0
3035	3045	60	CCC-ESP,SPECS	20000	0	0	24DEC84	22FEB85	24DEC84	22FEB85	0	0
3040	3045	0	D	0	0	0	22FEB85	22FEB85	22FEB85	22FEB85	0	0
3045	3050	30	CCC-EDE,ESTIMATE	5000	0	0	22FEB85	24MAR85	22FEB85	24MAR85	0	0
3050	5000	0	D	0	0	0	24MAR85	24MAR85	24MAR85	24MAR85	0	0

TOTAL COST OF WORK: 765000.
TOTAL COST OF WORK COMPLETED: 0.

# INDICATES ACTUAL START
INDICATES MILESTONE DATE

LATE START SORT

Figure 5.1-5: Initial IMPSS Output From *CPM

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5.2 Stage II Example:

If the initial output is accurate, the milestones, actual start dates, and percentages of completion for each activity can be added to constrain the network. The next run can then be made and its output analyzed for accuracy. Figure 5.2-1 shows the output of the second run.

If the initial output is accurate, it must then be determined if it is realistic. First, a check is made to ensure that all milestones can be met. Figure 5.2-1 shows that the milestones for activities (3030, 3035) and (3045, 3050) cannot be met. The network for Project CCC (Figure 5.1-3) shows that the duration of either activity (3010, 3015), (3020, 3025), or (3030, 3035) must be altered by a total of at least 54 days to meet the milestone. Discussions with each section chief reveal that the Hydrology Section can probably complete its activity in 80 days, Geotechnical Design can finish in 230 days, and General Engineering can finish in 85 days without adding to the project cost. (In other words, the initial duration estimates for Project CCC were fairly conservative, as would normally be expected.) The durations for these activities are then revised and another "*CPM" run is made. The output from that run, Figure 5.2-2, shows that all milestones can now be met. Because the output appears to be realistic, the graphics options are run, and Figures 5.2-3 and 5.2-4 are produced.

5.3 Stage III Example:

The resource histogram shows three distinct peaks (critical periods). The first occurs from 1 October 1983 to 30 October 1983. The second spans the period from 17 January 1984 to 15 March 1984, and the third runs from 1 August 1984 to 31 October 1984. The first attempt at leveling should be without regard to any particular resource amount (R_{max}). Using the Gantt Chart, activities which are ongoing during each critical period are identified. Those which have slack are listed in following table.

Table 5.3-1 Activities With Slack

Period	Activity	Slack (Days)	Resources ($/Day)
1 Oct–30 Oct 83	AAA–EGB Geotech Boring	60	833
	BBB–EGB Geotech Boring	60	833
	CCC–EHO Hydrology	55	312
	CCC–EGB Geotech Boring	105	833
17 Jan 84–15 Mar 84	AAA–EHA Hydraulic Design	180	722
	CCC–EHA Hydraulic Design	195	722
1 Aug 84–31 Oct 84	BBB–EGE General Engineering	60	777
	BBB–EDS Struc. Design	75	333
	BBB–EDN Nonstruc. Design	75	166
	BBB–EDN Nonstruc. Design	75	333
	CCC–EGD Geotech. Design	55	174

I-J SORT

3

REPORT EXAMPLE OUTPUT   11 MAR 83

UPDATE AS OF 10 383

THREE HYPOTHETICAL PROJECTS
ILLUSTRATES USE OF IMPSS ALGORITHM AND SAMPLE OUTPUTS

EVENT I	J	DUR ATION	ACTIVITY DESCRIPTION	TOTAL COST	CURRENT COST	PCT COMP	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	SLACK TOT	REM
1	1010	0	D	0.	0.	0.	1OCT83	1OCT83	1OCT83	1OCT83	0	0
1	2010	0	D	0.	0.	0.	1OCT83	1OCT83	30NOV83	30NOV83	60	60
1	3010	0	D	0.	0.	0.	1OCT83	1OCT83	1OCT83	1OCT83	0	0
1010	1015	90	AAA-EHO,HYDROLOGY	25000.	0.	0.	1OCT83#	30DEC83	1OCT83#	30DEC83	60	60
1010	1020	30	AAA-EGB,GEOTECH BORING	25000.	0.	0.	1OCT83#	31OCT83	1OCT83#	30DEC83	60	60
1015	1020	0	D	65000.	0.	0.	30DEC83	30DEC83	30DEC83	30DEC83	0	0
1020	1025	90	AAA-EHA,HYDRAULIC DESIGN	40000.	0.	0.	30DEC83	29MAR84	27JUN84	25SEP84	180	180
1020	1030	270	AAA-EGD,GEOTECH DESIGN	70000.	0.	0.	29MAR84	29MAR84	30DEC83	25SEP84	180	180
1025	1030	0	D	70000.	0.	0.	29MAR84	27JUN84	25SEP84	25SEP84	180	180
1025	1035	90	AAA-EGE,GENERAL ENGR	30000.	0.	0.	25SEP84	24DEC84	25SEP84	24DEC84	180	180
1030	1035	90	AAA-EIS,STRUCTURAL DESIGN	10000.	0.	0.	24DEC84	24DEC84	24DEC84	24DEC84	0	0
1035	1040	60	AAA-EID,DRAFTING PLANS	20000.	0.	0.	24DEC84	22FEB85	24DEC84	22FEB85	0	0
1035	1045	60	AAA-ESP,SPECS	0.	0.	0.	22FEB85	22FEB85	22FEB85	22FEB85	0	0
1040	1045	0	D	5000.	0.	0.	22FEB85	22FEB85	22FEB85	22FEB85	0	0
1045	1050	30	AAA-EDE,ESTIMATE	0.	0.	0.	24MAR85	24MAR85	24MAR85	24MAR85	0	0
1050	5000	0	D	25000.	0.	0.	1OCT83#	31OCT83	1OCT83#	30DEC83	60	60
2010	2015	30	BBB-EGB,GEOTECH BORING	40000.	0.	0.	31OCT83	27JUL84	31OCT83	25SEP84	60	60
2015	2020	270	BBB-EGD,GEOTECH DESIGN	10000.	0.	0.	31OCT83	30NOV83	16SEP84	16OCT84	315	315
2015	2025	30	BBB-EDS,STRUCTURAL DESIGN	0.	0.	0.	27JUL84	27JUL84	16OCT84	16OCT84	75	75
2020	2025	0	D	70000.	0.	0.	27JUL84	25OCT84	16OCT84	9DEC84	60	60
2020	2030	90	BBB-EGE,GENERAL ENGR	20000.	0.	0.	27JUL84	25SEP84	16OCT84	9DEC84	75	75
2025	2030	60	BBB-EDS,STRUCTURAL DESIGN	10000.	0.	0.	25SEP84	25SEP84	9DEC84	9DEC84	75	75
2025	2035	60	BBB-EDN,NONSTRUCTURAL DESIGN	0.	0.	0.	25SEP84	25SEP84	9DEC84	9DEC84	75	75
2030	2035	0	D	5000.	0.	0.	25SEP84	10OCT84	9DEC84	24DEC84	90	90
2030	2040	0	D	10000.	0.	0.	25OCT84	24DEC84	9DEC84	24DEC84	75	75
2035	2040	15	BBB-EDN,NONSTRUCTURAL DESIGN	20000.	0.	0.	25OCT84	24DEC84	24DEC84	24DEC84	60	60
2040	2045	60	BBB-EDD,DRAFTING PLANS	0.	0.	0.	24DEC84	24DEC84	24DEC84	22FEB85	60	60
2040	2050	60	BBB-ESP,SPECS	5000.	0.	0.	24DEC84	23JAN85	22FEB85	22FEB85	60	60
2045	2050	0	D	25000.	0.	0.	23JAN85	23JAN85	24MAR85	24MAR85	60	60
2050	2055	30	BBB-EDE,ESTIMATE	25000.	0.	0.	1OCT83#	30DEC83	1OCT83#	30DEC83	0	0
2055	5000	0	D	40000.	0.	0.	1OCT83#	31OCT83	1OCT83#	30DEC83	60	60
3010	3015	90	CCC-EHO,HYDROLOGY	65000.	0.	0.	30DEC83	30DEC83	30DEC83	30DEC83	0	0
3010	3020	30	CCC-EGB,GEOTECH BORING		0.	0.	30DEC83	29MAR84	27JUN84	25SEP84	180	180
3015	3020	0	D		0.	0.	25SEP84	25SEP84	25SEP84	25SEP84	0	0
3020	3025	270	CCC-EGD,GEOTECH DESIGN									
3020	3030	90	CCC-EHA,HYDRAULIC DESIGN									
3025	3030	0	D									

