APCRP

AQUATIC PLANT CONTROL RESEARCH PROGRAM

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

TECHNICAL REPORT A-82-1

SIMULATION FOR HARVESTING OF AQUATIC PLANTS

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This report describes a computer program entitled "Simulation for Harvesting of Aquatic Plants (SHAP)," and provides instructions and guidelines in planning for mechanical harvesting of plant-infested areas. The model provides a stochastic simulation that evaluates the harvesting system. SHAP utilizes linear programming theory for network flow analysis and queuing theory and is designed for using minimal input data in a conversational manner; that is, the

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20. ABSTRACT (Continued).

user interacts directly with the program and receives output immediately. The model has been verified using field data collection records.

The terrain subroutine organizes irregularly shaped plant-infested areas to be harvested into a distance-flow network (grid). The harvesting subroutine directs the harvesting procedure. The harvester (Aqua-Trio Equipment Co.) mows the aquatic plants; the transporter loads the plants and takes them to the conveyor located on the shoreline. The plants are then transferred from the transporter, via the conveyor, onto a dump truck for disposal at a convenient location. When the mowing, transporting, and disposal operations are complete, the statistics of time and queuing operations for each component are computed. Operational costs are compiled for each component (default 1977 dollars), including labor, supplies, and power costs required by the harvesting system. No prior experience with computer programming is required since all commands necessary to use SHAP are presented in this report.

PREFACE

This study was conducted under the Aquatic Plant Control Research Program (APCRP) and is part of the continuation of research assistance to the U. S. Army Engineer District, Jacksonville, on improvement of mechanical control technology for aquatic plants. Funds for the project were provided under authorizations 96X3122 (Construction General) and 96X4902 (O&M General).

The project was conducted by the Environmental Engineering Division (EED) of the Environmental Laboratory (EL) at the U. S. Army Engineer Waterways Experiment Station (WES), under the general supervision of Dr. John Harrison, Chief, EL; Mr. Lewis Decell, Program Manager, APCRP; and Mr. A. J. Green, Chief, EED. The work was under the direct supervision of Dr. Raymond L. Montgomery, Chief, Water Resources Engineering Group (WREG), EED.

This report was written by Dr. Eugene R. Perrier and Mr. Anthony C. Gibson, WREG. Appreciation is expressed to Dr. Thomas M. Walski of WREG for technical assistance and guidance in developing the study activities.

Commander and Director of WES during this study was COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
feet	0.3048	metres
feet per hour	0.3048	metres per hour
inches	0.0254	metres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per hour	0.4535924	kilograms per hour
tons per acre	0.22417	kilograms per square metre
tons (2000 lb, mass)	907.1847	kilograms

SIMULATION FOR HARVESTING OF AQUATIC PLANTS

PART I: INTRODUCTION

Background and Purpose

1. One method used for control of areas infested with aquatic plants is mechanical harvesting. Mr. S. J. Winfrey of the University of Florida at Gainesville developed a computer program (Winfrey 1977) for the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., to simulate mechanical harvesting of aquatic plants. This program was developed to evaluate the operations and costs of the mechanical harvesting system. The purpose of this report is to provide a communication-type computer package to aid planners by simulating mechanical harvesting of aquatic-plant-infested areas. The computer model, SHAP, permits rapid evaluation of project design, operations, and methodologies, as well as economic evaluation of the site.

2. The data of Culpepper and Decell (1978a) (a field evaluation of the Aqua-Trio System for harvesting aquatic plants in Florida) were used to verify the model operations and cost analysis. The data of Perrier and Gibson (1979), which noted that, with particular mechanical plant harvester designs, a harvester with a draw of at least 2 ft* could harvest only 25 percent or less of the infested areas, were also used in evaluating bathymetric and infested area data. They noted that 75 percent of the plant-infested areas were in water 0 to 2 ft deep, and 48 percent of the plant-infested areas were in water 1 ft or less in depth. However, effects of this type cannot be solved by the present version of SHAP and at this time only the Aqua-Trio system (2-ft draw) can be evaluated.

3. Mathematical modeling concepts deal with deterministic and

* A table of factors for converting U. S. customary units of measurement to metric (SI) is presented on page 3.

stochastic variables. A deterministic variable is one whose temporal and spatial properties are known, i.e., it is assumed that the behavior of a variable is definite and its characteristics can be predicted without uncertainty. A stochastic variable is one whose properties are governed by purely random-time events and sequential relations, as well as functional relations with other variables. SHAP is a stochastic model that utilizes linear programming theory for network flow analyses and queuing theory. SHAP is designed for using minimal input data in a conversational manner; that is, the user interacts directly with the program and receives output immediately.

Model Operation

4. The terrain subroutine organizes irregularly shaped plant-infested areas to be harvested into a distance-flow network (grid). The harvesting subroutine directs the harvesting procedure. The harvester mows the aquatic plants; the transporter loads the plants and takes them to the conveyor located on the shoreline where the plants are transferred from the transporter, via the conveyor, onto a dump truck for disposal at a nearby site. When the mowing, transporting, and disposal operations are complete, the statistics of time and queuing operations for each component are computed. In addition, the operational costs are tallied for each component (default 1977 dollars), including labor, supplies, and power costs required by the system. The flowchart for the SHAP model is shown in Figure 1 for the model operation steps. The terrain and harvesting portion of the model developed by Winfrey has been modified to expedite model options, needs, and usage.

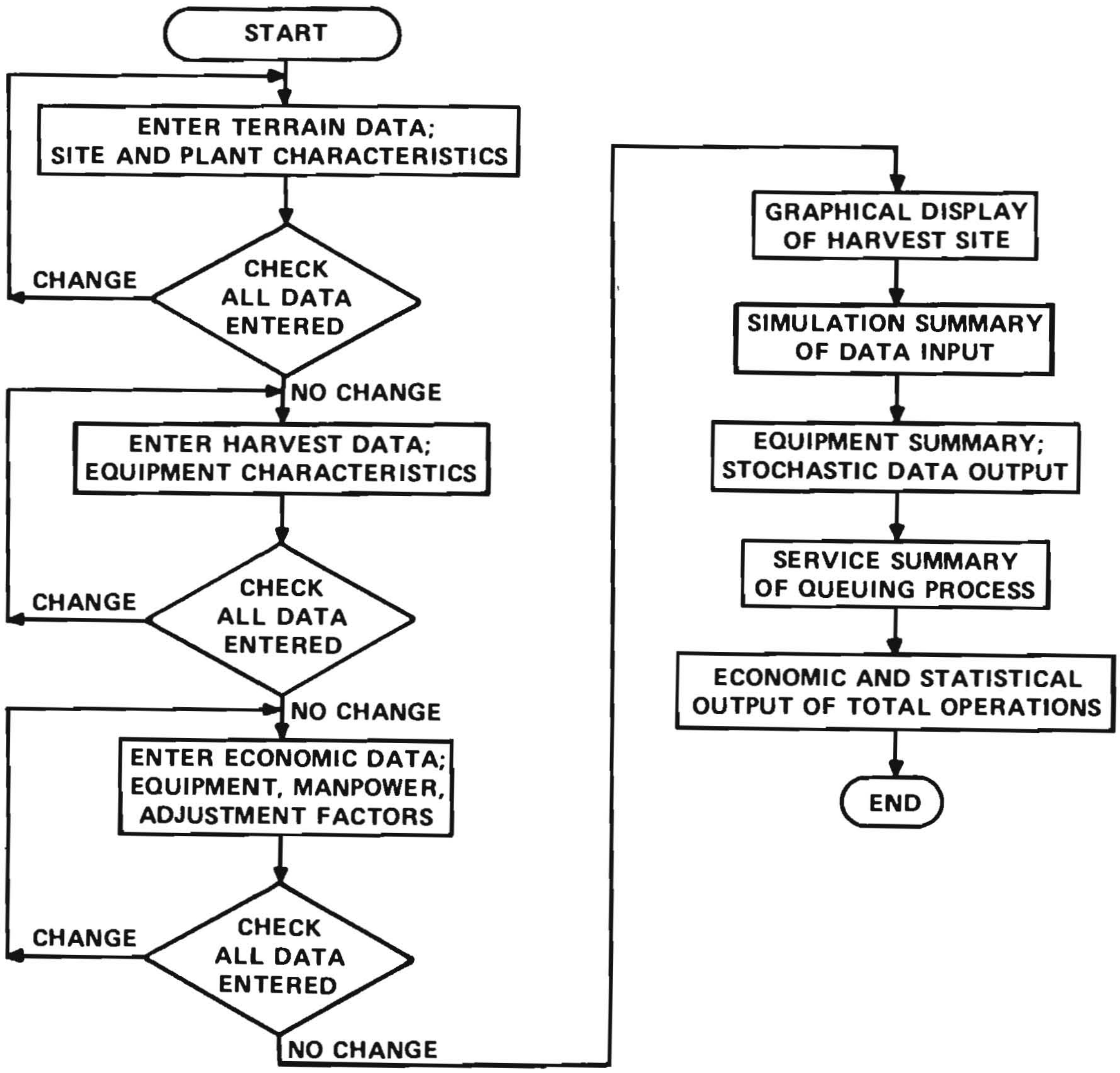

Figure 1. Generalized flowchart for the simulation model SHAP

PART II: SHAP USER'S MANUAL

Model Definition

5. The terrain model uses a labeling algorithm to locate the node/distance within the grid. These values are put into a table of 200 distances, which is randomly accessed by the transporters in the harvesting model. The terrain model has been modified so that two options may be expressed. If the harvest site has a relatively simple, rectangular geometry, only the boundary points will need to be entered. However, if the harvest site area has a more complex shape, then the interior points will have to be entered. Examples of the area geometry requirements will be delineated later in the report.

