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The rest is self-explanatory. Figures 1 and 2 are examples of the output documents.

CONCLUSION

Forests interested in these programs should contact Dick Wisehart, Stanislaus National Forest, 19777 Greenley Road, Sonora, California 95370, or call (209) 532-3671.

--*John E. Best*
Supervisory Civil Engineer
Stanislaus National Forest
Region 5

CONTRACT PAYMENT ESTIMATE AND INVOICE
Stanislaus National Forest
4/17/85

COMFORT STATIONS, INC.
46-9B66-2-72
Belcampo Construction Co.

Estimate No: Example
Cut Off Date: 4-17-85

Original Contract Amount:	$ 84,840.00
Increase or Decrease:	$ 5,000.00
New Contract Amount:	$ 89,840.00
Time Used:	50 %
Funds Used:	73 %

I certify that the amount listed is correct and payment has not been received.	Total Earned	$ 65,355.00
______________________ contractor's rep date	All Previous Payments	$ .00
Above items have been received and payment is recommended.	Amount Retained	$ 6,535.50
______________________ contracting officer's rep date	DUE THIS ESTIMATE	$ 58,819.50
Payment is approved. ______________________ Contracting Officer date		

REMARKS:

This pay estimate is an example only.

ITEM NO	ITEM DESCRIPTION	UNIT	PRICE	QUANTITY	AMOUNT
01900	Mobilization	LS	8,500.00	1.00	8,500.00
02110	Demolition	EA	400.00	1.00	400.00
02111	Removal of Existing Structures	EA	400.00	1.00	400.00
13610	Vault Toilet Building	EA	18,685.00	3.00	56,055.00
			CUMULATIVE TOTAL		65,355.00

Figure 1.--Sample contract payment estimate and invoice.

COST-TO-GOVERNMENT REPORT
Stanislaus National Forest
4/17/85

COMFORT STATIONS, INC.
46-9B66-2-72
Belcampo Construction Co.

Report No: 1

Construction Began: 7/26/84

Days Allowed: 120.
Extension Days: 20.
Total Days Available: 140.
Days Used: 70

Time Used: 50 %
Funds Used: 73 %
Funds Anticipated: 95 %

DOLLAR AMOUNTS

Original Contract	$ 84,840.00
All Modifications	$ 5,000.00
Present Contract	$ 89,840.00
Total To Date	$ 65,355.00
Total Probable	$ 85,240.00

REMARKS:

This cost-to-Government report is an example only.

BOB BADER ________ date
Forest Engineer

			QUANTITIES			AMOUNTS		
ITEM NO.	UNIT	PRICE	BID	TODATE	PROB	BID	TODATE	PROB
01900	LS	8,500.00	1.00	1.00	1.00	8,500.00	8,500.00	8,500.00
02110	EA	400.00	2.00	1.00	2.00	800.00	400.00	800.00
02111	EA	400.00	2.00	1.00	3.00	800.00	400.00	1,200.00
13610	EA	18,685.00	4.00	3.00	4.00	74,740.00	56,055.00	74,740.00

Figure 2.--Sample cost-to-Government report.

Is the Forest Service Ready for Artificial Intelligence?

Dale R. Petersen
Project Evaluation & Implementation Engineer
Washington Office

If the title question were posed, the answer might be "No." If we asked a similar question, but modified the time to "within 10 years," the answers might be "I hope so" or "I don't know." By the way, what is Artificial Intelligence (AI) anyway?

It may be a misunderstood term that has broad interpretation. Japan and the United States are in a race toward the fifth-generation computer and expert systems. On the other hand, software packages for microcomputers claiming to embrace AI are now available. The best concept of AI may have been expressed by William F. Zachmann, vice-president of International Data Corporation. During his interview in the May 6, 1985, Computerworld, he said, "I believe [artificial intelligence], expert systems, and software systems that aim in one way or another to extend human mental capabilities the way a bulldozer extends human physical capabilities will unquestionably be a very important part of the future." The same article states that expert systems will soon grow at a rate of 60 percent per year; and in 5 to 10 years, they will be everywhere.

Without realizing it at the time I purchased my computer, one software package designed to communicate with outside data bases is considered natural language processing, an element of AI. The program allows quick development of questions derived from a choice of English phrases to obtain data. The questions may be stored for reuse. This is elementary, to be sure. In fact, AI is in its infancy and at the same stage that computer programming was in the early 1950's. My understanding of AI incorporates natural language (not S2K variety), possibly speech recognition, and information from a knowledge base. This base is comprised of expert domain data or rules. For a given situation, it is possible to recall these rules to lead us through a proper sequence or to judgment choices, with certainty factors, at times using graphics. All of this involves heuristic problem-solving techniques using symbolic languages like LISP. Classical programming languages are considered inefficient and inadequate for developing symbolic processing applications.

AI is available for $3,000 on easy-to-use software on a microcomputer using up to 400 rules. Minicomputers can now handle up to 1,000 rules. Each rule is, in essence, an "if-then" law, rule, or expert opinion. Washington Office Engineering has a demonstration diskette of Personal Consultant, an expert system. Copies are available from Texas Instruments (TI) to run on TI or IBM personal computers.

I could envision several applications for AI. Three possibilities might be:

(1) Use of the Forest Service Manual. Imagine a Forest Service Engineer wanting to know the considerations for selecting a new bridge site or the process for obtaining a right-of-way. He or she uses the speech command microcomputer, asking questions relative to either a bridge or a right-of-way that might start, "How do I begin?" In the course of the computer dialogue, the Engineer is led to each important consideration in the Forest Service Manual (FSM), Regional supplement, Forest supplement, policy letters, Engineering practice considerations, decisions, and so forth, until he or she has a list of things to be done.

As conditions or policies change and as work progresses, the AI program is updated, and the Engineer can check to see if there are required changes or if anything has been overlooked. Important "first encountered" situations on these projects may become data for future considerations. It could lead to an "electronic FSM plus."

(2) Determining a Road Maintenance Program. It may be possible to include all of the requirements and considerations, conflicting or not, in developing a road maintenance budget into an AI program. By going through the rules and making certainty judgments that could incorporate features of tradeoff evaluation, value engineering, FSM requirements, and so forth, it may be possible to create a better, fairer budget. It would be interesting to try.

(3) A Ski Lift Safety Program. Suppose there is a ski lift derailment. What are all the considerations to be checked before the lift is put back into operation? We might ask our AI computer that question. We might find a number of "If this exists, do this" statements that may include such things as code requirements, State laws, lift history, personal contacts to make, field inspection items, reports to complete, operator factors, weather situations, and other reminders. This program might be a particularly good one to try, given the discontinuance of the Service-wide Ski Lift Engineer position. We could capture some of the incumbent's expertise before he or she departs.

These are but some examples of possible AI applications. Perhaps you can think of many more. Zachmann, in the Computerworld article, suggests that "the most important AI applications will run on personal computers." At this point, I pose the following possibilities as avenues that the Forest Service might pursue to explore AI in one of the above areas or in different areas:

(1) Interested users in the Forest Service might buy some of the AI microcomputer packages on the market and try an application. It does not have to be grandiose for starters. In fact, the smaller and simpler, the better are the chances for getting started. Any results should be shared Service-wide.

(2) Let Forest Service Research explore what is in the marketplace and recommend Forest Service applications that are most cost effective. If appropriate, Research might even develop some applications.

(3) Chief and Staff might determine how important AI is for the future. They, in turn, might charter a group to determine how big an AI program should be and at what rate it should be pursued, and for what priorities.

Perhaps if the Forest Service does pursue AI soon, we will be able to say "Yes!" to the question, "Is the Forest Service ready for Artificial Intelligence?"

Slave Your Old Demand Terminal or Serial Printer to a Data General Dasher D410 Video Display Terminal

Wayne T. Beddes
Civil Engineer, Systems Engineering
& L. Ray Flinn
Computer Programmer, Systems Engineering
Region 4

The purpose of this article is to increase awareness of the potential to use a surplus hard-copy terminal or an RS-232-compatible printer as a slave printer to the Data General Dasher D410 display terminal.