*** WARNING *** THE FOLLOWING MILESTONE CANNOT BE MET:

3030	3035	90	CCC-EGE,GENERAL ENGR	70000.	0.	0.	25SEP84	31OCT84##	25SEP84	31OCT84##	-54	0
3035	3040	60	CCC-EID,DRAFTING PLANS	10000.	0.	0.	24DEC84	22FEB85	24DEC84	22FEB85	0	0
3035	3045	60	CCC-ESP,SPECS	20000.	0.	0.	24DEC84	22FEB85	24DEC84	22FEB85	0	0
3040	3045	0	D	0.	0.	0.	22FEB85	22FEB85	22FEB85	22FEB85	0	0

*** WARNING *** THE FOLLOWING MILESTONE CANNOT BE MET:

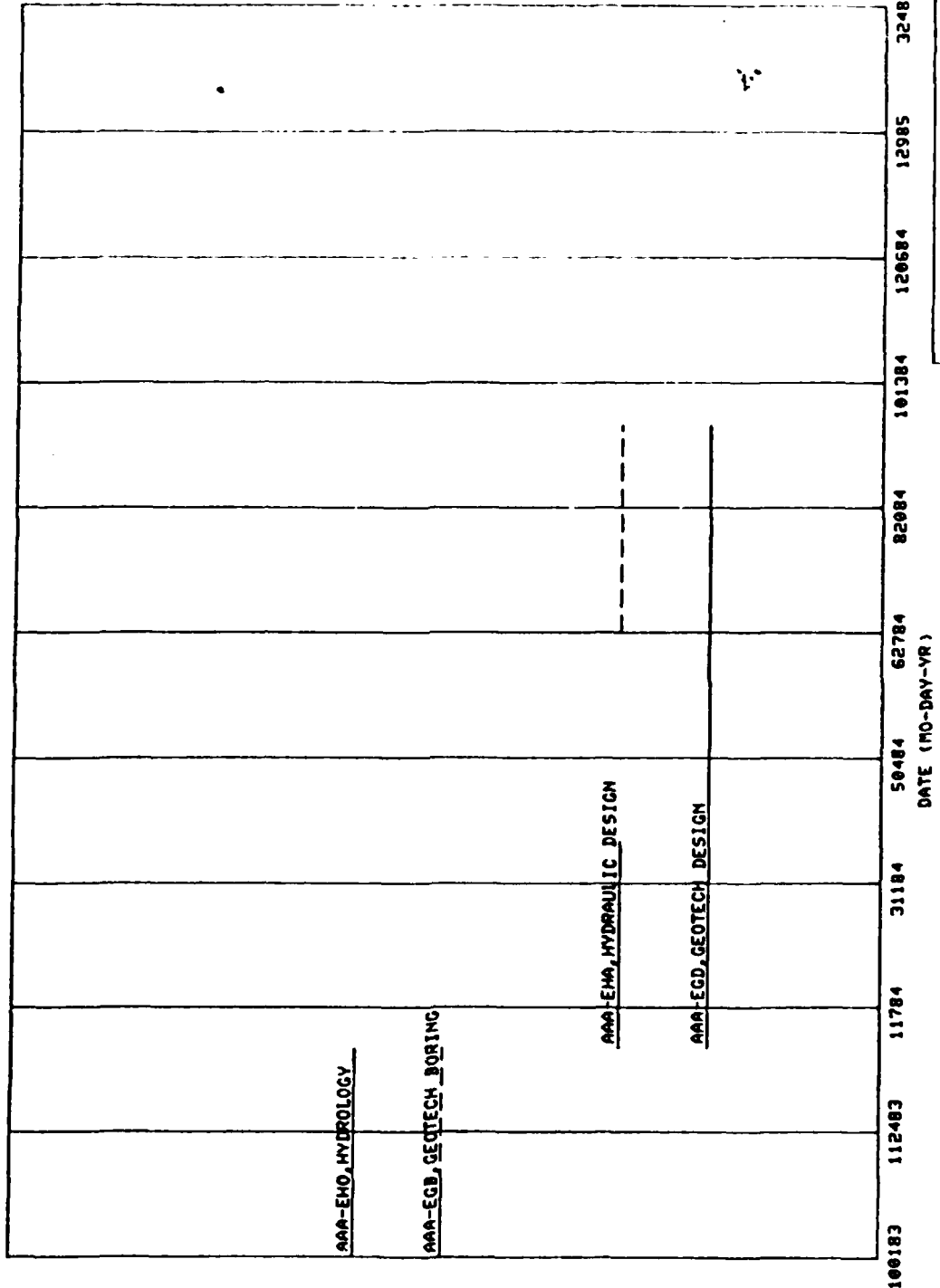| 3045 | 3050 | 30 | CCC-EDE,ESTIMATE | 5000. | 0. | 0. | 22FEB85 | 31JAN85## | 22FEB85 | 31JAN85## | -52 | 0 |
| 3050 | 5000 | 0 | D | 0. | 0. | 0. | 24MAR85 | 24MAR85 | 24MAR85 | 24MAR85 | 0 | 0 |

TOTAL COST OF WORK: 765000.
TOTAL COST OF WORK COMPLETED: 0.