6. In the harvest model, the harvester (Figure 2) is set to mowing aquatic plants of a given density and at a specified velocity. When the storage of the harvester is filled it stops mowing and waits for the

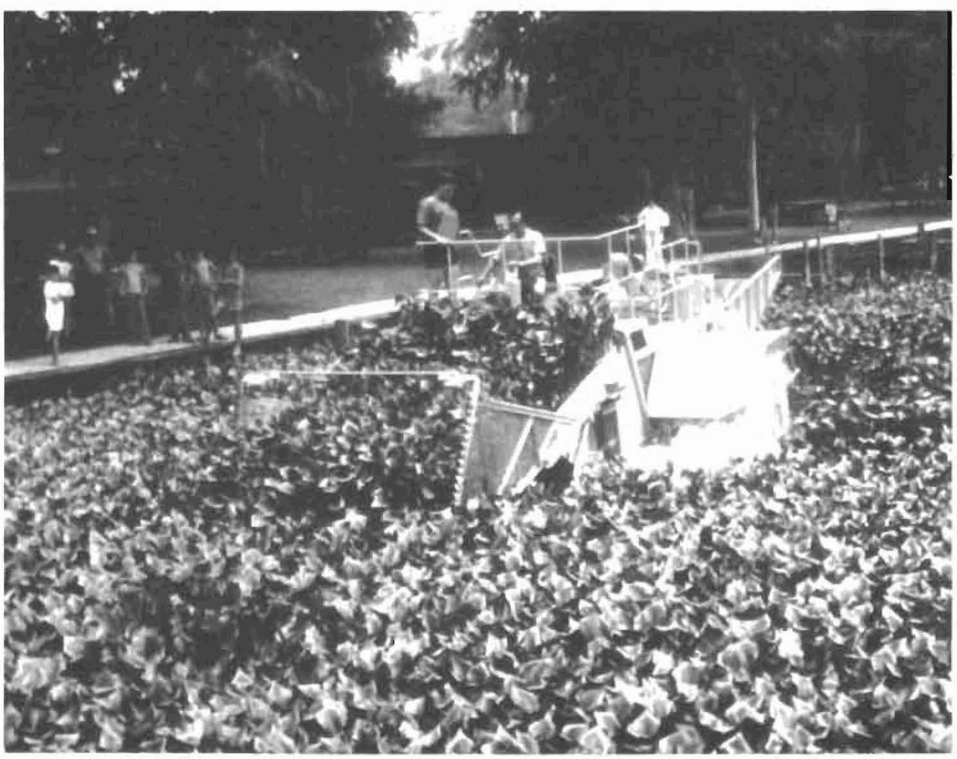

Figure 2. Aqua-Trio harvester in waterhyacinth showing harvester operation

transporter to remove the stored plants. The harvester enters the program only in the sense of harvesting an area of aquatic plants and, when it has harvested the entire site, the program prints out only the time the harvester was in operation (including breakdowns). The exact location or position of the harvester in the grid network is not known at any time; however, it is assumed to be at the position and distance the transporter has traveled to unload the harvester.

7. When the harvester capacity has been filled, the transporter is notified, the distance that the transporter must travel is randomly selected (at the assumed harvester position), and the transporter goes to unload the harvester. When the transporter is loaded with aquatic plants, another randomly selected distance is obtained and the transporter goes to the conveyor. At this time, the harvester starts mowing plants again and the transporter waits to unload the weeds onto the conveyor and into the trucks for eventual disposal.

8. The program clock keeps the time of the total harvest operation, and each subroutine keeps the time required for each component. The total time also includes the number of equipment failures, which increase operation time. When the harvest, transport, conveyor, and disposal operations are complete, the statistics of time and the queuing operations for each component are printed out.

9. Economic input data are entered and stored in the data base so that consistent comparisons can be made between costs of various components of the harvest system. The Engineering News Record (ENR) operation costs are used for updating the costs for the harvest area under consideration. The operation cost includes the costs of all material, equipment, and labor needed to complete the harvesting project (Perrier and Gibson 1979). Overhead consists of profit and legal, fiscal, administration, interest, and engineering costs, and is a function of the operation. The labor required to operate and maintain the equipment is estimated in man-hours per day. By multiplying this value by the wage rate, the labor cost is calculated. All supplies and power costs necessary to run the harvesting system are included in this estimate.

Log on/off

10. The steps to log on/off the Boeing Computer System (BCS)* are shown in Figure 3, which presents the eight steps to log on the computer and one step to log off. A work sheet is presented in Figure 4 for the entry of site and equipment characteristics data necessary to run the model. Most computer input requests are self-explanatory. The computer terminal that the user is operating should be set to enter information using all CAPITAL LETTERS. Initially, the program prints a heading that details the title, name, and address of the authors and the telephone number to call for information about the program and to clarify problems if and when they arise.

```
*********************************************************************
*********************************************************************
*                                                                   *
*       SIMULATION FOR HARVESTING OF AQUATIC PLANTS (SHAP)          *
*                                                                   *
*  THE WES VERSION OF THE MECHANICAL HARVESTING SIMULATION MODEL    *
*                  FOR THE AQUA-TRIO SYSTEM                         *
*                                                                   *
*********************************************************************
*                                                                   *
*                         WRITTEN BY                                *
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*                                                                   *
*********************************************************************
*                                                                   *
*      COPIES OF THE USERS MANUAL AVAILABLE UPON REQUEST            *
*             FOR CONSULTATION CONTACT AUTHORS AT                   *
*                      (601) 634-3710                               *
*                                                                   *
*********************************************************************
*********************************************************************
```

* To obtain information on using BCS and for an account number and password (ID, PASSWORD), call 1-800-426-7676 and ask for EKS customer service (see Appendix A).

STEP	OPERATION
1	Turn on data terminal
2	Dial 1-800-426-7676 (if a local number is available, it is less expensive)
3	Ask operator for: EKS1, 30 CPS data line. (Company or Organization)
4	Put telephone handle in the handset muff
5	Wait for green light to come on (you are now on line), then press RETURN key
6	The computer system types: USER NUMBER: You type: ID, PASSWORD (press RETURN key)
7	The computer system types: RECOVER/USER ID: You type: (your last name) (press RETURN key)
8	The computer system types: C> You type: -SHAP (- is a minus sign) (press RETURN key)

At this point, the program prints a heading and begins to ask questions (see Example 1, paragraph 11) for subroutine options.

9	When program is finished, the computer types: C> You type: BYE (press RETURN key) or repeat step 8 for reruns

Figure 3. Steps to log on/off BCS

WORK SHEET

Simulation for Harvesting of Aquatic Plants (SHAP)

TITLE: ____

Transporter Outlet: X = __________ ft Y = __________ ft

Plant Depth: __________ ft

Standard deviation: __________ ft

Plant Density: __________ lb/cu ft

Standard deviation: __________ lb/cu ft

Truck distance to disposal site: __________ ft

Number of boundary points: __________

Boundary Points X	Boundary Points Y	Interior Points X	Interior Points Y

Number of Harvesters: . . . . __________

Breakdowns per unit time . . . . __________ no./hr

Average repair time . . . . __________ hr

Cutting bar width . . . . __________ ft

Figure 4. Suggested work sheet for SHAP (Continued)

Speed	________	ft/hr
Capacity	________	lb
Blade depth	________	ft
Number of <u>Transporters</u>:	________	
Breakdowns per unit time	________	no./hr
Average repair time	________	hr
Unloading rate	________	lb/hr
Speed	________	ft/hr
Capacity	________	lb
Distance to conveyor	________	ft
Number of <u>Trucks</u>:	________	
Breakdowns per unit time	________	no./hr
Average repair time	________	hr
Unloading rate	________	lb/hr
Speed	________	ft/hr
Capacity	________	lb
Number of <u>Conveyors</u>:	________	
Breakdowns per unit time	________	no./hr
Average repair time	________	hr
Unloading rate	________	lb/hr