Are you currently using a Data General video terminal with no convenient means to print? Are you walking long distances to your letter-quality printer when all you really wanted was a simple screen dump? If you have an old hard-copy terminal that is collecting dust, why not slave it to the video terminal to accomplish screen dumps or to print anything displayed on the screen? To accomplish this, you need one more item in addition to your hard-copy terminal or serial printer--you must obtain or construct a printer port cable (shown in figure 1).

The slave printer attaches to the female 9-pin cannon connector on the rear of the D410 terminal. When you attach the printer or hard-copy terminal to the D410, make sure that the baud rates are the same by setting the printer DIP switches on the rear of the D410 according to table 1.

Table 1.--Baud rates.

Baud rate	Switches		
	2	3	4
192,000	1	1	1
9,600	1	1	0
4,800	1	0	1
2,400	1	0	0
1,200	0	1	1
600	0	1	0
300	0	0	1
110	0	0	0

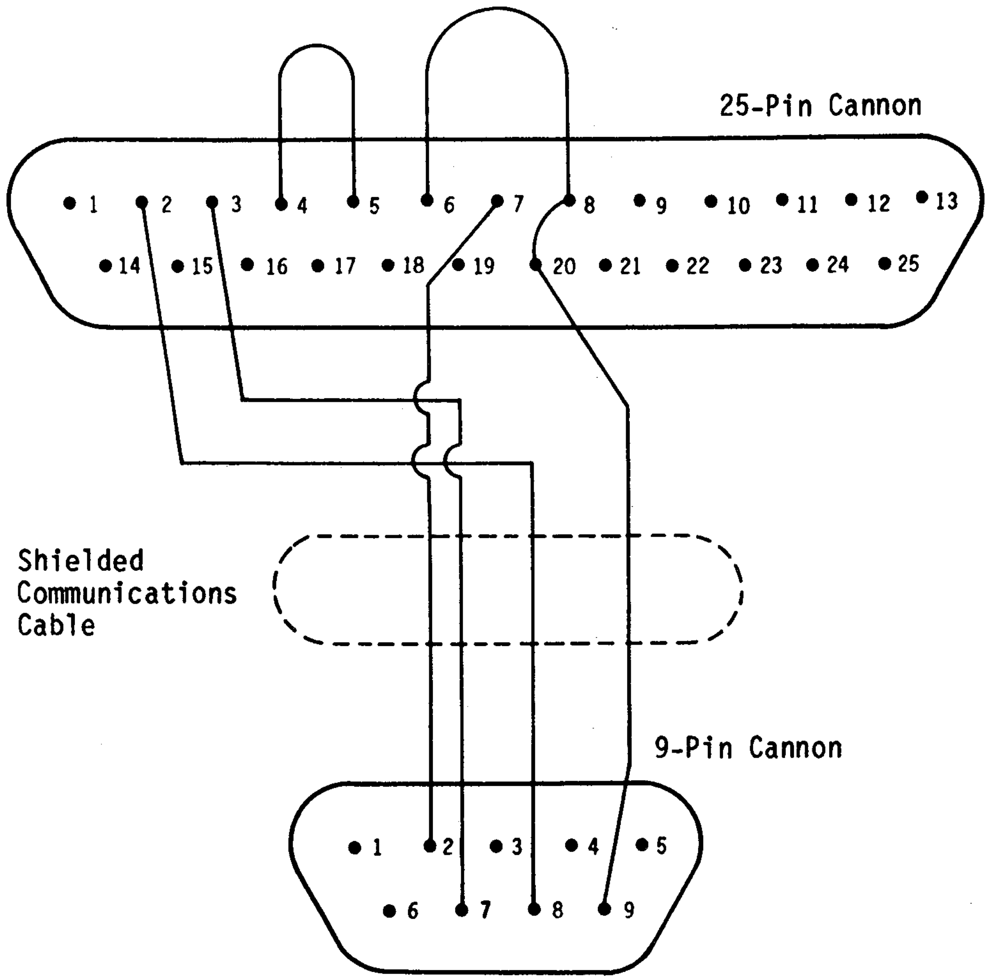


Figure 1.--Printer port cable.

To construct the printer port cable, you will need a male 9-pin cannon connector, 5 to 6 feet of shielded 4-conductor communications cable, and a male or female 25-pin cannon connector (commonly referred to as an RS-232 plug). (According to the RS-232 standard, remote terminals should have a male connector, but check your particular device since not all do.)

Jump pins 6, 8, and 20 together and pins 4 and 5 together on the 25-pin connector, then connect pin 8 of the 25-pin connector to pin 9 of the 9-pin connector; pin 7 to pin 2; pin 3 to pin 7; and pin 2 to pin 8. Refer to figure 1 or to your Dasher D410 and D460 display terminals user's manual.

With the terminal or printer attached to the D410, depress the LOCAL PRINT key to print the contents of the screen. This will home the cursor and then print everything on the screen from the cursor on down. If you try to print a Comprehensive Electronic Office screen and the cursor is trapped inside a screen window preventing you from printing the entire screen, you may negate the screen window by taking the terminal offline. To take the terminal offline, depress CMD-ON LINE and then depress CMD-BREAK ESC, FB000. Put the terminal back online and continue your screen dump in the normal way.

When you want to print more than one screen, put the D410 in print passthrough mode and you can direct all output that would ordinarily go to the screen to the printer. To engage the print passthrough mode, take the terminal offline, simultaneously depress the CMD and BREAK ESC keys, then sequentially depress F ? 3 (ALPHA LOCK must be on). The cursor will disappear from the screen, indicating that print passthrough is engaged. Put the D410 back online, and execute Command Line Interpreter commands such as TYPE or FILESTATUS. When you are finished with the printer, disengage the print passthrough by taking the terminal offline and depressing CMD-BREAK ESC F ? 2. If you want to execute print passthrough without taking the terminal offline, write a BASIC program such as the following to engage print passthrough:

```
10 print chr$(30)&chr$(70)&chr$(96)
20 end
```

Use the following to disengage print passthrough:

```
10 print chr$(30)&chr$(70)&chr$(97)
20 end
```

Alternatively, use a FORTRAN program such as this to engage print passthrough:

```
PRINT *,"<036><106><140>"
END
```

Use the following FORTRAN program to disengage print passthrough:

```
PRINT *,"<036><106><141>"
END
```

Engage and disengage print passthrough by executing the programs.

The hard-copy terminals require that you change the terminal characteristics so the host will send carriage returns in place of new lines. Do this by typing the Command Line Interpreter command CHAR/NAS. When you are finished with the printer, reset the terminal characteristics by typing the Command Line Interpreter command CHAR/RESET.

If you would like further information, contact Wayne Beddes (FTS 586-5200) or Ray Flinn (FTS 586-5199).

Aerial Photography Flight Altitude Determination

Dave Wolf
Assistant Geometronics Leader
Region 2

BACKGROUND

When obtaining aerial photography for mapping or other purposes requiring measurements using precision stereoplotters, it is necessary to control the altitude of the aircraft above sea level within fairly close tolerances. Region 2 specifies a tolerance of ± 5 percent of the nominal flight height above the ground, with a minimum tolerance of 100 feet for flight heights less than 2,000 feet.

For various reasons, much of the mapping photography procured by Region 2 actually is taken at altitudes that exceed this specification. However, such photography may still be usable; maps or measurements derived from photography taken at too high an altitude will be less likely to meet its accuracy specifications. Because flying seasons are short and waiting for replacement photography may cause delays of up to a year, it is often desirable to accept the out-of-specification photography along with the risks associated with its use.