# INDICATES ACTUAL START
INDICATES MILESTONE DATE
EOT..

Figure 5.2-1: Output of Second *CPM Run With Milestones
And Actual Start Date Included

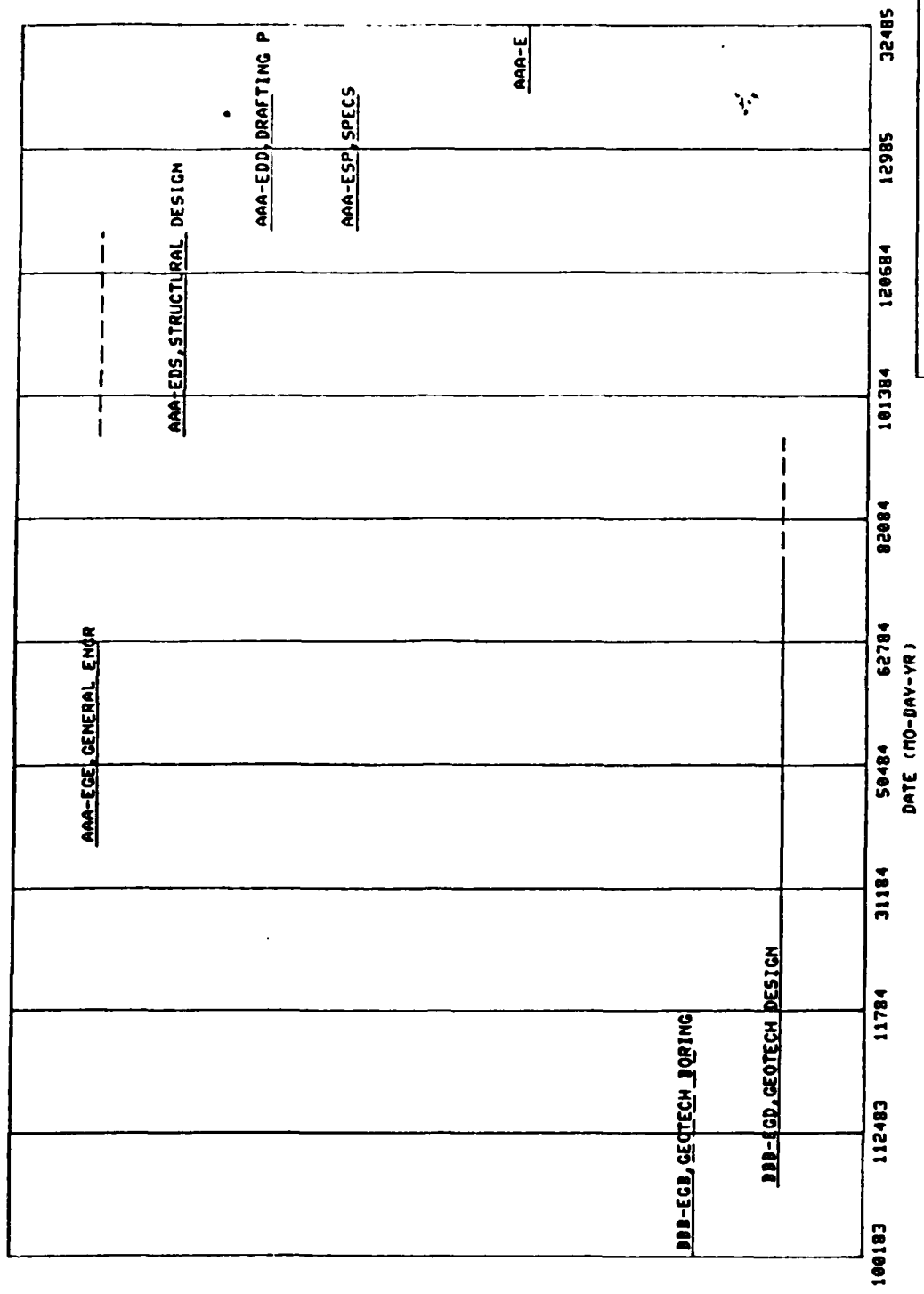DI.SAMPLE2
1
I-J SORT
1   UPDATE AS OF 10 383