Cost of harvester	________	$/hr
Cost of operator	________	$/hr
Cost of transporter	________	$/hr
Cost of operator	________	$/hr
Cost of conveyor	________	$/hr
Cost of truck	________	$/hr
Cost of driver	________	$/hr
Disposal cost	________	$/hr
Mobilization fee	________	$/hr
Distance to site	________	miles
Locale adjustment factor	________	
Engineering News Record (ENR) adjustment factor	________	

Figure 4. (Concluded)

Example 1

11. The following example illustrates the interaction that occurs between the program and the user to evaluate a hydrilla harvesting project in Orange Lake East, Fla. After the heading, the computer gives the following commands to input the data:

```
DO YOU WANT THE TERRAIN, HARVESTING, ECONOMIC, OR OUTPUT MODEL?

          ENTER Ø FOR TERRAIN MODEL
          ENTER 1 FOR HARVESTING MODEL
          ENTER 2 FOR ECONOMIC MODEL
          ENTER 3 FOR OUTPUT OF ALL MODELS
          ENTER 4 TO STOP PROGRAM


I>Ø
```

The terrain model input data include the title, plot geometry, transporter outlet, plant characteristics, and distance truck must drive to the disposal site. The harvesting model input data include characteristics of the harvester, transporter, conveyor, and trucks. The economic model input data include hourly costs for equipment, equipment operators, disposal costs, mobilization fees, distance to site, and economic adjustment factors. The output model prints figures and tables of the input and simulated data. The title information is printed in the output for the user's interest only.

```
ENTER TWO STATEMENTS FOR REFERENCE PURPOSES:
       PROJECT TITLE, AND
       TODAY'S DATE.
       **ENTER 1 VALUE PER LINE**


I>ORANGE LAKE EAST,HYDRILLA
I>15 AUGUST 198Ø
```

12. Note, the user must enter a word or value for each input prompt I>. After the word or value has been entered, the user must also press the RETURN key. In the event an error was committed when typing, i.e., ORANGE LAKE AEST (HYDRILLA), press and hold the CONTROL (CTRL) key,

and press the H key 14 times (14 backspaces).* Then type EAST (HYDRILLA) to correct the spelling, and press the RETURN key.

```
I>ORANGE LAKF [AST ,HYDRILLA
I>15 AUGUST 1980
```

13. To correct an entire line error, the user may press the BREAK key and the computer will type *DEL*. Then the user should type in the correct message as shown:

```
I>ORANGE LAKE AEST,HYDRILLA *DEL*

ORANGE LAKE EAST,HYDRILLA
I>15 AUGUST 1980
```

14. At this point, the user inputs the data from the work sheet as shown in Figure 5 by answering the following commands:

```
ENTEP TWO VALUES FOR THE PLANT DEPTH:
       MEAN (FEET) AND
       STANDARD DEVIATION (FEET)
       **ENTEP 1 VALUE PER LINE**

I>5
I>0

ENTEP TWO VALUES FOP THE PLANT BULK DENSITY:
       MEAN (POUNDS PER CUBIC FOOT) AND
       STANDARD DEVIATION (POUNDS PER CUBIC FOOT)

I>.09
I>0

ENTEP THE DISTANCE THE TRUCK DRIVES TO THE DISPOSAL SITE
     (FEET)

I>1056

ENTEP ONE SET OF VALUES FOR THE POSITION OF THE TRANSPOPTER OUTLET (X & Y)
       **ENTEP 2 VALUES ON 1 LINE**
                 --------

I>720 20

****************************************************************************

 INPUT POSITION OF TRANSPORTEP OUTLET
        X= 720.0       Y=  20.0

 PLANT       MEAN     STD. DEV.
DEPTH        5.00      0.000
DENSITY       .090     0.000

DISTANCE TRUCK DRIVES TO DISPOSAL SITE=   1056.00

****************************************************************************

 DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES?
     (ANSWER YES OR NO)

I>NO
```

* Some computer terminals use a different backspace command.

WORK SHEET

Simulation for Harvesting of Aquatic Plants (SHAP)

TITLE: Orange Lake East, Hydrilla

Transporter Outlet: X = 720 ft Y = 20 ft

Plant Depth: 5 ft

Standard deviation: 0 ft

Plant Density: 0.09 lb/cu ft

Standard deviation: 0 lb/cu ft

Truck distance to disposal site: 1056 ft

Number of boundary points: 6

Boundary Points X	Boundary Points Y	Interior Points X	Interior Points Y
0	0		
0	350		
1000	350		
1000	1400		
1400	1400		
1400	0		

Number of Harvesters: 1

Breakdowns per unit time . . . . 0.32 no./hr

Average repair time . . . . 0.28 hr

Cutting bar width . . . . 8 ft

Figure 5. Work sheet for Example 1 (Continued)

Speed	7866	ft/hr
Capacity	6322	lb
Blade depth	5	ft
Number of Transporters:	2	
Breakdowns per unit time	0.21	no./hr
Average repair time	0.24	hr
Unloading rate	101025	lb/hr
Speed	9523	ft/hr
Capacity	6322	lb
Distance to conveyor	900	ft
Number of Trucks:	2	
Breakdowns per unit time	0.04	no./hr
Average repair time	0.17	hr
Unloading rate	379320	lb/hr
Speed	25728	ft/hr
Capacity	6322	lb
Number of Conveyors:	1	
Breakdowns per unit time	0.02	no./hr
Average repair time	0.17	hr
Unloading rate	65969	lb/hr

Cost of harvester	25.00	$/hr
Cost of operator	12.80	$/hr
Cost of transporter	5.50	$/hr
Cost of operator	10.00	$/hr
Cost of conveyor	4.50	$/hr
Cost of truck	10.00	$/hr
Cost of driver	8.50	$/hr
Disposal cost	4.20	$/hr
Mobilization fee	11.75	$/hr
Distance to site	0.0	miles
Locale adjustment factor	1	
Engineering News Record (ENR) adjustment factor	1	

Figure 5. (Concluded)

After a portion of the terrain model data has been entered, the computer will print:

```
******************************* NOTICE ************************

 ALL DATA POINTS SHOULD BE ENTERED IN A CLOCKWISE DIRECTION
                            (FEET)
***************************************************************
```

If any data have been input in error, it can be corrected at this time. If not, continue on to the next data entry. It is assumed that the size and shape of the area to be harvested are known; these distances will now be entered into the computer program. Note, all data points describing the area must be entered in a clockwise direction. The program assumes that the harvesters and transporters can travel anywhere within the site. The user must construct the site boundary to exclude areas of insufficient water depth (Aqua-Trio requires a 2-ft draw).

```
 ENTER THE NUMBER OF BOUNDARY POINTS

I>6

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>Ø Ø

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>Ø 35Ø

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1ØØØ 35Ø

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1ØØØ 14ØØ

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>14ØØ 14ØØ
```

```
 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1400 0
************************************************************

USER INPUT OF BOUNDARY POINTS IN FEET
         X                Y

          0.0              0.0
          0.0            350.0
       1000.0            350.0
       1000.0           1400.0
       1400.0           1400.0
       1400.0              0.0

************************************************************

************************************************************

 DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES?
     (ANSWER YES OR NO)


I>NO
```

15. Again, the computer asks if the values are correct. Also, the program asks if the harvest area has a complex geometry. For the given example, the answer is NO; however, a more complex geometry will be examined in a later example.

```
DOES YOUR HARVEST AREA HAVE A COMPLEX GEOMETRY?
(ANSWER YES OR NO)

I>NO
```

16. This completes the entry of data into the terrain model; now the user proceeds to the harvesting model.

```
************************************************************

END OF TERRAIN MODEL INPUT
************************************************************
```

17. The user must now enter the information on the work sheet for the harvester:

```
 ENTER THREE VALUES:
       NUMBER OF HARVESTERS
       BREAKDOWNS PER UNIT TIME (NUMBER/TOTAL HOURS) AND
       REPAIR TIME (HOURS).
         ** 1 VALUE PER LINE **

I>1
I>.32
I>.28

 ENTER TWO VALUES:
       HARVESTER CUTTING BAR WIDTH (FEET) AND
       SPEED (FEET PER HOUR).

I>8
I>7866

ENTER TWO VALUES:
       HARVESTER CAPACITY (POUNDS) AND
       BLADE DEPTH (FEET).

I>6322
I>5

*******************************************************************

 INPUT OF HARVESTER VALUES
 NUMBER                1
 BREAKDOWNS              .3200
 REPAIR TIME             .2800
 BAR WIDTH             8.0
 SPEED              7866.0
 CAPACITY           6322.0
 BLADE DEPTH           5.00

*******************************************************************

 DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES?
     (ANSWER YES OR NO)


I>NO
*******************************************************************
```