Because it is difficult to apply a monetary value to this increased risk, Region 2 aerial photography specifications arbitrarily allow for a reduction in payment of 10 percent for each whole altitude tolerance increment or portion thereof that the actual flight altitude exceeds the specified altitude plus tolerance, up to a maximum payment reduction of 50 percent. For example, if the specified altitude for a flight was 11,000 feet (± 100 feet) and it was actually flown at 11,425 feet, there could be a 40 percent reduction in payment for that flight (11,000 + 100 = 11,100; 11,425 - 11,100 = 325/100 = 3.25, round up to 4 x 10 = 40 percent). Because contract payment can depend upon the determination of the actual flight altitude, it is extremely important that it be computed as accurately as possible.

THEORY

The flight altitude H is computed from the scale equation:

$$S = \frac{f}{H - h} \qquad (1)$$

or

$$S = \frac{f}{S} + h$$

where

f = the camera focal length;

S = the photo scale at a particular terrain elevation h.

The camera focal length f is always known. The scale S can be determined by measuring the photo distance between two points whose ground position has been surveyed or can be determined from a $7\frac{1}{2}$-minute quad (within $\pm$ 40 feet). Ordinarily, the elevations of points on a photograph are known from ground surveys or can be estimated within 20 feet or less from U.S. Geological Survey $7\frac{1}{2}$-minute quads (40-foot contour interval). Unfortunately, a photo scale (and, ultimately, the flight altitude) computed in this manner will be accurate only if the two points used have the same elevation. With typical Forest Service large-scale mapping photography, it is often difficult to find two points at any elevation that are identifiable on both a photo and a map, much less two that have the same elevation. Even if surveyed targeted points are available and two fall on a single photo, it is likely that they will have different elevations.

The error in photo scale determined from points with different elevations relates to the fact that the location of a point on a photo with a fixed ground position varies with its elevation and its position relative to the photo nadir. (The nadir, or ground point directly below the camera, can be assumed to be equivalent to the photo center, as indicated by the fiducials, for near-vertical mapping photography. The term "photo center" will be used hereafter.) As points increase in elevation, they are displaced radially outward from the photo center. Figure 1 illustrates this effect and the effect on the photo

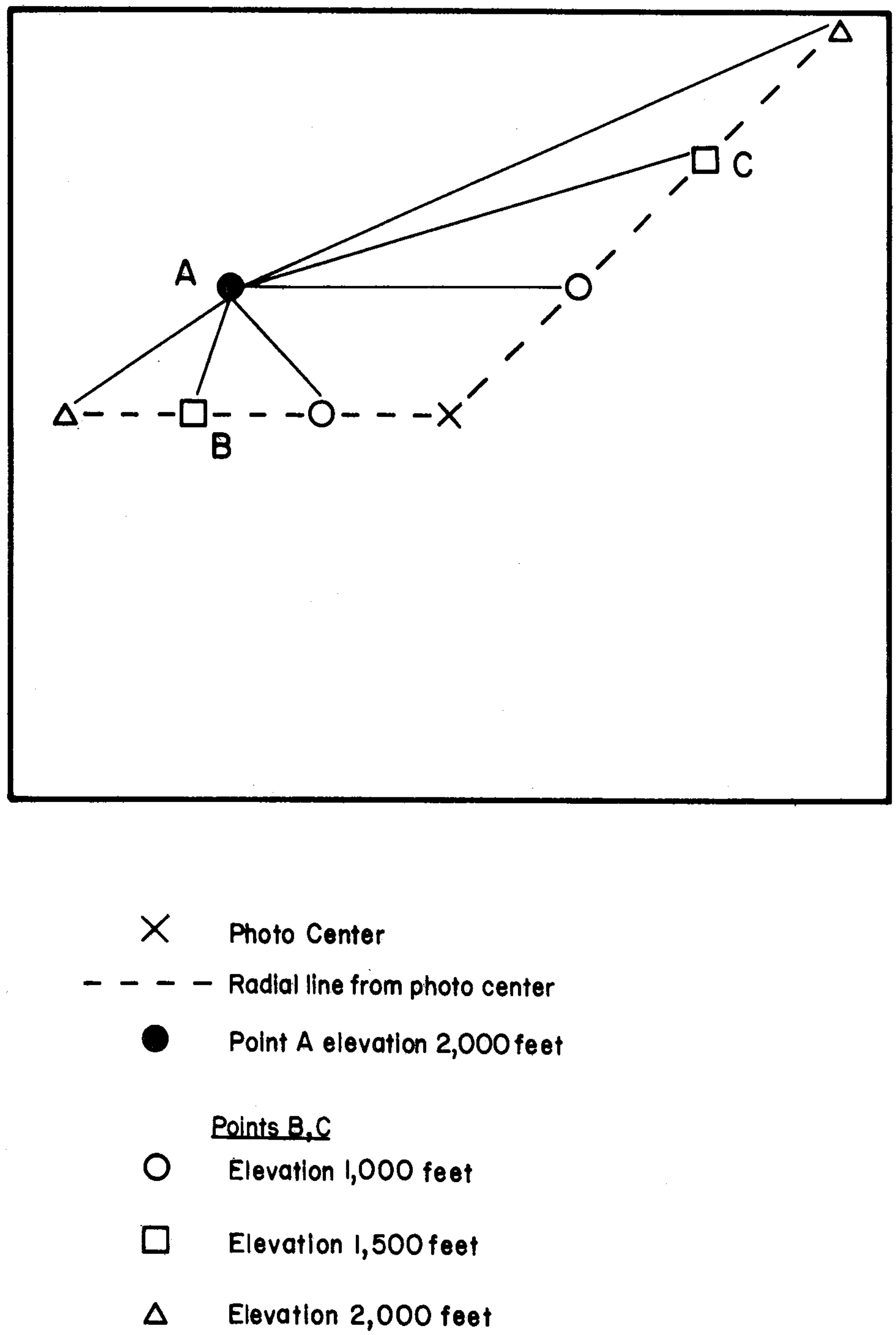


Figure 1.--The effect of elevation change on photo distance.

distance between point A (fixed) and points B and C (position fixed, elevation varies).

Figure 1 shows how the effect of elevation change on photo distance depends on the location of two points relative to the photo center and to each other. As the elevation of point C increases, the photo distance to point A also increases. The photo distance from point B to point A shortens as point B rises from 1,000 to 1,500 feet, then lengthens as point B rises to 2,000 feet. The true photo scale at elevation 2,000 feet could be computed from the photo distance to point A from either points B or C at elevation 2,000 feet. The true scale at any known datum could not be determined directly using point A and points B or C at elevation 1,000 or 1,500 feet.

Figure 2 illustrates the geometry of the effect of elevation change on photo point location. Using similar triangles, it can be shown that

$$r' = \frac{r\ (H-E)}{(H-E')} \qquad (2)$$

PROCEDURE for FLIGHT ALTITUDE DETERMINATION

Assuming a flight altitude H (that is, specified altitude) and with elevations h and h' known, a new radial distance at h' is computed by measuring the radial distance of a point on a photo. Then, the new location of the point at radial distance r' is plotted, and the photo distance measured to another point at elevation h'. The altitude is computed using the scale equation. If this altitude agrees with the assumed value within acceptable limits (that is, within 20 percent of the specified flight altitude tolerance), then this altitude is accepted; otherwise the process is repeated.

PRACTICAL APPLICATION

A 10-inch square piece of matte drafting film is prepared with two perpendicular lines parallel to the edges and intersecting at the center (see figure 3). The overlay is placed over a print or the negative of the pertinent air photo and taped so that the lines intersect the four side fiducials (diagonal lines could be used with corner fiducials). The intersection of the lines indicates the photo center. Two points are selected for photo scale determination, and the ground distance between them is noted. The radial distance r to the low point A is measured to the nearest 0.01 inch. (The high point B could just as well be used, but, for consistency, the low point is always used.)