REPORT EXAMPLE OUTPUT   11 MAR 83
THREE HYPOTHETICAL PROJECTS
ILLUSTRATES USE OF IMPSS ALGORITHM AND SAMPLE OUTPUTS

I-J SORT
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EVENT I	J	DURATION	ACTIVITY DESCRIPTION	TOTAL COST	CURRENT COST	PCT COMP	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	SLACK TOT REM
1	1010	0	D	0.	0.	0.	1OCT83	1OCT83	1OCT83	1OCT83	0
1	2010	0	D	0.	0.	0.	1OCT83	1OCT83	30NOV83	30NOV83	60
1	3010	0	D	0.	0.	0.	1OCT83	1OCT83	25NOV83	25NOV83	55
1010	1015	90	AAA-EHO,HYDROLOGY	25000.	0.	0.	1OCT83*	30DEC83	1OCT83*	30DEC83	0
1010	1020	30	AAA-EGB,GEOTECH BORING	25000.	0.	0.	1OCT83*	31DEC83	1OCT83*	30DEC83	60
1015	1020	0		0.	0.	0.	30DEC83	30DEC83	30DEC83	30DEC83	0
1020	1025	90	AAA-EHA,HYDRAULIC DESIGN	65000.	0.	0.	30DEC83	29MAR84	27JUN84	25SEP84	180
1020	1030	270	AAA-EGD,GEOTECH DESIGN	40000.	0.	0.	30DEC83	25SEP84	30DEC83	25SEP84	0
1025	1030	0		0.	0.	0.	29MAR84	29MAR84	25SEP84	25SEP84	180
1025	1035	90	AAA-EGE,GENERAL ENGR	70000.	0.	0.	29MAR84	27JUN84	25SEP84	24DEC84	180
1030	1035	90	AAA-EDS,STRUCTURAL DESIGN	30000.	0.	0.	25SEP84	24DEC84	25SEP84	24DEC84	0
1035	1040	60	AAA-EDD,DRAFTING PLANS	10000.	0.	0.	24DEC84	22FEB85	24DEC84	22FEB85	0
1035	1045	60	AAA-ESP,SPECS	20000.	0.	0.	24DEC84	22FEB85	24DEC84	22FEB85	0
1040	1045	0		0.	0.	0.	22FEB85	22FEB85	22FEB85	22FEB85	0
1045	1050	0	D	0.	0.	0.	22FEB85	22FEB85	22FEB85	22FEB85	0
1050	5000	30	AAA-EDE,ESTIMATE	5000.	0.	0.	24MAR85	24MAR85	24MAR85	24MAR85	0
2010	2015	30	BBB-EGB,GEOTECH BORING	25000.	0.	0.	1OCT83*	31OCT83	1OCT83*	30DEC83	60
2015	2020	270	BBB-EGD,GEOTECH DESIGN	40000.	0.	0.	31OCT83	27JUL84	30DEC83	25SEP84	60
2015	2025	30	BBB-EDS,STRUCTURAL DESIGN	10000.	0.	0.	31OCT83	30NOV83	19SEP84	10OCT84	315
2020	2025	0	D	0.	0.	0.	27JUL84	27JUL84	10OCT84	10OCT84	75
2020	2040	90	BBB-EGE,GENERAL ENGR	70000.	0.	0.	27JUL84	25OCT84	25SEP84	24DEC84	60
2025	2030	60	BBB-EDS,STRUCTURAL DESIGN	20000.	0.	0.	27JUL84	25SEP84	10OCT84	9DEC84	75
2025	2035	60	BBB-EDN,NONSTRUCTURAL DESIGN	10000.	0.	0.	27JUL84	25SEP84	10OCT84	9DEC84	75
2030	2035	0	D	0.	0.	0.	25SEP84	25SEP84	9DEC84	9DEC84	75
2030	2040	0	D	0.	0.	0.	25SEP84	25SEP84	24DEC84	24DEC84	90
2035	2040	15	BBB-EDN,NONSTRUCTURAL DESIGN	5000.	0.	0.	25SEP84	10OCT84	9DEC84	24DEC84	75
2040	2045	60	BBB-EDD,DRAFTING PLANS	10000.	0.	0.	25OCT84	24DEC84	24DEC84	22FEB85	60
2045	2050	60	BBB-ESP,SPECS	20000.	0.	0.	25OCT84	24DEC84	24DEC84	22FEB85	60
2050	2055	0	D	0.	0.	0.	24DEC84	24DEC84	22FEB85	22FEB85	60
2055	5000	30	BBB-EDE,ESTIMATE	5000.	0.	0.	23JAN85	23JAN85	24MAR85	24MAR85	60
3010	3015	80	CCC-EHO,HYDROLOGY	25000.	0.	0.	1OCT83*	20DEC83	1OCT83*	13FEB84	55
3010	3020	30	CCC-EGB,GEOTECH BORING	25000.	0.	0.	1OCT83*	31OCT83	1OCT83*	13FEB84	105
3015	3020	0	D	0.	0.	0.	20DEC83	20DEC83	13FEB84	13FEB84	55
3020	3025	230	CCC-EGD,GEOTECH DESIGN	40000.	0.	0.	20DEC83	6AUG84	13FEB84	30SEP84	55
3020	3030	90	CCC-EHA,HYDRAULIC DESIGN	65000.	0.	0.	20DEC83	19MAR84	2JUL84	30SEP84	195
3025	3030	0	D	0.	0.	0.	6AUG84	6AUG84	30SEP84	30SEP84	55
3030	3035	85	CCC-EGE,GENERAL ENGR	70000.	0.	0.	6AUG84	30OCT84	30SEP84	31OCT84**	54
3035	3040	60	CCC-EDD,DRAFTING PLANS	10000.	0.	0.	30OCT84	29DEC84	24DEC84	22FEB85	55
3035	3045	0	CCC-ESP,SPECS	20000.	0.	0.	30OCT84	29DEC84	24DEC84	22FEB85	55
3040	3045	30	D	0.	0.	0.	29DEC84	29DEC84	22FEB85	22FEB85	55
3045	3050	30	D	5000.	0.	0.	29DEC84	28JAN85	22FEB85	31JAN85**	52
3050	5000		D		0.	0.	28JAN85	28JAN85	24MAR85	24MAR85	55

TOTAL COST OF WORK: 765000.
TOTAL COST OF WORK COMPLETED: 0.

* INDICATES ACTUAL START
** INDICATES MILESTONE DATE
EOT..

Figure 5.2-2: Output After Durations Have Been Changed to
Allow Milestones to be Met

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Figure 5.2-3 (Page 1): Gantt Chart