Then the user must enter the data for the transporter:

```
ENTER THREE VALUES:
       NUMBER OF TRANSPORTERS,
       BREAKDOWNS (NUMBER/TOTAL HOURS) AND
       REPAIR TIME (HOURS).

I>2
I>.21
I>.24
```

```
ENTER TWO VALUES:
       TRANSPORTER UNLOADING RATE (POUNDS/HOUR) AND
       SPEED (FEET PER HOUR).

I>101025
I>9523

 ENTER TWO VALUES:
       TRANSPORTER CAPACITY (POUNDS) AND
       DISTANCE TO CONVEYOR.

I>6322
I>900

*************************************************************

 INPUT OF TRANSPORTER VALUES
 NUMBER                2
 BREAKDOWNS              .2100
 REPAIR TIME             .2400
 UNLOADING          101025.0
 SPEED                9523.0
 CAPACITY             6322.0
 DISTANCE              900.0

*************************************************************

 DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES?
     (ANSWER YES OR NO)


I>NO
*************************************************************
```

Now the user must enter the data for the truck operation:

```
ENTER THREE VALUES:
       NUMBER OF TRUCKS
       BREAKDOWNS (NUMBER/TOTAL HOURS) AND
       REPAIR TIME (HOURS).

I>2
I>.04
I>.17

 ENTER THREE VALUES:
       TRUCK UNLOADING RATE (POUNDS PER HOUR)
       SPEED (FEET PER HOUR) AND
       TRUCK CAPACITY (POUNDS).

I>379320
I>25728
I>6322
```

```
******************************************************************************

 INPUT OF TRUCK VALUES
 NUMBER                   2
 BREAKDOWNS                .0400
 REPAIR TIME               .1700
 UNLOADING          379320.0
 SPEED               25728.0
 CAPACITY             6322.0

******************************************************************************

 DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES?
     (ANSWER YES OR NO)


I>NO
******************************************************************************
```

And, finally, the user inputs the data for the conveyor, which completes the information on the work sheet for the equipment (Figure 5) and also completes the information required by the harvesting model:

```
 ENTER TWO VALUES:
       NUMBER OF CONVEYORS AND
       BREAKDOWNS (NUMBER PER TOTAL HOURS).

I>1
I>.02

 ENTER TWO VALUES:
       CONVEYOR REPAIR TIME AND
       UNLOADING RATE (POUNDS PER HOUR).

I>.17
I>65969

******************************************************************************

 INPUT OF CONVEYOR VALUES
 NUMBER                   1
 BREAKDOWNS                .0200
 REPAIR TIME               .1700
 UNLOADING           65969.0

******************************************************************************

 DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES?
     (ANSWER YES OR NO)
 I>NO
```

18. After both the terrain and harvesting input data have been entered, it will be necessary to enter data into the economic model. If this information is not available, the user may desire to go directly to the output model. In this instance, the model will operate on 1977 default dollars values obtained from Culpepper and Decell (1978a). However, if information is available, the following entries could be made:

```
ENTEP TWO VALUES:
 **ENTER 1 VALUE PER LINE**

       COST FOR HARVESTER ($/HOUR) AND
       COST FOR OPERATOR ($/HOUR)

I>25
I>12.8

ENTEP TWO VALUES:

       COST OF TRANSPORTER ($/HOUR) AND
       COST FOR OPERATOR ($/HOUR)

I>5.5
I>10

************************************************************

           HAPVESTER   TRANSPORTER
 COST         25.00      12.80
 OPERATOR      5.50      10.00

************************************************************

 DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES?
     (ANSWER YES OR NO)


I>NO

 ENTER COST OF CONVEYOR(DOLLARS/HOUR)


I>4.5
```

```
ENTER TWO VALUES:

        COST OF TRUCK ($/HOUR) AND
        COST FOR DRIVER ($/HOUR)

I>10
I>8.5
```

At this point, the program asks for the site distance, disposal costs, and adjustment factors:

```
ENTER THREE VALUES:

        DISPOSAL COST (DOLLARS/HOUR),
        MOBILIZATION FEE (DOLLARS/MILE)
        AND DISTANCE TO SITE (MILES)

I>4.2
I>11.75
I>0

ENTER TWO VALUES:

        LOCALE ADJUSTMENT FACTOR AND
        ENGINEERING NEWS RECORD (ENR) ADJUSTMENT FACTOR

I>1
I>1
```

19. This completes the required data entry; the questions about output follow:

```
DO YOU WANT THE TERRAIN, HARVESTING, ECONOMIC, OR OUTPUT MODEL?

          ENTER 0 FOR TERRAIN MODEL
          ENTER 1 FOR HARVESTING MODEL
          ENTER 2 FOR ECONOMIC MODEL
          ENTER 3 FOR OUTPUT OF ALL MODELS
          ENTER 4 TO STOP PROGRAM


I>3
```

SHAP output

20. The model prints out the economic values entered by the user:

ECONOMIC PARAMETERS

	COSTS	
HARVESTER	25.00	$/HOUR
OPERATOR	12.80	$/HOUR
TRANSPORTER	5.50	$/HOUR
OPERATOR	10.00	$/HOUR
CONVEYOR	4.50	$/HOUR
TRUCK	10.00	$/HOUR
DRIVER	8.50	$/HOUR
DISPOSAL	4.20	$/HOUR
MOBILZATION	11.75	$/MILES
DISTANCE TO SITE	0.0	MILES
LOCALE FACTOR	1.0000	
ENR RATIO	1.0000	

Then the output model prints out the necessary information from the terrain model and allows the opportunity to check the graph of the terrain for reasonableness and accuracy. However, it should be remembered that there is a slight distortion due to the height and width of the letters on the typewriter. Also, the size of the harvest area is given (square feet), together with the grid interval (feet) and numbers, and the maximum distance the transporter must travel within the harvest site from the harvester to the transporter exit (feet). In addition, some of the input parameters are reprinted for checking purposes.

```
DO YOU WANT A GRAPHICAL DISPLAY OF THE TERRAIN TO BE HARVESTED?
       (ANSWER YES OR NO)

I>YES


THE HARVEST AREA IS INDICATED BY ZEROS
THE TRANSPORTER EXIT POSITION IS INDICATED BY X.
IF ENTIRE AREA OF INTEREST IS NOT ZERO FILLED,
RE-RUN AND USE COMPLEX GEOMETRY OPTION


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```

THE HARVEST AREA IS .978272E+06 (SQUARE FEET)
THE AREA GRID NUMBERS ARE X= 64 AND Y= 64
THE GRID INTERVAL IS .222222E+02 (FEET)
THE MAXIMUM DISTANCE FROM THE TRANSPORTER EXIT IS .168520E+04 (FEET)

```
******************************************************************

DO YOU WANT TO RETURN TO THE TERRAIN MODEL?
(ANSWER YES OR NO)

I>NO

******************************************************************
```

21. The output for the harvesting model includes an echo printout of the input data:

```
                           HARVESTING INPUT

ORANGE LAKE EAST,HYDRILLA
15 AUGUST 1980

             HARVESTERS  TRANSPORTERS   CONVEYORS      TRUCKS

NUMBER OF        1            2             1             2
BREAKDOWNS        .32          .21           .02           .04   NO./HR
REPAIR            .28          .24           .17           .17   HOURS
SPEED          7866.00      9523.00                    25728.00   FEET/HR
CAPACITY       6322.00      6322.00                     6322.00   POUNDS
UNLOAD RATE               101025.00      65969.00    379320.00   LBS/HR

HARVESTER CUTTING HEAD WIDTH    8.0      AND DEPTH         5.0    FEET
```

The input summary gives the total area harvested, the total time required for the entire operation, and a brief summary of the site characteristics:

```
                          INPUT SUMMARY
                          -------------

AREA HARVESTED       .978272E+06 SQUARE FEET OR   .225E+02 ACRES

TIME REQUIRED        .331281E+02 HOURS OR   .414E+01 DAYS

PLANT DEPTH    MEAN        .500000E+01   FEET

               STD.     0.               FEET

PLANT DENSITY MEAN         .900000E-01   POUNDS/CUBIC FEET

               STD.     0.               POUNDS/CUBIC FEET

DIST. TO CONVEYOR          .900000E+03   FEET

DUMP SITE DISTANCE         .105600E+04   FEET
```

22. The equipment summary gives a record of each equipment item, including busy time, the percent that the busy time represents of the entire simulation time, the number of times the item broke down in service, the number of events, and the loading/trip rate:

EQUIPMENT SUMMARY

HARVESTER NUMBER	BUSY TIME(HRS)	BUSY TIME(%)	EQUIPMENT FAILURES	NUMBER LOADS	LOAD * RATE(M/L)
1	.3284E+02	99.12	4	70	28.1

TRANSPORTER NUMBER	BUSY TIME(HRS)	BUSY TIME(%)	EQUIPMENT FAILURES	NUMBER TRIPS	TRIP * RATE(M/T)
1	.1921E+02	57.98	4	35	32.9
2	.1779E+02	53.71	2	37	28.9

CONVEYOR NUMBER	BUSY TIME(HRS)	BUSY TIME(%)	EQUIPMENT FAILURES	TRANS. UNLOADED	LOAD * RATE(M/L)
1	.6673E+01	20.14	0	70	5.7

TRUCK NUMBER	BUSY TIME(HRS)	BUSY TIME(%)	EQUIPMENT FAILURES	NUMBER TRIPS	TRIP * RATE(M/T)
1	.6811E+01	20.56	0	35	11.7
2	.6775E+01	20.45	0	35	11.6

* M/L = MINUTES PER LOAD AND M/T = MINUTES PER TRIP

23. The service summary shows the operations of the truck, conveyor, and transporter service systems. It consists of the total number of service requests, total number of queue entries, maximum queue length, average queue length, and average waiting time:

SERVICE SUMMARY

SERVICE SYSTEM	TOTAL SERVICE REQUESTS	TOTAL QUEUE ENTRIES	MAXIMUM QUEUE LENGTH	AVERAGE QUEUE LENGTH	AVERAGE WAITING TIME(HRS)
TRANSPORTER	72	2	1	.00	.08
CONVEYOR	70	0	0	0.00	0.00
TRUCK	70	0	0	0.00	0.00

The total number of service requests represents the total number of times that service was requested for the particular system, whether or not it was immediately available. If the service was not available immediately, the request entered the respective queue and waited. The maximum queue length represents the maximum number of items in the queue at any time during the simulation. A large number would suggest a need for more units of this equipment item. The average queue length is the average length of the respective queue for the entire time of the simulation--including times when the queue was empty. This number is not influenced by time that the queue was empty. A large number here would suggest a need for additional units of this equipment item. However, a small number here could suggest that too many of these equipment items are on the plant-harvesting project.

24. The output model now prints out the economics summary, which includes the distance to the job site (miles) and the length of job in terms of the number of 8-hr days:

```
                 ECONOMICS SUMMARY
                 -----------------

DISTANCE TO JOB SITE            0.000  MILES
LENGTH OF JOB           .414E+01  DAYS (8 HRS)
```

The total operation costs for the harvester, transporter, conveyor, truck, and operators are given below. The disposal cost, cost of the disposal site operations converted to a total time cost, and the mobilization fee, which includes transporting all of the equipment to the harvest area from some distance, are also included. Next, the total job cost is computed and converted to values of cost per ton and cost per acre. In addition, the total mass (tons) of aquatic plants harvested is given.

OPERATION COSTS

HARVESTER	$	828.20
OPERATOR	$	424.04
TRANSPORTER	$	182.20
OPERATER	$	331.28
CONVEYOR	$	149.08
TRUCK	$	331.28
DRIVER	$	281.59

TOTAL	$	2527.67
DISPOSAL COST	$	139.14
MOBILIZATION FEE	$	0.00

TOTAL JOB COST	$	2666.81
COST PER TON	$	12.12
COST PER ACRE	$	118.75

TOTAL VOLUME HARVESTED 220.11 TONS

25. If the program session is completed, then the log off command BYE is typed at the next prompt.

```
ENTER -SHAP TO START NEXT RUN
  REMEMBER -- ALL INPUT DATA FILES ARE PERMANENT, OR

  ENTER BYE TO LOG OFF COMPUTER SYSTEM
```

C>BYE

However, if the user would like to re-enter the simulation model, the user should enter -SHAP. At this point, the program heading would be reprinted and the beginning questions asked.

Example 2

26. As previously mentioned, the terrain model has two options as to the complexity of the area to be harvested. Example 1 presented a

relatively simple rectangular geometry. In this example, a harvest site area with a more complex shape will be discussed. The following computer program statements illustrate the interaction that occurs between the program and the user to evaluate a harvesting project with a complex geometry. Note, all data points describing both boundary and interior points must be entered in a clockwise direction.

```
                    MECHANICAL HARVESTING SIMULATION
                    --------------------------------

DO YOU WANT THE TERRAIN, HARVESTING, ECONOMIC, OR OUTPUT MODEL?

          ENTER 0 FOR TERRAIN MODEL
          ENTER 1 FOR HARVESTING MODEL
          ENTER 2 FOR ECONOMIC MODEL
          ENTER 3 FOR OUTPUT OF ALL MODELS
          ENTER 4 TO STOP PROGRAM


I>0

ENTER TWO STATEMENTS FOR REFERENCE PURPOSES:
       PROJECT TITLE, AND
       TODAY'S DATE.
       **ENTER 1 VALUE PER LINE**

I>LAKE WINFREY (EXAMPLE), HYDRILLA
I>14 JUNE 1980


ENTER TWO VALUES FOR THE PLANT DEPTH:
       MEAN (FEET) AND
       STANDARD DEVIATION (FEET)
       **ENTER 1 VALUE PER LINE**

I>1.75
I>0


ENTER TWO VALUES FOR THE PLANT BULK DENSITY:
       MEAN (POUNDS PER CUBIC FOOT) AND
       STANDARD DEVIATION (POUNDS PER CUBIC FOOT)

I>.005
I>0

ENTER THE DISTANCE THE TRUCK DRIVES TO THE DISPOSAL SITE
     (FEET)


I>22500

ENTER ONE SET OF VALUES FOR THE POSITION OF THE TRANSPORTER OUTLET (X & Y)
       **ENTER 2 VALUES ON 1 LINE**
                 --------

I>1000 250
```

27. Now the computer asks the user to enter the boundary points (two values per line prompt I>):

```
 ENTER THE NUMBER OF BOUNDARY POINTS

I>10

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1000 0

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>0 1000

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1000 2000

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>2000 1500

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1750 1250

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1000 1750

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>500 1000

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1000 250

 ENTER ONE SET OF BOUNDARY POINTS (X & Y)
      (2 VALUES PER LINE)

I>1750 750
```

```
ENTER ONE SET OF BOUNDARY POINTS (X & Y)
     (2 VALUES PER LINE)

I>2000 500
**********************************************************************

USER INPUT OF BOUNDARY POINTS IN FEET
          X                 Y

       1000.0              0.0
          0.0           1000.0
       1000.0           2000.0
       2000.0           1500.0
       1750.0           1250.0
       1000.0           1750.0
        500.0           1000.0
       1000.0            250.0
       1750.0            750.0
       2000.0            500.0
```

After the boundary points have been entered, the interior points have to be entered for a site with a complex geometry. It must be remembered that the program assumes that the equipment can travel anywhere within the site and that the area excludes insufficient water depth for the harvesters and transporters. In this instance, the user should draw a grid network plot of the site boundaries using rectangular coordinates as shown in Figure 6. Convenient straight lines and distances to boundary points should be added to the plot. The boundary coordinates should represent actual ground distances (feet). The interior points for this example were set at 50 ft within the site from the boundary point. If the graph of the terrain is distorted, then the interior grid points should be increased to 100 ft within the site from the boundary point. The program output includes a graph of the harvest area; any need for additional or different internal points will be immediately obvious and the program can be rerun.

```
DOES YOUR HARVEST AREA HAVE A COMPLEX GEOMETRY?
(ANSWER YES OR NO)