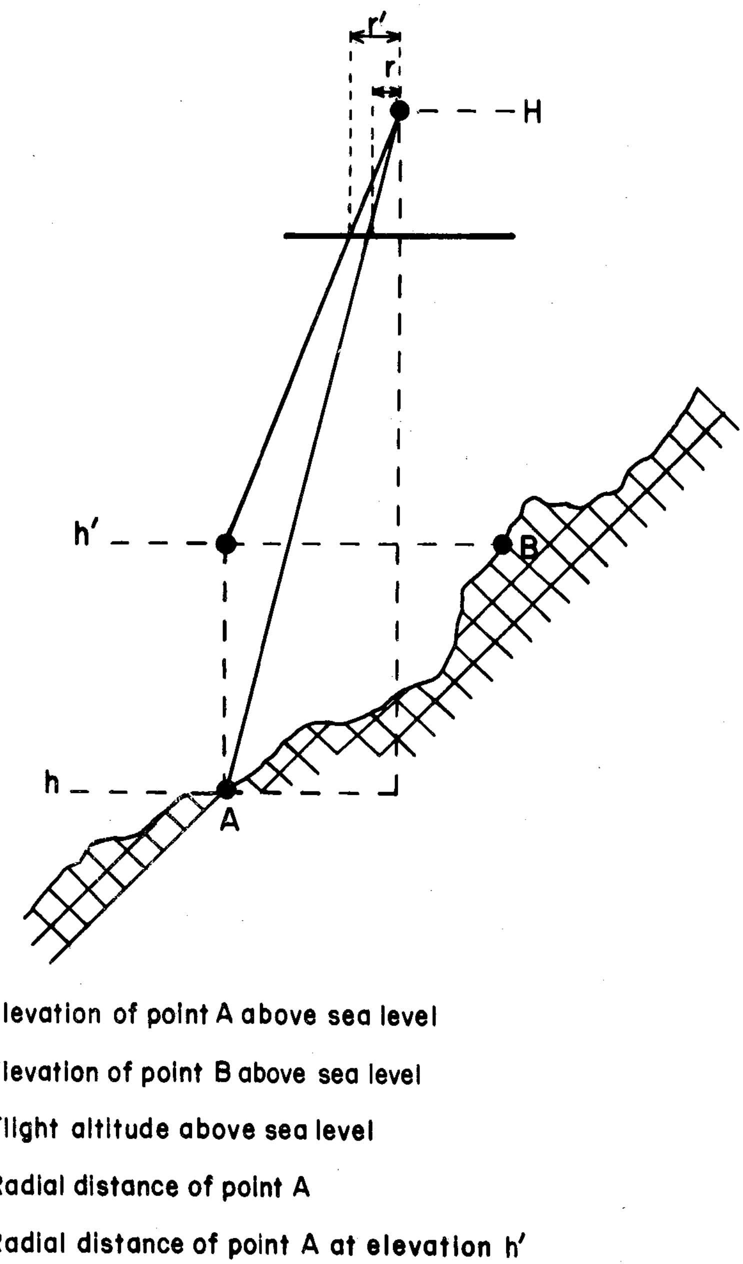


Figure 2.--The effect of elevation change on photo point location.

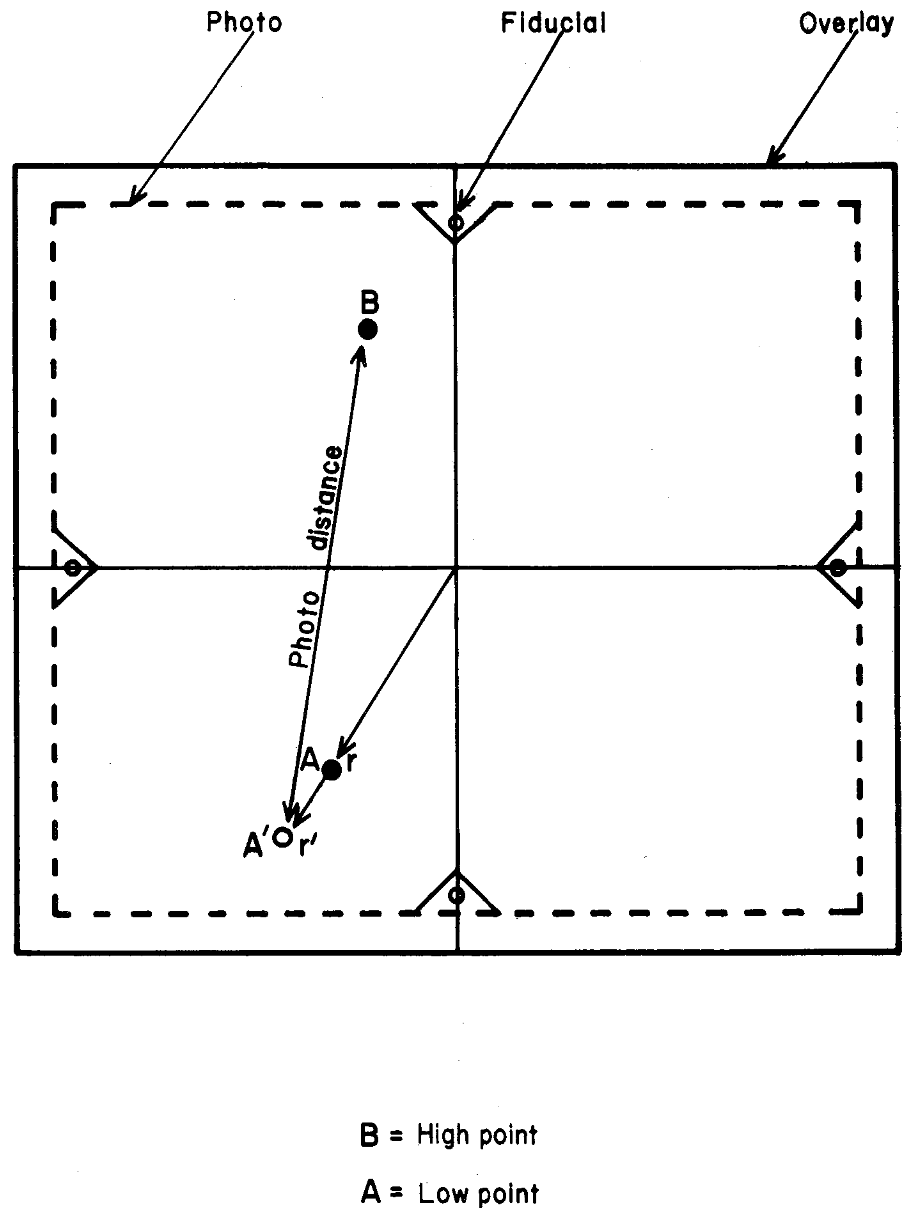


Figure 3.--Determining the photo center and flight altitude.

Equation 2 is used to calculate the radial distance r' at the elevation of point B. Using a scale aligned with the photo center and point A, a point A' is marked on the overlay at the new radial distance. This point is the photo location of point A if it were at the same elevation as point B. The photo distance is measured between A' and B and is used to compute the flight altitude using equation 1. This value is compared with the flight altitude assumed for use in equation 2. And if the value is not acceptable, a new radial distance r' is computed using this flight altitude and the process is repeated.

HAND CALCULATOR PROGRAM

The following program was developed for use in a Hewlett-Packard 41C. The author intends no endorsement of this calculator.

Storage Registers

00-04	Work registers
05	Nominal camera focal length f (feet)
06	Ground distance D between 2 points (feet)
07	Flight altitude convergence test value T (feet)

Registers 05 and 07 are loaded once for a photo project with a single camera and altitude tolerance; register 06 is loaded at the beginning of each problem.