Figure 5.2-3 (Page 2): Gantt Chart
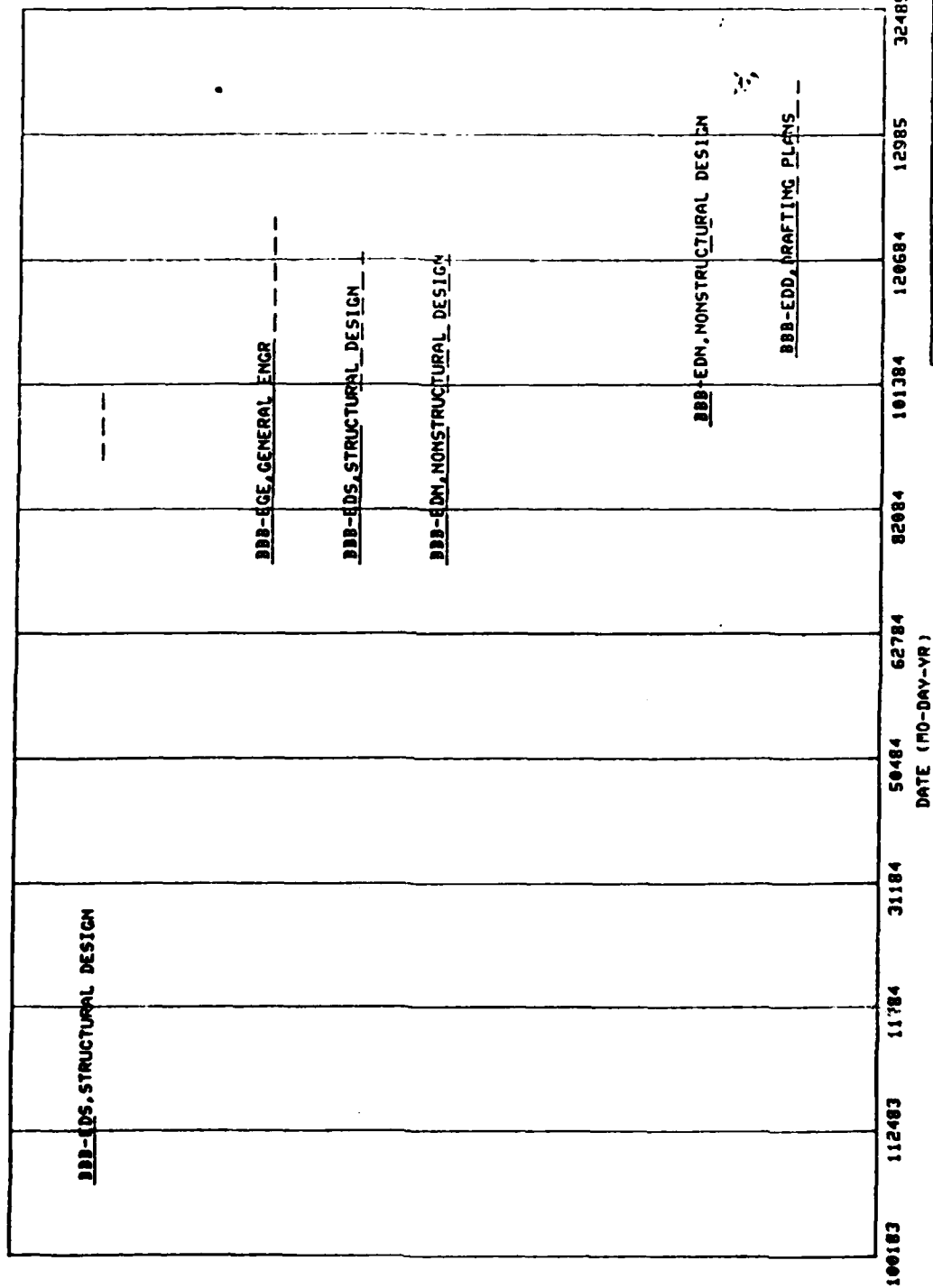
28

Figure 5.2-3 (Page 3): Gantt Chart
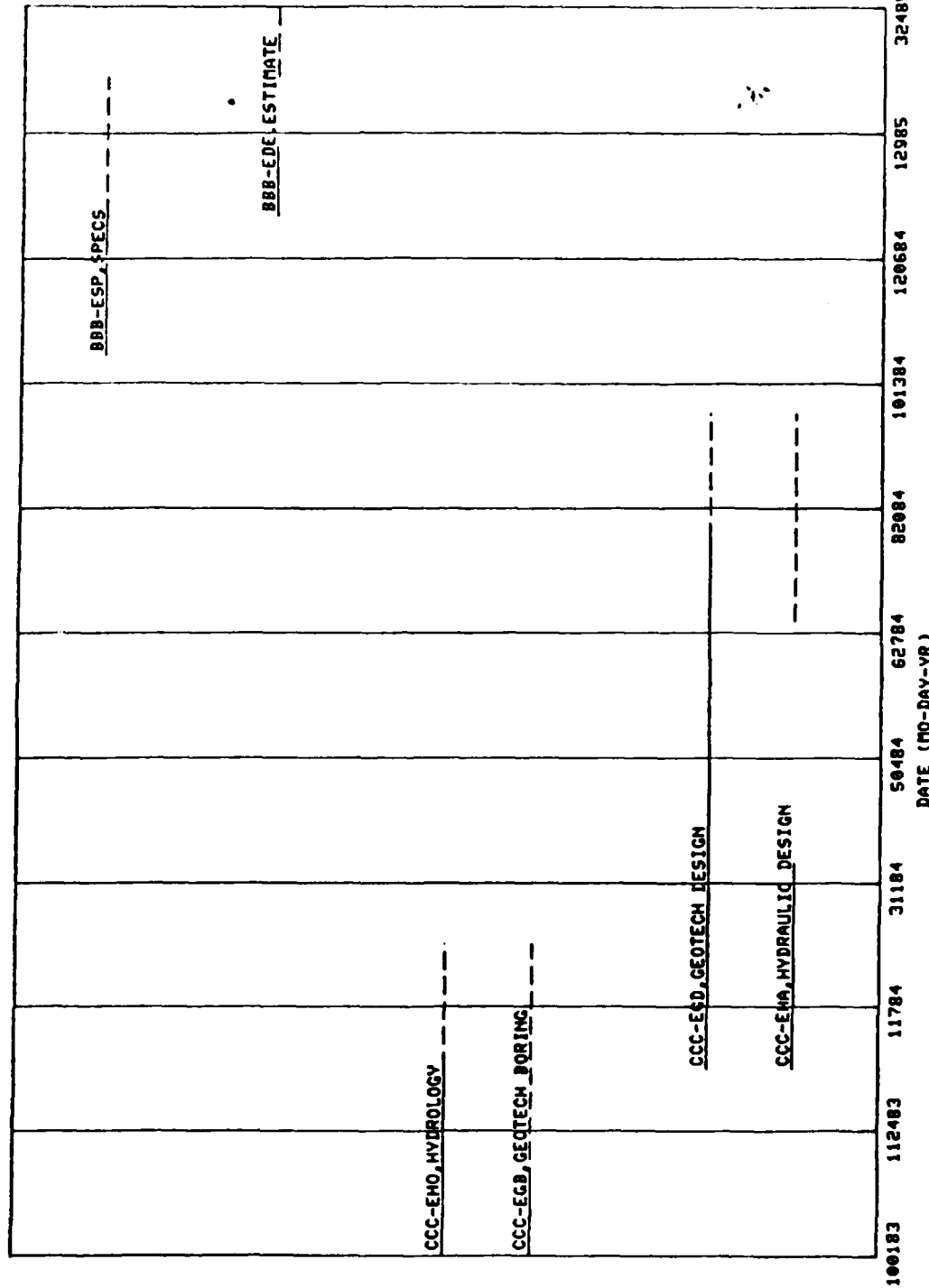
BBB-EDS,STRUCTURAL DESIGN