I>YES
```

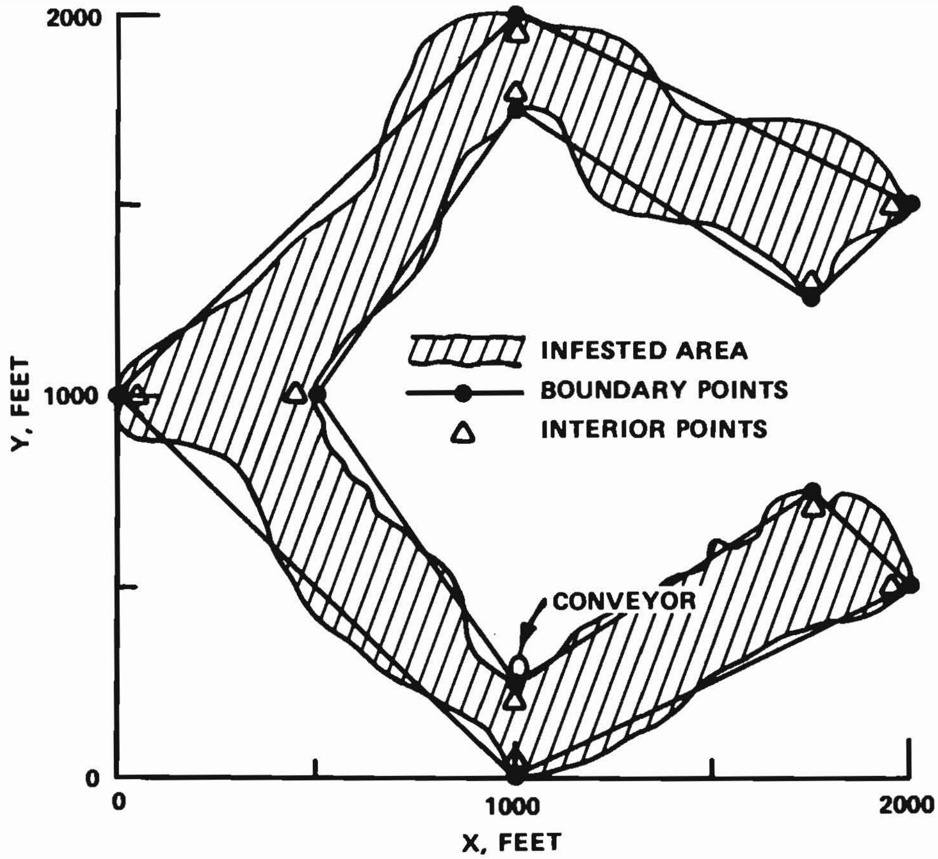


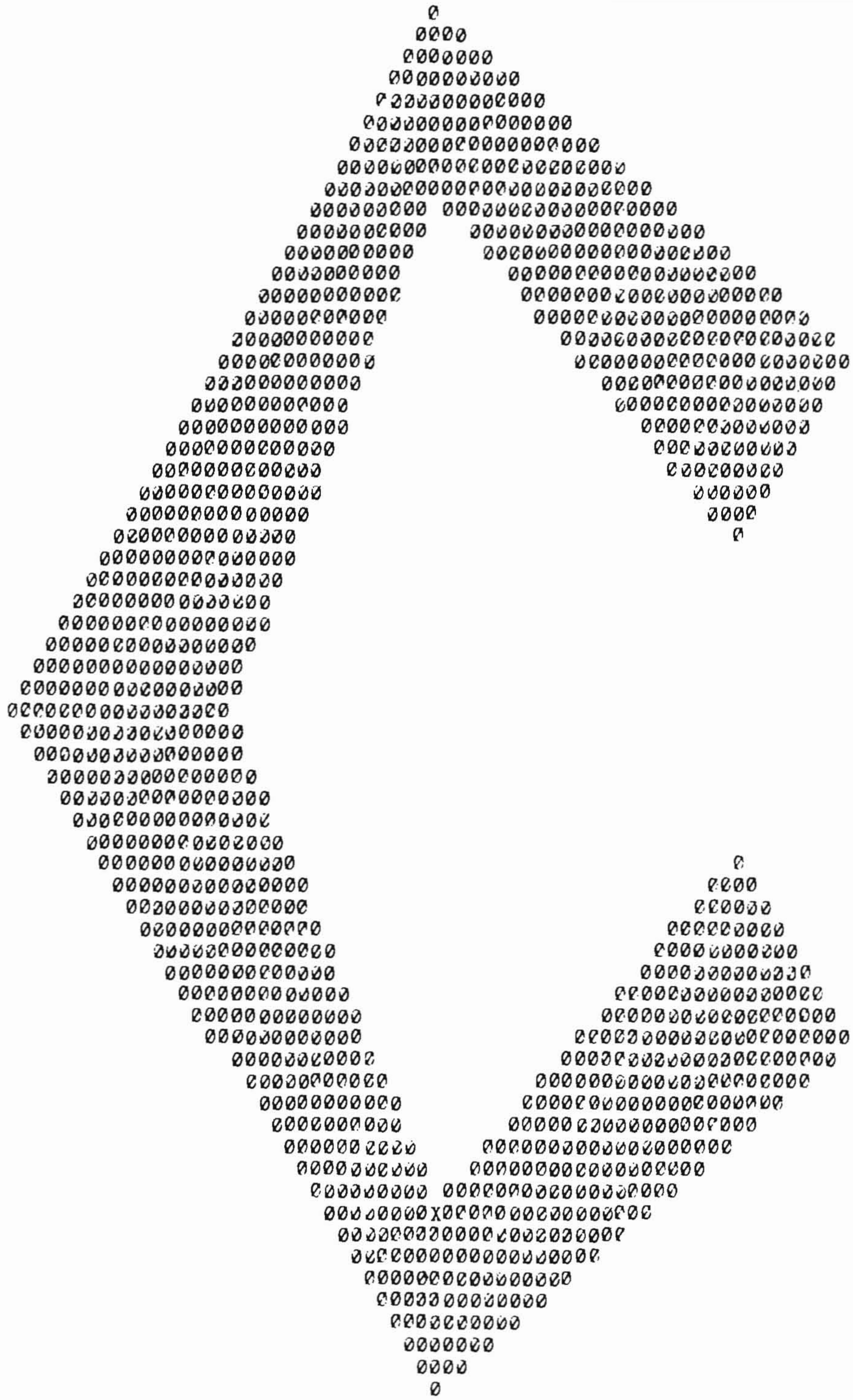
Figure 6. Grid network plot of proposed aquatic plant harvest area

```
 ENTER ONE SET OF INTERIOR POINTS (X & Y)
I>1000 50
 ENTER ONE SET OF INTERIOR POINTS (X & Y)
I>50 1000
 ENTER ONE SET OF INTERIOR POINTS (X & Y)
I>1000 1950
 ENTER ONE SET OF INTERIOR POINTS (X & Y)
I>1950 1500
 ENTER ONE SET OF INTERIOR POINTS (X & Y)
I>1750 1300
```

```
 ENTER ONE SET OF INTERIOR POINTS (X & Y)

I>1ØØØ 18ØØ

 ENTER ONE SET OF INTERIOR POINTS (X & Y)

I>45Ø 1ØØØ

 ENTER ONE SET OF INTERIOR POINTS (X & Y)

I>1ØØØ 2ØØ

 ENTER ONE SET OF INTERIOR POINTS (X & Y)

I>175Ø 7ØØ

 ENTER ONE SET OF INTERIOR POINTS (X & Y)

I>195Ø 5ØØ
*****************************************************************

USER INPUT OF INTERIOR POINTS (FEET)
         XI                YI

       1ØØØ.Ø             5Ø.Ø
         5Ø.Ø           1ØØØ.Ø
       1ØØØ.Ø           195Ø.Ø
       195Ø.Ø           15ØØ.Ø
       175Ø.Ø           13ØØ.Ø
       1ØØØ.Ø           18ØØ.Ø
        45Ø.Ø           1ØØØ.Ø
       1ØØØ.Ø            2ØØ.Ø
       175Ø.Ø            7ØØ.Ø
       195Ø.Ø            5ØØ.Ø
```

28. In the output model, the following questions are asked and a graph of the terrain is printed out:

```
DO YOU WANT A GRAPHICAL DISPLAY OF THE TERRAIN TO BE HARVESTED?
       (ANSWER YES OR NO)