Command	Comments and Run Instructions
LBL FLTALT	
R/S	Key in: (1) radial distance r (inches) to low point, press ENTER (2) elevation h (feet) of low point, press ENTER (3) elevation h' (feet) of high point, press ENTER (4) estimated flight altitude H (feet), press R/S
STO 01	Estimated H in register 01
RDN	
STO 02	h' in register 02
RDN	
STO 03	h in register 03

Command	Comments and Run Instructions (cont'd)
RDN	
12	
/	Convert r to feet
STO 04	r in register 04
LBL AGAIN	
RCL 01	Begin equation 2
RCL 03	h'
—	
RCL 01	Estimated H
RCL 02	h
—	
/	r' (feet)
12	
*	Convert to inches
R/S	Display r', key in photo distance in inches, press R/S
12	
/	Convert to feet
1/X	Begin photo scale computation
RCL 06	D
*	Photo scale (1/S), begin equation 1
RCL 05	f
*	
RCL 02	h'
+	Calculated H
STO 00	Calculated H to register 00

Command	Comments and Run Instructions (cont'd)
RCL 01	Estimated H
—	
ABS	Difference between estimated H and calculated H
RCL 07	T
X @ Y?	Is T larger than difference?
GTO CONVRG	Yes
RCL 00	No, calculated H is new estimate
RCL 04	Recall r
GTO AGAIN	Repeat equation 2
LBL CONVRG	
RCL 00	Display final H
GTO FLTALT	Return for new problem

Metal Open-Top Drainage Structure: "Flying W" Study

Ellen Lafayette
Civil Engineer
Ochoco National Forest
Region 6

HISTORY

The Ochoco National Forest has tried several methods of eliminating surface water on roads. We have tried insloping, outsloping, wood open-tops, drain-dips, and drivable waterbars. Their effectiveness is limited on grades exceeding 10 percent. The Willowa-Whitman National Forest has used an open-top drainage structure made of guardrail metal. This structure functions well but requires a concrete base and excavation equipment to the site.

Leroy Burk, Ochoco National Forest Road Crew Foreman, suggested the use of the "Flying W" guardrail configuration and a series of long anchor pins to hold the structure in place (see figure 1). Two such structures have been installed on the Spanish Peak road on the Ochoco National Forest and have been functioning well for some time.

Doug Daniels of the Coral Sales Company in Clackamas, Oregon, provided information on different guardrail configurations and their availability. The "Flying W" type guardrail is no longer manufactured, but the Coral Sales Company does keep it on hand for scrap metal.

In June 1984, a three-person crew installed three "Flying W" open-tops on timber sale roads of various grades and conditions. Installation took half an hour and only required hand tools. The grades ranged from 10 percent favorable to 14 percent sustained adverse. Surfacing types were crushed aggregate and native. Two of the installations had some clays in the subgrade that were pumping.

Figures 2 through 5 are photographs of an installed drainage structure. They illustrate the skew and type of surfacing, the interception of the road surface water, the need for some type of fillslope

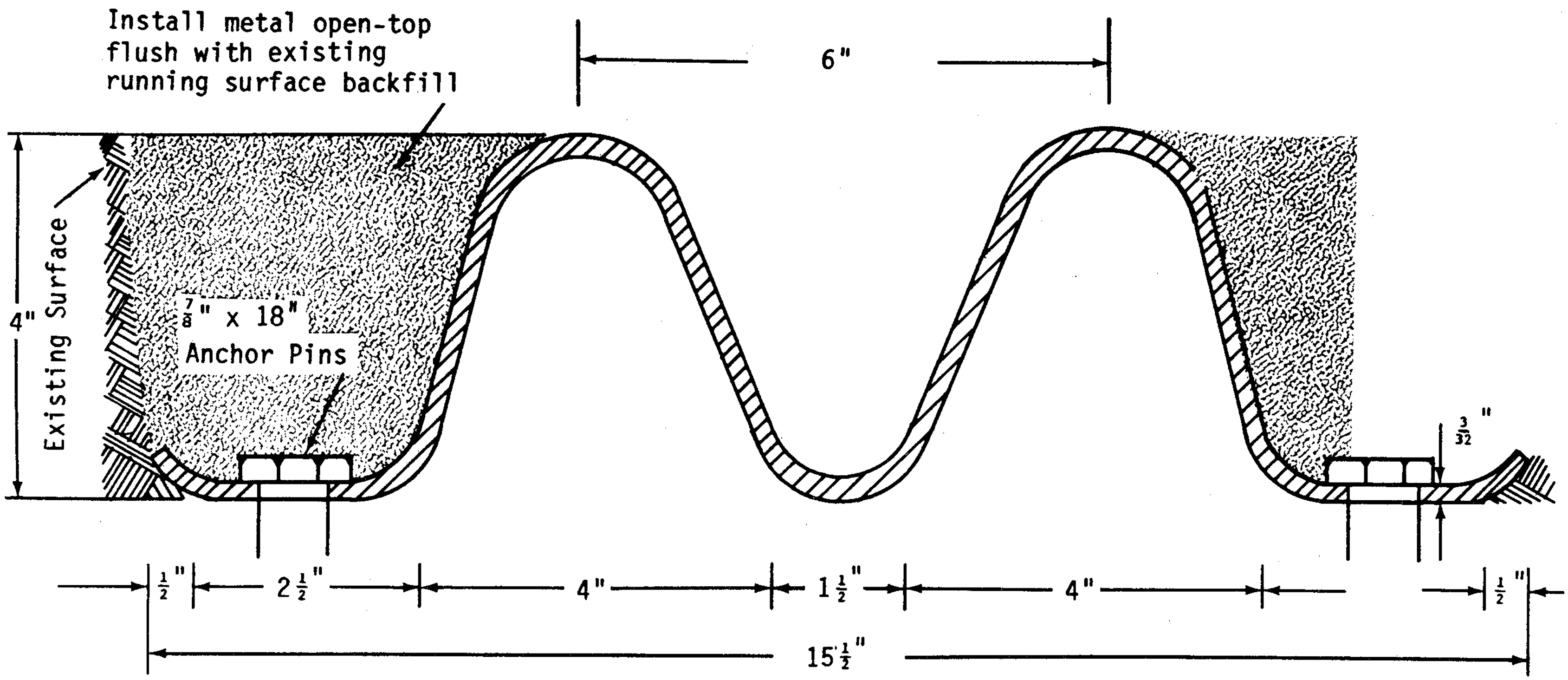
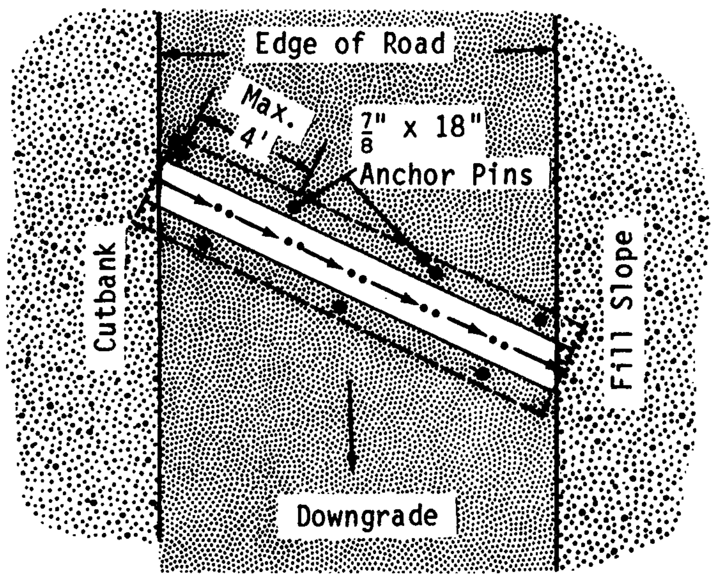


Figure 1.--"Flying W" metal open-top drainage structure.

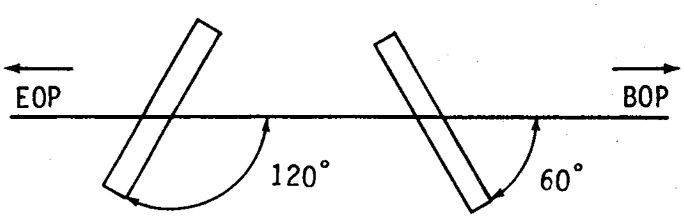
Method of Installation
Plan View



Install flying W open-tops at the locations, skews, and lengths shown on the drainage listing.

Refer to the end view for specific configuration and dimensions.

$\frac{7}{8}$" x 18" anchor pins, staggered as shown above, shall have a maximum spacing of 4 feet. They shall be driven flush with the wings as shown in the end view.