BBB-EGE,GENERAL ENGR
BBB-EDS,STRUCTURAL DESIGN
BBB-EDM,NONSTRUCTURAL DESIGN

BBB-EDM,NONSTRUCTURAL DESIGN
BBB-EDD,DRAFTING PLANS

100183 112483 11384 31184 50484 62784 82084 101384 120684 12985 32485
DATE (MO-DAY-YR)

REPORT EXAMPLE OUTPUT   11 MAR 83
THREE HYPOTHETICAL PROJECTS
ILLUSTRATES USE OF IMPSS ALGORITHM
PLOT FILE IS BARGRAM2
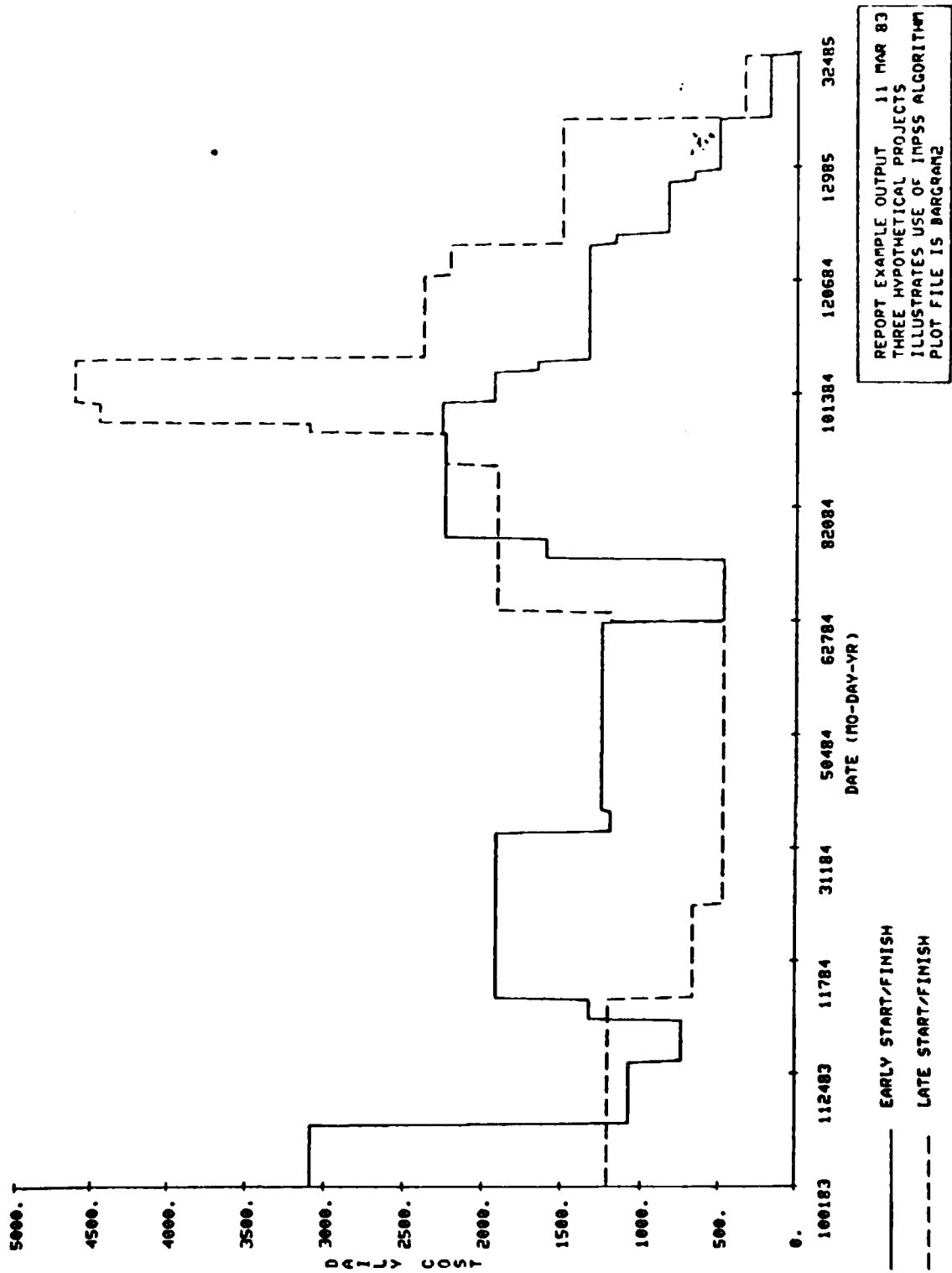
Figure 5.2-3 (Page 4): Gantt Chart

REPORT EXAMPLE OUTPUT   11 MAR 83
THREE HYPOTHETICAL PROJECTS
ILLUSTRATES USE OF IMPSS ALGORITHM
PLOT FILE IS BARGRAM2

30

CCC-EGE,GENERAL ENGR

CCC-EDD DRAFTING PLANS

CCC-ESP SPECS — —

CCC-EDE ESTIMATE

DATE (MO-DAY-YR)

100183   112483   11784   31184   50484   62784   82084   101384   120684   12985   32485

Figure 5.2-3 (Page 5): Gantt Chart

Figure 5.2-4: Resource Histogram

At this point, a system limitation concerning slack must be remembered. Because the projects are tied together with artificial dummies at the beginning and end, the criterion for determining critical activities within a single project changes from activities with zero slack to those with the least amount of slack within the project. Therefore, activities BBB-EGE, CCC-EGD, CCC-EHO, and CCC-EGB are critical and should be removed from initial consideration during resource leveling.

On the basis of analysis of the output, the following changes will be made during the first attempt to level resource requirements:

   a. Schedule activity CCC-EGB, Geotech Boring (3010, 3020) to start on 31 Oct 83.

   b. Schedule activity AAA-EGB, Geotech Boring, (1010, 1020) to start on 30 Nov 83.

   c. Schedule activity AAA-EHA, Hydraulic Design (1020, 1025) to start on 1 Apr 84.

   d. Schedule activity BBB-EDS, Structural Design, (2025, 2030) to start on 10 Oct 84.

   e. Schedule activity BBB-EDN, Nonstructural Design, (2025, 2035) to start on 10 Oct 84.

   f. Schedule activity BBB-EDN, Nonstructural Design (2025-2040) to start on 9 Dec 84.