I>YES


THE HARVEST AREA IS INDICATED BY ZEROS
THE TRANSPORTER EXIT POSITION IS INDICATED BY X.
IF ENTIRE AREA OF INTEREST IS NOT ZERO FILLED,
RE-RUN AND USE COMPLEX GEOMETRY OPTION
```



Most harvest areas may not reach this complexity and it may be more feasible to break up large areas into smaller ones for harvest. For example, if an area is very long and narrow, the best solution might be to harvest one end and then move the entire operation to the other end to finish the job. If an area is extremely large, it might be sub-divided into several smaller areas for harvest (Winfrey 1972).

PART III: MODEL VERIFICATION

29. Verification of the SHAP model was accomplished using four studies from the field tests of Culpepper and Decell (1978a, b). Verification of the model with field data was done to test the reasonableness between the model output and the actual system performance. The four sites evaluated were entitled:

a. Orange Lake East, Hydrilla.

b. Orange Lake West, Hydrilla.

c. St. Johns River, 2AT-13B4, Hyacinth.

d. St. Johns River, 2AT-13B5, Hyacinth.

The time and operational equipment data for these study sites are described in detail by Culpepper and Decell (1978a, b). For verification purposes, only initial estimates of the input parameters were used.

Orange Lake East

30. This site was located in the southeast corner of Orange Lake, Fla. About 70 percent of the harvest area was covered with topped-out hydrilla and 30 percent with hydrilla that was 1 to 2 ft below the water surface (10 tons/acre). The water depth in the harvest area was 4 to 6 ft. The transporter traveled 900 ft to the conveyor and the truck route was 0.2 mile in length. The equipment and site data are presented on the work sheet in Figure 7.

31. The comparison of the SHAP output to the field test data (Culpepper and Decell 1978b) is shown in Table 1. In general, the values compare favorably. The field data collection does not measure exactly the same values as the simulation model, so some discrepancy can be expected. The model havested the area in a shorter time than was recorded by actual field operations. This time difference probably occurred in the description of the plant density as the total mass harvested was about 70 tons greater for the field test than for the simulation. Also, the transporters were busy fewer hours and traveled at a faster rate than the model estimated. The output for both methods suggests that only

WORK SHEET

Simulation for Harvesting of Aquatic Plants (SHAP)

TITLE: Orange Lake East, Hydrilla

Transporter Outlet: X = 1400 ft Y = 720 ft

Plant Depth: 5 ft

Standard deviation: 0 ft

Plant Density: 0.09 lb/cu ft

Standard deviation: 0 lb/cu ft

Truck distance to disposal site: 1056 ft

Number of boundary points: 6

Boundary Points X	Boundary Points Y	Interior Points X	Interior Points Y
0	0		
0	350		
1000	350		
1000	1400		
1400	1400		
1400	0		

Number of Harvesters: 1

Breakdowns per unit time . . . . 0.32 no./hr

Average repair time . . . . 0.28 hr

Cutting bar width . . . . 8 ft

Figure 7. SHAP work sheet for Orange Lake East (Continued)

Speed	7866	ft/hr
Capacity	6322	lb
Blade depth	5	ft
Number of <u>Transporters</u>:	2	
Breakdowns per unit time	0.21	no./hr
Average repair time	0.24	hr
Unloading rate	101025	lb/hr
Speed	9523	ft/hr
Capacity	6322	lb
Distance to conveyor	900	ft
Number of <u>Trucks</u>:	2	
Breakdowns per unit time	0.04	no./hr
Average repair time	0.17	hr
Unloading rate	379320	lb/hr
Speed	25728	ft/hr
Capacity	6322	lb
Number of <u>Conveyors</u>:	1	
Breakdowns per unit time	0.02	no./hr
Average repair time	0.17	hr
Unloading rate	65969	lb/hr

Cost of harvester	25.00	$/hr
Cost of operator	12.80	$/hr
Cost of transporter	5.50	$/hr
Cost of operator	10.00	$/hr
Cost of conveyor	4.50	$/hr
Cost of truck	10.00	$/hr
Cost of driver	8.50	$/hr
Disposal cost	4.20	$/hr
Mobilization fee	11.75	$/hr
Distance to site	0.0	miles
Locale adjustment factor	1	
Engineering News Record (ENR) adjustment factor	1	

Figure 7. (Concluded)

one transporter and one truck were needed to complete the job efficiently, thus saving considerable costs.

Orange Lake West

32. This site was located on Samsons Point in Orange Lake, Fla. The harvesting area was covered with topped-out hydrilla and extended 2300 ft into the lake from the shore (13 tons/acre). The average water depth of the area was 10 to 12 ft. Strong winds with heavy rains frequently blew across the large, open lake and prevented efficient operation of the harvester and transporter. The equipment and site data are shown in the work sheet in Figure 8.

33. The comparison of the SHAP output to the field test data (Culpepper and Decell 1978b) is shown in Table 2. In this data set, some of the time data were missing, which gave low values for the busy time of the field data. The number of equipment failures did compare favorably. The total mass of hydrilla was not measured at the field test and no data were available for the trucks. However, once again, the conclusion could be reached that to accomplish the harvest only one transporter and one truck would be required.

St. Johns River

34. Sites 2AT-13B4 and 2AT-13B5 were on a series of small, connecting canals forming a residential waterfront community. The canals were 65 to 80 ft wide and 750 and 1250 ft long. The average water depth was 6 ft and, at the time of the harvesting operation, there were a few floating logs in the water. Plants in these canals had stem and leaf heights of 13 to 31 in. and root lengths of 16 to 31 in. (84 tons/acre - B4, and 110 tons/acre - B5).

35. The comparison of the SHAP output to the field test data (Culpepper and Decell 1978b) is shown in Tables 3 and 4. The equipment and site data are shown in the work sheet in Figures 9 and 10. The tabular data show that the model and field data compare quite favorably for these two sites. The truck and, therefore, the total mass harvested data were not available for these data sets.

WORK SHEET

Simulation for Harvesting of Aquatic Plants (SHAP)

TITLE: Orange Lake West, Hydrilla

Transporter Outlet: X = 10 ft Y = 10 ft

Plant Depth: 5 ft

Standard deviation: 0 ft

Plant Density: 0.12 lb/cu ft

Standard deviation: 0 lb/cu ft

Truck distance to disposal site: 2112 ft

Number of boundary points: 8

Boundary Points X	Boundary Points Y	Interior Points X	Interior Points Y
0	0		
0	1025		
650	1025		
650	825		
1100	825		
1100	350		
1700	350		
1700	0		

Number of Harvesters: 1

Breakdowns per unit time . . . . 0.06 no./hr

Average repair time . . . . 0.32 hr

Cutting bar width . . . . 8 ft

Figure 8. SHAP work sheet for Orange Lake West (Continued)

Speed	6061	ft/hr
Capacity	5000	lb
Blade depth	5	ft
Number of Transporters:	2	
Breakdowns per unit time	0.27	no./hr
Average repair time	0.03	hr
Unloading rate	108303	lb/hr
Speed	6818	ft/hr
Capacity	5000	lb
Distance to conveyor	450	ft
Number of Trucks:	2	
Breakdowns per unit time	0	no./hr
Average repair time	0	hr
Unloading rate	300000	lb/hr
Speed	41480	ft/hr
Capacity	5000	lb
Number of Conveyors:	1	
Breakdowns per unit time	0.04	no./hr
Average repair time	0.34	hr
Unloading rate	88370	lb/hr

Cost of harvester	25.00	$/hr
Cost of operator	12.80	$/hr
Cost of transporter	5.50	$/hr
Cost of operator	10.00	$/hr
Cost of conveyor	4.50	$/hr
Cost of truck	10.00	$/hr
Cost of driver	8.50	$/hr
Disposal cost	4.20	$/hr
Mobilization fee	11.75	$/hr
Distance to site	0.0	miles
Locale adjustment factor	1	
Engineering News Record (ENR) adjustment factor	1	

Figure 8. (Concluded)

WORK SHEET

Simulation for Harvesting of Aquatic Plants (SHAP)

TITLE: St. Johns River Site 2AT-13B4, Hyacinth

Transporter Outlet: X = 40 ft Y = 10 ft

Plant Depth: 2 ft

Standard deviation: 0.17 ft

Plant Density: 0.77 lb/cu ft

Standard deviation: 0.085 lb/cu ft

Truck distance to disposal site: 5808 ft

Number of boundary points: 4

Boundary Points X	Boundary Points Y	Interior Points X	Interior Points Y
0	0		
0	750		
65	750		
65	0		

Number of Harvesters: 1

Breakdowns per unit time . . . . 0.26 no./hr

Average repair time . . . . 0.54 hr

Cutting bar width . . . . 8 ft

Figure 9. SHAP work sheet for St. Johns River site 2AT-13B4 (Continued)

Speed	1530	ft/hr
Capacity	5000	lb
Blade depth	2	ft
Number of Transporters:	1	
Breakdowns per unit time	0	no./hr
Average repair time	0	hr
Unloading rate	205560	lb/hr
Speed	7980	ft/hr
Capacity	5000	lb
Distance to conveyor	665	ft
Number of Trucks:	1	
Breakdowns per unit time	0	no./hr
Average repair time	0	hr
Unloading rate	240000	lb/hr
Speed	52800	ft/hr
Capacity	5000	lb
Number of Conveyors:	1	
Breakdowns per unit time	0.70	no./hr
Average repair time	0.18	hr
Unloading rate	112997	lb/hr

Cost of harvester	25.00	$/hr
Cost of operator	12.80	$/hr
Cost of transporter	5.50	$/hr
Cost of operator	10.00	$/hr
Cost of conveyor	4.50	$/hr
Cost of truck	10.00	$/hr
Cost of driver	8.50	$/hr
Disposal cost	4.20	$/hr
Mobilization fee	11.75	$/hr
Distance to site	0	miles
Locale adjustment factor	1	
Engineering News Record (ENR) adjustment factor	1	

Figure 9. (Concluded)

WORK SHEET

Simulation for Harvesting of Aquatic Plants (SHAP)

TITLE: St. Johns River Site 2AT-13B5, Hyacinth

Transporter Outlet: X = 40 ft Y = 10 ft

Plant Depth: 2 ft

Standard deviation: 0.17 ft

Plant Density: 0.77 lb/cu ft

Standard deviation: 0.085 lb/cu ft