Skew Diagram

Figure 1. (cont.)--"Flying W" metal open-top drainage structure.

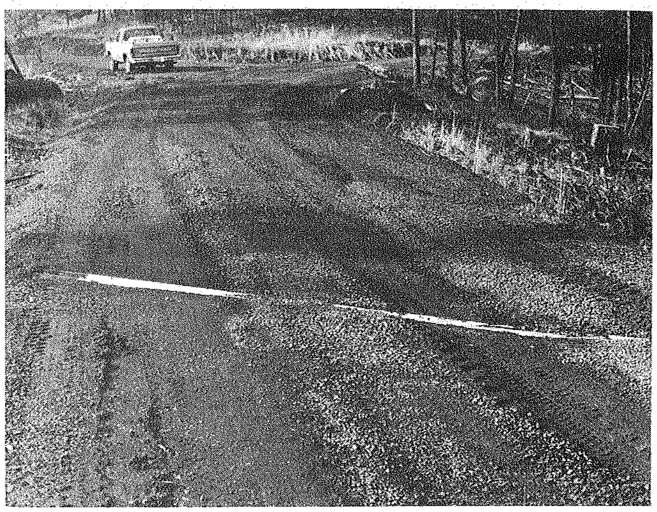


Figure 2.--Skew and type of road surface.

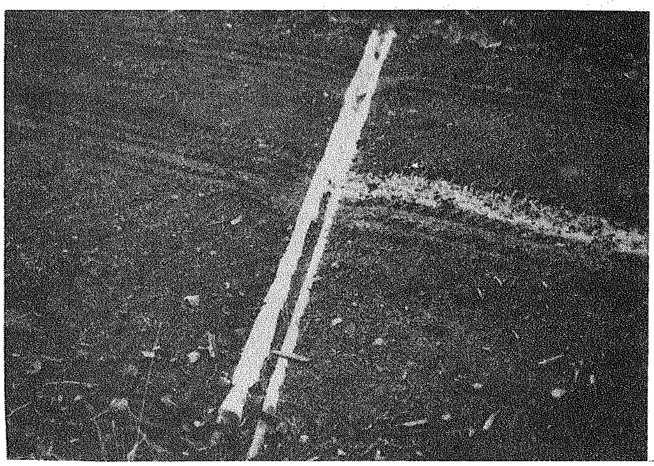


Figure 3.--Interception of road surface water.

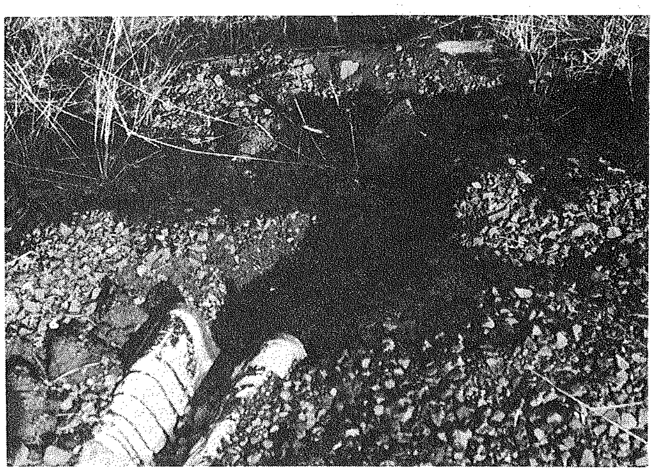


Figure 4.--Need for fillslope protection.

Figure 5.--End view of "Flying W" configuration showing the effect of log haul on the freshly bladed road.

protection, and an end view that also shows the tracking effect that the log haul has on the freshly bladed road.

TEST EVALUATIONS

We had anticipated the following problems:

(1) Guardrail buckling.

(2) Weld failing.

(3) Plugging.

(4) Grades hooking.

(5) Anchor pins pulling out.

The haul over the installations varied from 200,000 board feet to 2 million board feet from June 6 through October 26, 1984. The installation performed well. Of the five problems anticipated, only plugging occurred. It occurred on aggregate roads where the truck traffic tracked aggregate into the installation. Material tended to accumulate where the drift pins were placed in the trough.

From the limited testing, we anticipate that the plugging can be minimized by installing the drift pins only in the flanges and by decreasing the skew angle to a maximum of 60 degrees from the centerline. Energy dissipators (rock aprons) at the outlets also are recommended in erosive soils. Maintenance is simple; material can be removed during hauling or grading operations.

The test locations were all in cohesive soils; installations in granular soils have not yet been tested.

COSTS for MANUFACTURING the "FLYING W" CONFIGURATION

The use of the "Flying W" guardrail requires purchasing used or reconditioned material because the configuration no longer is commonly made. Normally, however, used material cannot be specified in Forest Service contracts. One solution to this problem is for the Government to supply the material. An independent manufacturer is interested in fabricating the product if there is enough interest.

Workman & Sons, of Prineville, Oregon, has provided the following information for the manufacturing of the "Flying W" configuration.

There would be an initial one-time only cost of $25,000 to $30,000 for tooling up. The company would have to recover this in the first year for the project to be cost effective for them. After tooling up, costs would be $3.75 per linear foot. If 5,000 feet were ordered in the first year, the costs would be $8.75 to $9.75 per linear foot ($3.75 per linear foot for materials, fabrication, and profit, $5.00 to $6.00 per linear foot for tooling up). After the first year, costs would drop to $3.75 per linear foot.

If demand develops, the specifications would be changed to contractor-furnished materials (see figure 7 for sample Special Project Specification 649).

Cost Comparison

The following installation costs reflect the cost of materials from Coral Sales and the cost of using a force account crew for the installation work. The costs would increase if costed to comply with the attached specification and drawings. The compaction method in the specification would require a mechanical tamper. The rest of the equipment required to install the open-top structure would remain the same.

The cost of a metal drainage structure using the "Flying W" guardrail configuration are as follows:

Material (18 feet) ($2.40/LF) + $1.80	
Fabrication Cost	$50.00
Anchor Pins	5.00
Installation (allow 1 hour for 3 laborers with shovels; this includes moves between site	52.00
Pickup with trailer	25.00
Total	$132.00

Adding maintenance costs gives a total of $135.00, which is $7.50 per linear foot.

CONCLUSION

The "Flying W" configuration has proven to be a cost-effective drainage installation. Important features are low material cost, low installation cost, minimal equipment, and ease of maintenance. The Ochoco National Forest is including these installations in contracts on local roads where drainage is required on grades exceeding 8 percent. At present, the "Flying W" guardrail is Government furnished. To eliminate the effect on Forest funds, we hope to correct that situation.

Readers interested in further information on the "Flying W" can contact Ellen Lafayette, Ochoco National Forest, at (503) 446-6247.

SPECIAL PROJECT SPECIFICATION

Section 649 - METAL OPEN-TOP DRAINAGE STRUCTURE (GUARDRAIL TYPE)

DESCRIPTION

649.01. This work shall consist of installing metal open-top drainage structures in accordance with these specifications and in reasonable close conformity with the lines and grades SHOWN ON THE DRAWINGS. This work includes all excavation, bedding, and backfill required to complete the work. Installation also includes furnishing the anchor pins, and any necessary cutting and welding of sections.

MATERIALS

649.02. Drainage structure material shall be standard metal beam guardrail furnished by the Government.

649.03. Anchor pins. Anchor pins shall be galvanized or zinc-coated steel and may be round or rectangular cross-section. Anchor pins shall be a minimum 5/8-inch diameter x 18 inches long, with a 1-1/8-inch diameter head and used with a 1-1/2-inch diameter washer.

CONSTRUCTION REQUIREMENTS

649.04. - Installation. The metal open-top drainage structures shall be installed at the locations and to the lines and grades SHOWN ON THE DRAWINGS and staked on the ground. Guardrail shall be cut and spliced as needed to provide continuous drainage structures at each installation. Welding shall be done in accordance with Section 555 and as SHOWN ON THE DRAWINGS.