5.4 Stage IV Example:

After entering these changes, another run can be made and another Gantt Chart and resource histogram produced. The histogram, Figure 5.4-1, shows that, while the resource requirements are more level, there are still two critical periods--31 October 1983 to 30 December 1983 and 27 July 1984 to 30 October 1984. Again using the Gantt Chart to identify activities with slack during those critical periods, a decision to schedule activity BBB-EDS, Structural Design (2015, 2025) to start on 19 March 1984 is made to flatten the first peak. The second peak is caused by a bottleneck in the General Engineering Section. The decision to contract out activities AAA-EGE (1025-1035) and AAA-EDS (1030-1035) is made. These changes produce Figure 5.4-2.

Setting R_{max}=\$1,750/day and plotting that line on the histogram reveals two new critical periods. The first is from 20 December 1983 to 30 December 1983. Analysis of the Gantt Chart shows that the peak is caused by a bottleneck in the Hydrology Section. Because the period is only 10 days long, it can probably be discounted or a decision could be made to shift funds to allow overtime to be worked during that period. The second peak is from 25 September 1984 to 25 October 1984 and is primarily the result of the General Engineering Section's workload. This problem can only be solved by allowing the completion date for either Project BBB or
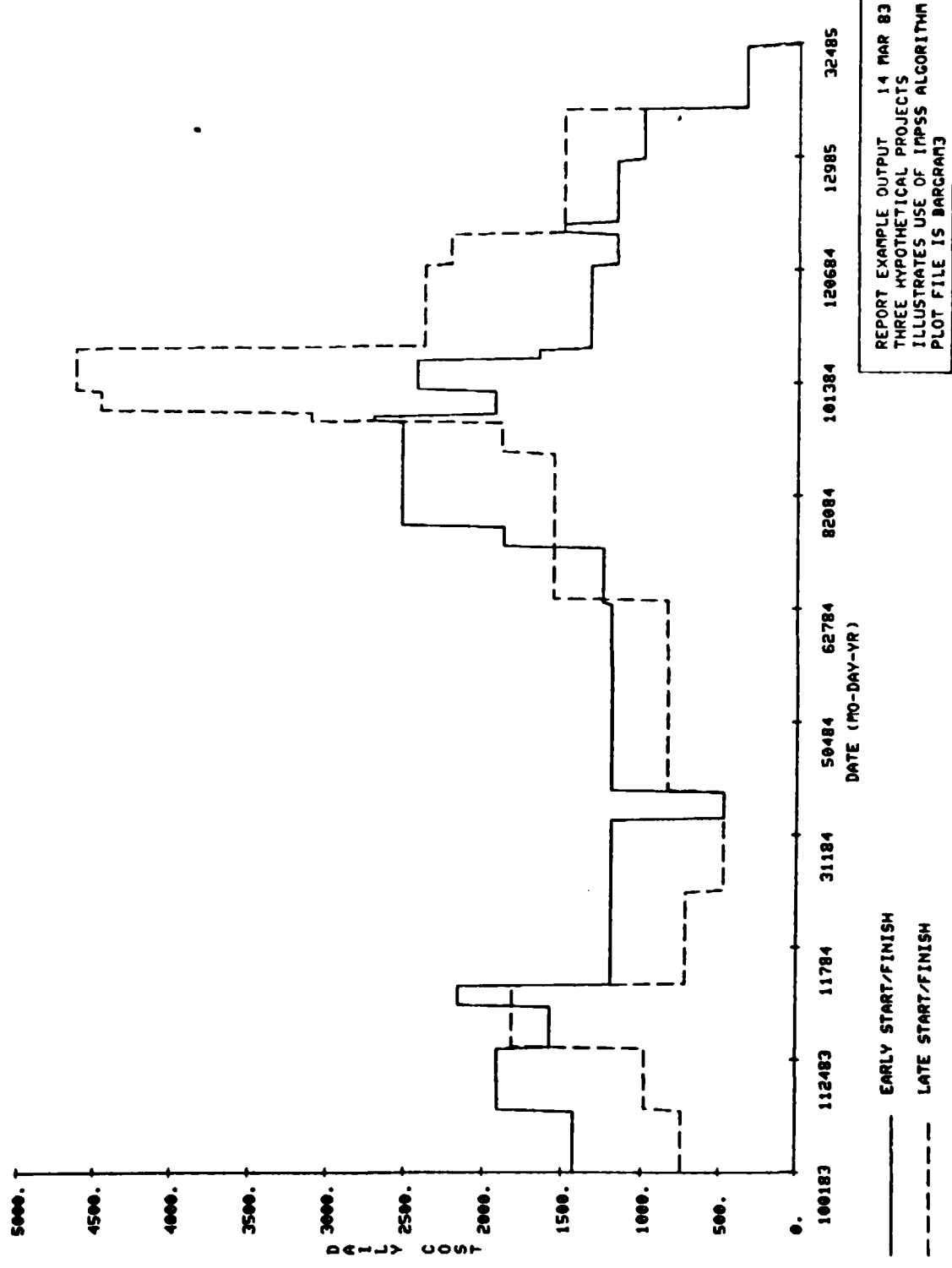
33

REPORT EXAMPLE OUTPUT   14 MAR 83
THREE HYPOTHETICAL PROJECTS
ILLUSTRATES USE OF IMPSS ALGORITHM
PLOT FILE IS BARGRAM3

——— EARLY START/FINISH

— — — LATE START/FINISH

DAILY COST

DATE (MO-DAY-YR)

100183 112483 11784 31184 50484 62784 82084 101384 120684 12985 32485

5000. 4500. 4000. 3500. 3000. 2500. 2000. 1500. 1000. 500. 0.