Truck distance to disposal site: 5808 ft

Number of boundary points: 4

Boundary Points X	Boundary Points Y	Interior Points X	Interior Points Y
0	0		
0	1150		
80	1150		
80	0		

Number of Harvesters: 1

Breakdowns per unit time . . . . 0.16 no./hr

Average repair time . . . . 0.05 hr

Cutting bar width . . . . 8 ft

Figure 10. SHAP work sheet for St. Johns River site 2AT-13B5 (Continued)

Speed	1822	ft/hr
Capacity	6270	lb
Blade depth	2	ft
Number of Transporters:	1	
Breakdowns per unit time	0.05	no./hr
Average repair time	0.02	hr
Unloading rate	103186	lb/hr
Speed	10754	ft/hr
Capacity	6270	lb
Distance to conveyor	1080	ft
Number of Trucks:	1	
Breakdowns per unit time	0	no./hr
Average repair time	0	hr
Unloading rate	240000	lb/hr
Speed	105600	ft/hr
Capacity	6270	lb
Number of Conveyors:	1	
Breakdowns per unit time	0.49	no./hr
Average repair time	0.01	hr
Unloading rate	113000	lb/hr

Cost of harvester	25.00	$/hr
Cost of operator	12.80	$/hr
Cost of transporter	5.50	$/hr
Cost of operator	10.00	$/hr
Cost of conveyor	4.50	$/hr
Cost of truck	10.00	$/hr
Cost of driver	8.50	$/hr
Disposal cost	4.20	$/hr
Mobilization fee	11.75	$/hr
Distance to site	0	miles
Locale adjustment factor	1	
Engineering News Record (ENR) adjustment factor	1	

Figure 10. (Concluded)

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

36. The computer program entitled "Simulation for Harvesting of Aquatic Plants (SHAP)" has been developed for simulating the operation of mechanical harvesting (Aqua-Trio system) of aquatic plants. This program permits the user to evaluate the harvesting operation as to equipment efficiency and cost analyses of the proposed project. SHAP is designed for using minimal input data in a conversational manner; that is, the user interacts directly with the program and receives output immediately. After SHAP has completed the initial run, the input and data files will be fixed and permanent. At this time, the user can repeat step 8 of Figure 3 and make countless runs without re-entering data for the total model. Various scenarios of aquatic plant harvest designs can be run for a particular site to obtain the most efficient and cost-effective plan.

37. The verification of SHAP showed that the model compared favorably with the field test data (Culpepper and Decell 1978a, b). However, it pointed out some of the weaknesses of the model to input the same type of data collected in the field.

Recommendations

38. An increase in the number of statistical variables is needed; that is, the running vehicles (harvester, transporter, conveyor, and truck) do not operate at a constant velocity. A provision could be made in SHAP to allow for a standard deviation and for a normal distribution (Markovian process) of velocity. Similar modifications to loading and unloading operations would permit SHAP to better represent actual field practices.

39. Default data for a particular type of equipment and aquatic plant should be added to estimate normal equipment and harvesting operations. However, in SHAP, the user would have the option to override all

default values. When estimates of harvesting operations are not known, default values would permit the planner to better understand and estimate actual field-tested conditions.

40. SHAP should be modularized to permit simulation of other aquatic plant harvesting systems and techniques besides Aqua-Trio, Inc. The use of modules would permit the user to select (and partially design) the specific equipment needs along with any harvesting peculiarity that is required to complete a project. Modularization would also permit the user of SHAP to evaluate specific chemical spray equipment systems as to methodology, application efficiency, and cost-effectiveness.

41. A critical path analysis package should be added to SHAP to permit the user to observe the most efficient harvesting or spraying path to follow to minimize gaps and overlaps. Critical path analysis could be used to direct the position of the harvester as well as the transporter. This package would present the user with the most energy-efficient, work-efficient, and cost-effective plan for harvesting an aquatic plant site.

42. The SHAP should be modified to accept digitized data from a graphics tablet of a map of the area to be harvested. These data could be entered into the terrain model for any variety of complex field geometries. This modification would permit the user to "draw-up" the surface area shape of a harvest site, including bathymetric data (Perrier and Gibson 1979), and enter it directly to the model from the graphics tablet. Therefore, a more complete evaluation of the various harvester designs could be performed by the planner/user. For example, is there adequate boat draft, is the harvester or cutting head designed for shallow water areas, and what are the peripheral equipment requirements to complete the project within the proposed time span?

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Table 1

Comparison of SHAP Output to Field Data* for Orange Lake East

Function	Harvester		Transporter 1		Transporter 2		Conveyor		Truck 1		Truck 2	
	SHAP	Field	SHAP	Field	SHAP	Field	SHAP	Field	SHAP	Field	SHAP	Field
Busy time												
Hours	32.7	42.0	19.1	11.2	17.7	14.5	6.7	5.1	6.8	6.2	6.7	13.1
Percent	99.1	75.0	58.0	20.0	53.7	25.9	20.1	9.1	20.6	10.9	20.5	23.4
Equip. failures	4	18	4	8	2	4	0	1	0	2	0	0
No. of loads	70	88	35	31	37	57	70	88	35	25	35	68
Load rate, m/L**	28.1	25.0					5.7	3.5				
Trip rate, m/T†			32.7	21.7	28.7	15.3			11.7	14.9	11.6	11.6
Area harvested, acres	22.5	20.0										
Time required, hr	33.0	56.0										
Total mass harvested, tons	220.1	289.8										

* From Culpepper and Decell (1978b).
** m/L = minutes per load.
† m/T = minutes per trip.

Table 2

Comparison of SHAP Output to Field Data* for Orange Lake West

Function	Harvester		Transporter 1		Transporter 2		Conveyor		Truck 1		Truck 2	
	SHAP	Field	SHAP	Field	SHAP	Field	SHAP	Field	SHAP	Field	SHAP	Field
Busy Time												
Hours	69.3	38.9	39.7	24.8	41.4	11.4	8.8	5.9	13.8	--	13.7	--
Percent	99.4	81.7	56.9	31.0	59.4	23.6	12.7	12.4	19.8	--	19.6	--
Equip. failures	2	5	7	7	7	7	0	2	0	--	0	--
No. of loads	257	132	83	80	84	48	157	128	79	--	78	
Load rate, m/L	26.5	17.7					3.4	2.8				
Trip rate, m/T			28.7	11.1	29.6	14.1			10.5	--	10.5	--
Area harvested, acres	29.9	28.6										
Time required, hr	69.7	47.7										
Total mass harvested, tons	391	--										

* From Culpepper and Decell (1978b).

Table 3

Comparison of SHAP Output to Field Data for St. Johns River Site 2AT-13B4

Function	Harvester SHAP	Harvester Field	Transporter SHAP	Transporter Field	Conveyor SHAP	Conveyor Field	Truck SHAP	Truck Field
Busy time								
Hours	7.4	6.8	5.6	5.9	1.0	1.4	5.1	--
Percent	95.3	39.0	72.4	33.6	12.4	8.2	65.4	--
Equip. failures	0	2	0	2	1	1	0	--
No. of loads	17	38	17	33	18	33	18	--
Load rate, m/L	26.0	10.7			3.2	2.6		
Trip rate, m/T			19.7	13.1			16.8	--
Area harvested, acres	1.3	1.1						
Time required, hr	7.7	17.5						
Total mass harvested, tons	44.0	--						

* From Culpepper and Decell (1978b).

Table 4

Comparison of SHAP Output to Field Data for St. Johns River Site 2AT-13B5

Function	Harvester		Transporter		Conveyor		Truck	
	SHAP	Field	SHAP	Field	SHAP	Field	SHAP	Field
Busy time								
Hours	13.6	7.4	12.7	8.1	2.7	1.7	6.4	--
Percent	97.5	31.9	91.2	35.0	19.3	7.2	45.7	--
Equip. failures	0	2	0	14	1	1	0	--
No. of loads	25	34	27	27	28	27	28	--
Load rate, m/L	32.6	13.1			5.8	3.8		
Trip rate, m/T			28.2	18.0			13.6	--
Area harvested, acres	2.3	2.1						
Time required, hr	13.9	23.1						
Total mass harvested, tons	78.3	--						

* From Culpepper and Decell (1978b).

APPENDIX A: COST BREAKDOWN OF BOEING COMPUTER SERVICES

1. There are three cost parameters associated with Boeing Computer Services (BCS): connect, storage, and central computer unit costs. The costs included in this appendix are for the Ciber 175 computer system, which is the computer used by the authors of this report at the U. S. Army Engineer Waterways Experiment Station.

2. The connect cost occurs during the interactive mode. This cost is $8.50 per hour for the 30 characters per second printed.

3. Disc and magnetic tape are the two types of storage costs. The disc storage cost is $0.007 per day for the first 8,000 sectors; for 8,001 to 16,000 sectors, the cost is $0.005 per day; for 16,001 to 24,000 sectors, the cost is $0.0035 per day; for 24,001 to 50,000 sectors, the cost is $0.0025 per day; and for 50,001 sectors and up the cost is $0.0015 per day. The magnetic tape cost for the first 200 sectors is $0.20 per day for Government users. The next 200 sectors are $0.15 per reel per day. Over 400 sectors, the cost is $0.10 per reel per day.

4. The computer charging units (CCU) costs depend on the mode interactive or remote batch. The interactive process during prime time is $0.20 per CCU. The CCU cost for the remote batch process for 0.5 hr is $0.15 per CCU; for 1 hr, $0.125 per CCU; for 4 hr, $0.10 per CCU; for 8 hr, $0.085 per CCU; for 16 hr, $0.075 per CCU; and for 48 hr, $0.06 per CCU.

5. The costs presented above are given without the Government discount (30 percent).

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

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