649.05. - Excavation. Excavation shall be in accordance with the requirements of Section 206A.

649.06. - Bedding. The bedding shall provide a firm foundation of uniform density throughout the length of the structure.

649.07. - Anchoring. Anchor pins shall be placed as SHOWN ON THE DRAWINGS. Alternative anchoring devices may be used if approved in writing by the Engineer.

649.08. - Backfilling. Metal open-top drainage structures shall not be placed or backfilled until the structure, excavation, and bedding have been approved by the Engineer.

Figure 7.--Sample Special Project Specification.

After bedding is prepared and the drainage structure is placed, the excavated area around the structure shall be backfilled with suitable granular material not exceeding 1-1/2 inches in diameter. The backfill material shall be of a moisture content suitable for effective compaction and shall be compacted with a mechanical tamper until visual displacement ceases.

METHOD OF MEASUREMENT

649.09. The method of measurement will be DESIGNATED in the SCHEDULE OF ITEMS and measured in accordance with Section 106.

BASIS OF PAYMENT

649.10. The accepted quantities will be paid for in accordance with Section 106 at the contract unit price for each pay item shown in the SCHEDULE OF ITEMS.

Pay Item		Pay Unit
649(01)	Install Metal Open-Top Drainage Structure, Government-Furnished Materials	Linear Foot
649(02)	Install Metal Open-Top Drainage Structure, Government-Furnished Materials	Each

Figure 7. (cont.)--Sample Special Project Specification.

HP-41 Road Data & Design System (41-RDADS)

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Chattahoochee-Oconee National Forests
Region 8

INTRODUCTION

This article describes a collection of calculator and computer programs that were developed on the Chattahoochee-Oconee National Forests for use in staking out route locations, collecting survey data, and field designing Forest roads. The program outputs can be used either as electronic input to RDS or as final design quantity and slope-stake printouts, depending on whether the design is performed on the UNIVAC mainframe or entirely on the HP-41 and Data General equipment. The system consists of the following:

(1) HP-41 programs that provide information and assistance in staking out route locations and that store the collected survey data.

(2) HP-41 programs that assist the user in field designing low-cost Forest roads; calculate and store clearing, earthwork, and seeding quantities; and provide slope-stake data.

(3) HP-41 programs that transfer data from one device to another.

(4) Programs that run on Data General equipment and either:

  (a) Format the collected survey data for transmission to Fort Collins Computer Center (FCCC) for subsequent use by RDS, or

  (b) Provide an output with clearing, earthwork, surfacing, and seeding quantities, and slope-stake and grade information for field-designed Forest roads.

The system reflects the types of survey and design methods we currently use on the Chattahoochee-Oconee National Forests. The procedure is described by the flow chart in figure 1.

The following is a list and brief description of the programs that are currently part of this system:

HP-41 PROGRAMS

STA. Provides centerline stationing and minimum lane width; allows selection of curves by choosing radius, tangent, or external; calculates maximum radius curves fitting between two points of intersection; provides information for staking out centerline stations circular curves; and collects and stores RDS card type 16 data. Figure 2 illustrates the use of this program.

Will road be field-designed or will RDS be used?

RDS
(Level C and Difficult terrain Level D)

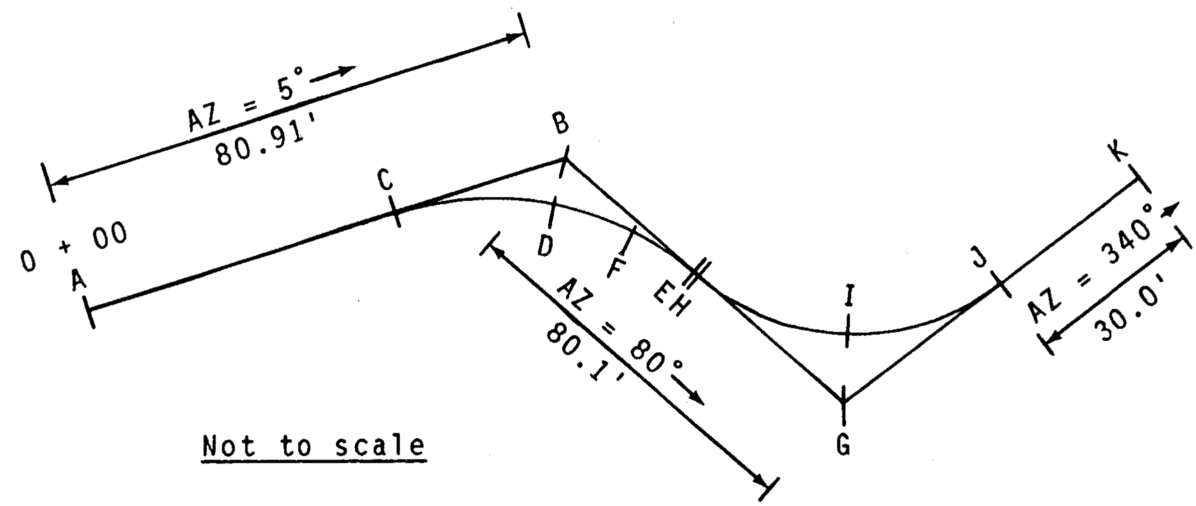
1. Centerline is staked with STA program. CT 16 data are stored.
2. Cross-section and profile data are taken with XSECT program, and CT 52 data are stored.
3. Data are dumped into Data General equipment and transmitted to FCCC.
4. Road is designed on UNIVAC mainframe using RDS.
5. Road is slope staked.

Field Design
(Favorable terrain Level D)

1. Centerline is staked with STA program. This step is not necessary in terrain where free-flowing alignment will work.
2. Road is designed and slope staked in field using BALANCE program.
3. Data are dumped into Data General computer for output with slope-stake information and quantities.

Plans and contract document are completed.

Figure 1.--Procedures for determining route locations.



LOC.	CALCULATOR PROMPTS	USER INPUTS	CALCULATOR RESPONDS	COMMENTS
	TRUCK L1?	15.00		
	TRUCK L2?	30.00		
A	BEG STA?	0.00		
	BEG AZ?	5.00		
B	DIST?	80.91	STA=80.91	USER STAKES PI
	DIST?	R/S		NEEDS AZ PROMPT
	AZ?	80.00	DELTA=R75.00	
	TANG?	R/S		
	RAD?	R/S		
	EX?	R/S		
	TAN?	40.00	DEG=109.54	MUST RESPOND
			EX=13.58	
			LC=68.24	
			RAD=52.13	
			MIN WID=19.58	
	IS TANG OK?	Y	PI=80.91	
C			PC=40.91	USER SETS PC
D			EX=75.03	USER SETS EX
E			PT=109.15	USER SETS PT
	DIST?	XEQ POC		TO SET POC
	POC TO SET?	95.00		
	SET FROM?	75.03	SC=19.85	
F			AZ=53.2835	USER SETS POC
		POC TO SETµ	R/S	NO MORE POCs
G	DIST?	40.1	STA=149.25	USER SETS PI
	DIST?	R/S		NEEDS AZ PROMPT
	AZ?	340.00	DELTA=L100	
	TAN?	RIS		
	RAD?	52.13	TANG=62.13	
			DEG=109.54	
			EX=28.97	
			LC=90.98	
			RAD=52.13	
			MIN WID=23.90	
	IS TANG OK?	Y	PI=149.25	
H			PC=87.12	USER SETS PC
I			EX=132.61	USER SETS EX
J			PT=178.11	USER SETS PT
K	DIST?	30.00	STA=208.11	PROCEED AS ABOVE

Figure 2.--Staking centerline with 41-RDADS STA program.

XSECT. Collects and stores cross-section and profile data (RDS card type 52). Figure 3 illustrates the use of this program.