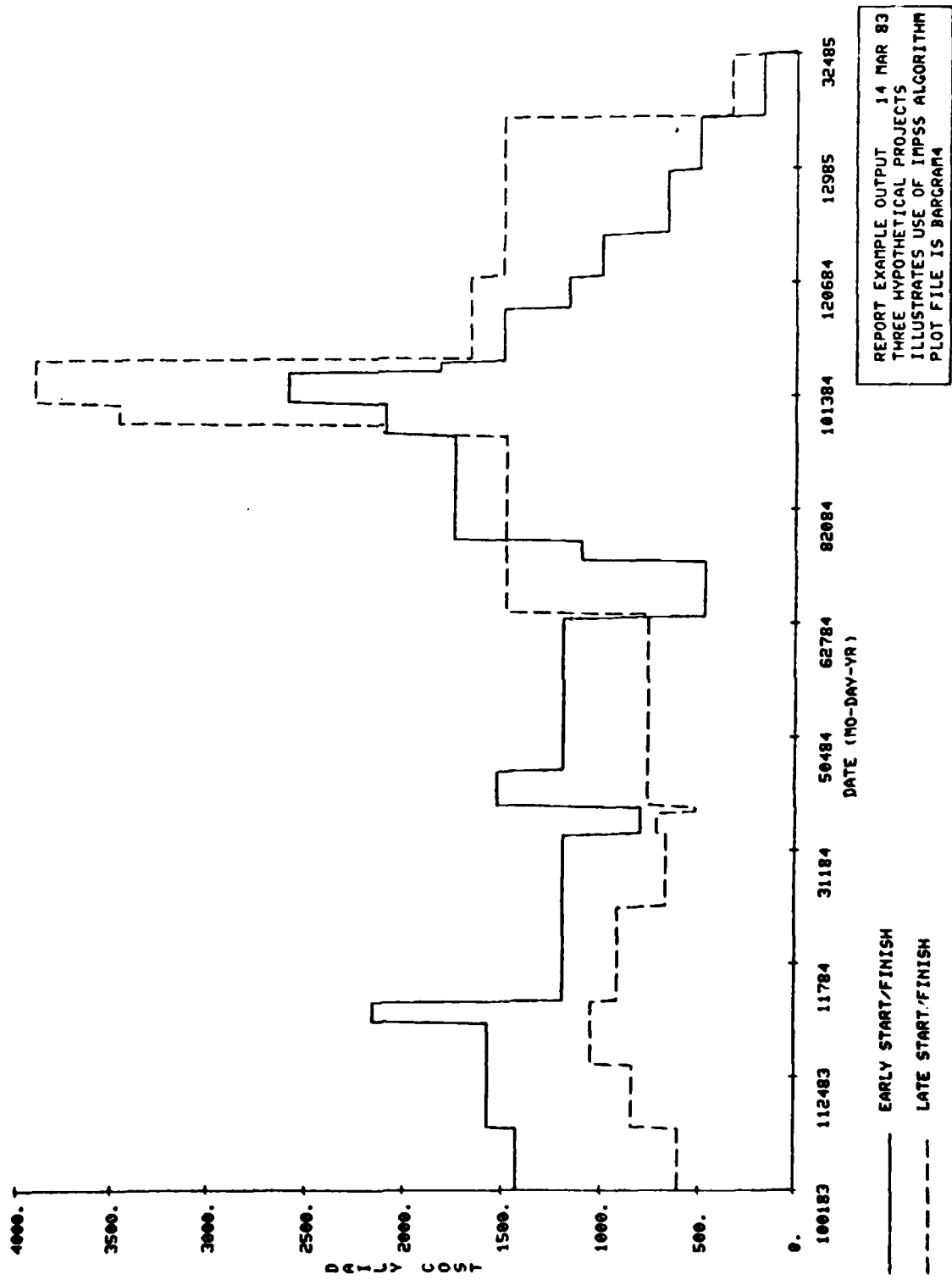Figure 5.4-1: Resource Histogram After First Attempt at Leveling

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Figure 5.4-2: Resource Histogram After Second Attempt at Leveling

Project CCC to be slipped by 60 days.

5.5 <u>Stage V Example</u>:

Further iterations of the system must be made until the corporate body is
satisfied with the output. Additionally, iterations can be made to
illustrate various alternatives for decision making. Once a satisfactory
product is achieved, a final run of "*CPM" can be made to produce the
graphics required to illustrate the wishes of the decision-makers. This
is the point in the process where the search options of "*CPM" would most
likely be used to produce charts and tables for each functional area and
project.

6. Conclusions:

The example in section 5 and a similar test of IMPSS using three real projects demonstrated this system's potential for providing a viable solution to the problem of integrated, multiple-project scheduling. The key to maximizing the value of this system is the human factor in the decision-making process. If project managers do a reasonable job of developing project networks and input data, the mathematical model built by IMPSS will be of sufficient quality to allow the executive group to make intelligent decisions. The system's ability to handle 30 projects (the anticipated load for IMPSS) is yet to be demonstrated. However, the system does have the capacity for that number of projects, and though analysis will no doubt become tedious, there is no reason why it cannot be properly carried out. Therefore, the system as presented in this report should be considered as the best available solution to the problem of scheduling multiple projects within the St. Paul District.

7. Recommendations:

The following recommendations are made:

    a. Consider adopting IMPSS as the base for making project scheduling decisions for fiscal year 1984.

    b. Schedule a short course on IMPSS input development for project managers no later than 1 May 1983.

    c. Schedule a short course on IMPSS output interpretation for functional area managers and their supervisors no later than 1 July 1983.

    d. Establish and support a suspense date of 1 June 1983 for completion of all input for the first full-scale fun of IMPSS.

Appendix A

Abbreviations and Definitions

A/E: Architect/Engineer

Algorithm: A set of rules for solving a problem in a finite number of steps.

Bar Chart: A scaled, graphical representation of a schedule.

CPM: Critical Path Method.

CRT: Cathode Ray Tube.

EF: Early Finish - The earliest time an activity can be completed.

ES: Early Start - The earliest time an activity can be started.

Gantt Chart: A bar chart which shows slack.

Heuristics: A set of rules which serve to indicate the arrival at a desired solution.

Histogram: A graph of frequency distribution.

I Number: The event number at the tail of an activity arrow.

IMPSS: Integrated Multiple Project Scheduling System.

J Number: The event number at the head of an activity arrow.

LF: Late Start - the latest time an activity can be finished.

LS: Late Start - the latest time an activity can be started.

Milestone: The date on which an activity must be completed.

Precedence Networking: A system of networking, similar to CPM, which allows activities to overlap.

RA/PM: Resource Allocation/Project Management.

RS: Remaining Slack - the amount of slack remaining in an activity after it has actually been started.

Software: A computer program.

Sort: An organization of data in a specific format.

TS: Total Slack, the difference between the LF and EF of an activity.

"*CPM": A canned program used with IMPSS.

Appendix B

Sample Form for Input and Updating

The following page is a sample form which can be used to organize the
required input for each individual project. These forms could constitute
the bulk of a periodic report from project managers which would be used
to update the master network.

Project Input for IMPSS

Project:_____   Project Manager:_____

				(Network Sketch)		As of Date:	
		Cost	Dur	Description Codes	Milestone	Actual Start	%
I	J	($)	(Days)	(Proj-Org)	(MMDDYY)	(MMDDYY)	Complete

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