BALANCE. Assists in field design of Forest roads; provides a self-balanced sidehill template on shallow sideslopes or a bench template on steep sideslopes; allows for user-input limits such as maximum vertical cuts and daylight extensions; allows user-input centerline cut/fills; provides finished road grade and adjusted net mass in field; provides slope stake and clearing flag information; and stores data necessary for computing clearing, earthwork, surfacing, and seeding quantities. Figure 4 illustrates the use of this program.

DUMPEM. Transfers data from HP-41 extended memory to HP cassette tape.

XDUMP. Transfers cross-section and profile data from HP cassette tape to Data General AOS file.

RDUMP. Transfers centerline retrace data from HP cassette tape to Data General AOS file.

BDUMP. Transfers BALANCE data from cassette to Data General AOS file.

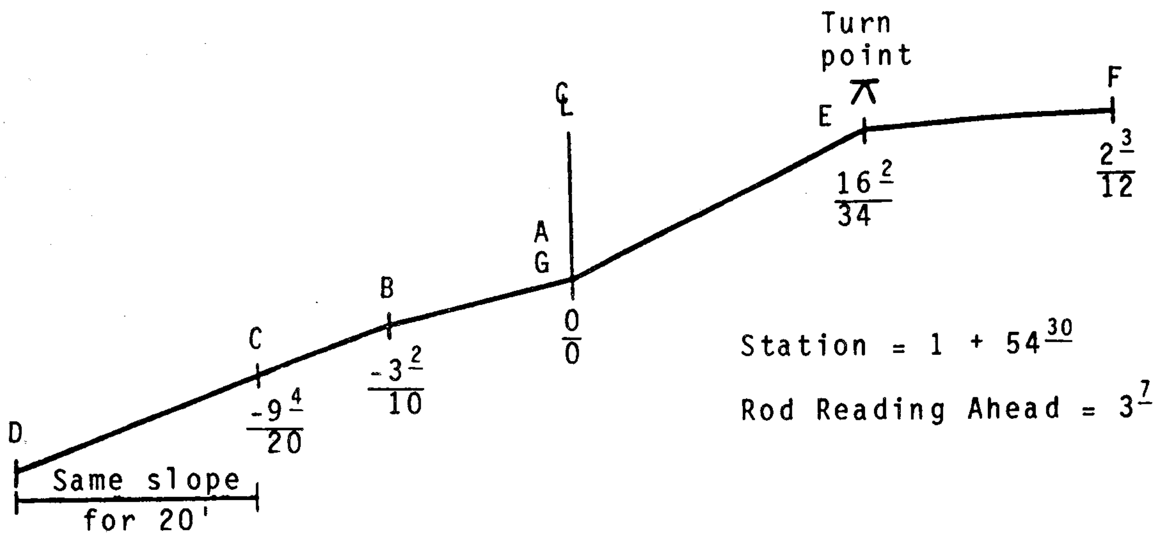
DATA GENERAL PROGRAMS

These programs are written in BASIC and were developed on the Chattahoochee-Oconee National Forests. They are all executed from the "41CV" master program, which was written in CLI by the Engineering Computer Applications Group in Region 8 and modified by the Forests.

RETRACEFMT. Reformats card type 16 data for RDS use and sets up a file for transmission via 2780 communications to FCCC.

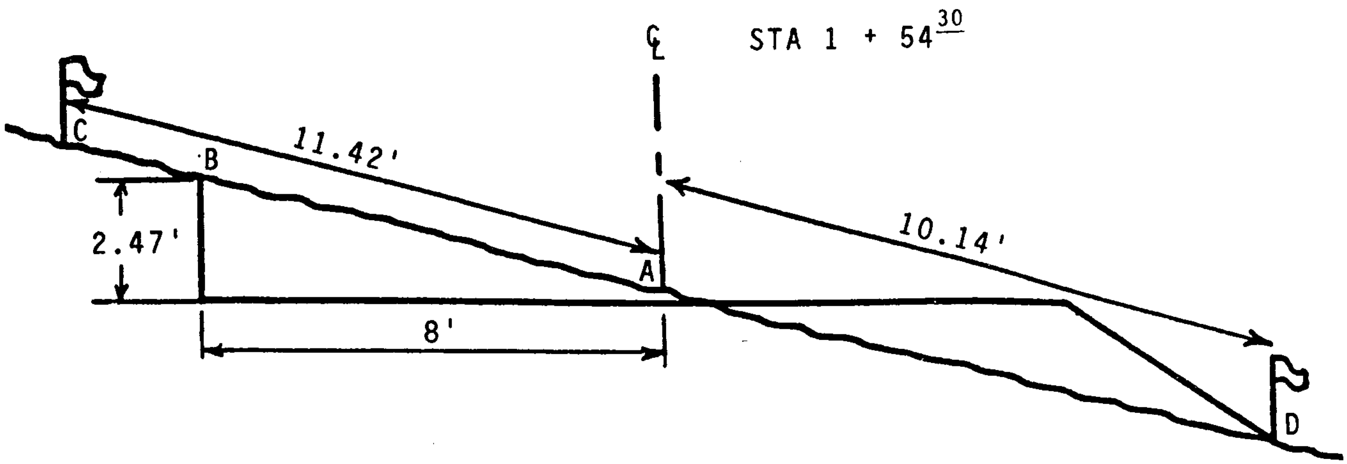
CROSSFMT. Reformats card type 52 data for RDS use and sets up a file for transmission via 2780 communications to FCCC.

BALANCE. Computes clearing, earthwork, surfacing, and seeding quantities; produces formatted output of field book information, staked road characteristics, quantities, and slope stake data for field-designed roads. Figure 5 shows a sample output from this program.



LOCATION	CALCULATOR PROMPTS	USER INPUTS	CALCULATOR RESPONDS
EARLIER	SD.SHT.R/D?	Y	
	SHT.AHD.ROD?	Y	
	LT.SD.1ST?	Y	
A	STATION?	154.30	LEFT SIDE
B	L ROD?	-3.2	
	DIST?	1 (error)	
C	L ROD?	-9.4	
	DIST?	20	
D	L ROD?	99	
	DIST OF SS?	20	RIGHT SIDE
E	ROD? R	16.2	
	DIST?	34	
	ROD? R	-99	TN AT LAST PT
F	ROD? R	2.3	
	DIST?	12	
	ROD? R	R/S	6 PTS
G	ROD AHEAD?	3.7	
	O.K TO STORE?	R/S	STA=154.30
		R/S	AHEAD=3.70
		R/S	9900.020
		R/S	-94.020
		R/S	-32.001
		-32.010	-32.010
		R/S	0.000
		R/S	99162.034
		R/S	23.012
		R/S	
	O.K. TO STORE?	Y	STORED
NEXT A	STATION?		

Figure 3.--Recording cross-section and profile data with 41-RDADS.



LOCATION	CALCULATOR PROMPTS	USER INPUTS	CALCULATOR RESPONDS
EARLIER	CUT SLP ?/1	0.75	
	FILLSLP ?/1	1.5	
	% SHRINK	40	
	MAX VRT CUT?	5	
	AD. V CT CLR?	3	
	AD. S CT CLR?	3	
	ADD. FIL CLR?	0	
	TOTAL WIDTH?	14	
	W/2 TO CUT?	8	
A	STATION?	154.30	
	% SIDESLOPE?	28	
A,B	CL C/F?	R/S	CUT=2.47
NOTE:	On line above, user hits R/S to self-balance. He could also input his own CL cut or fill.		
B		R/S	DIST=8.00
		R/S	VERT CUT
C			S=11.42
D		R/S	F=10.14
A		R/S	CL C/F=0.23
		R/S	% R.GRD=6.19
	% AHEAD?	9	
	O.K. TO STORE?	R/S	UP TO 154.30 MASS=0.00
	O.K. TO STORE?	Y	STORED
NEXT A	STATION?		

NOTE: The section shown above is a normal sidehill section with a vertical cut. It is also possible to have a sidehill section with a sloped cut, a full bench section, a through cut section, and a through fill section. Examples of these sections follow.

Figure 4.--Designing and slope staking with 41-RDADS BALANCE program.

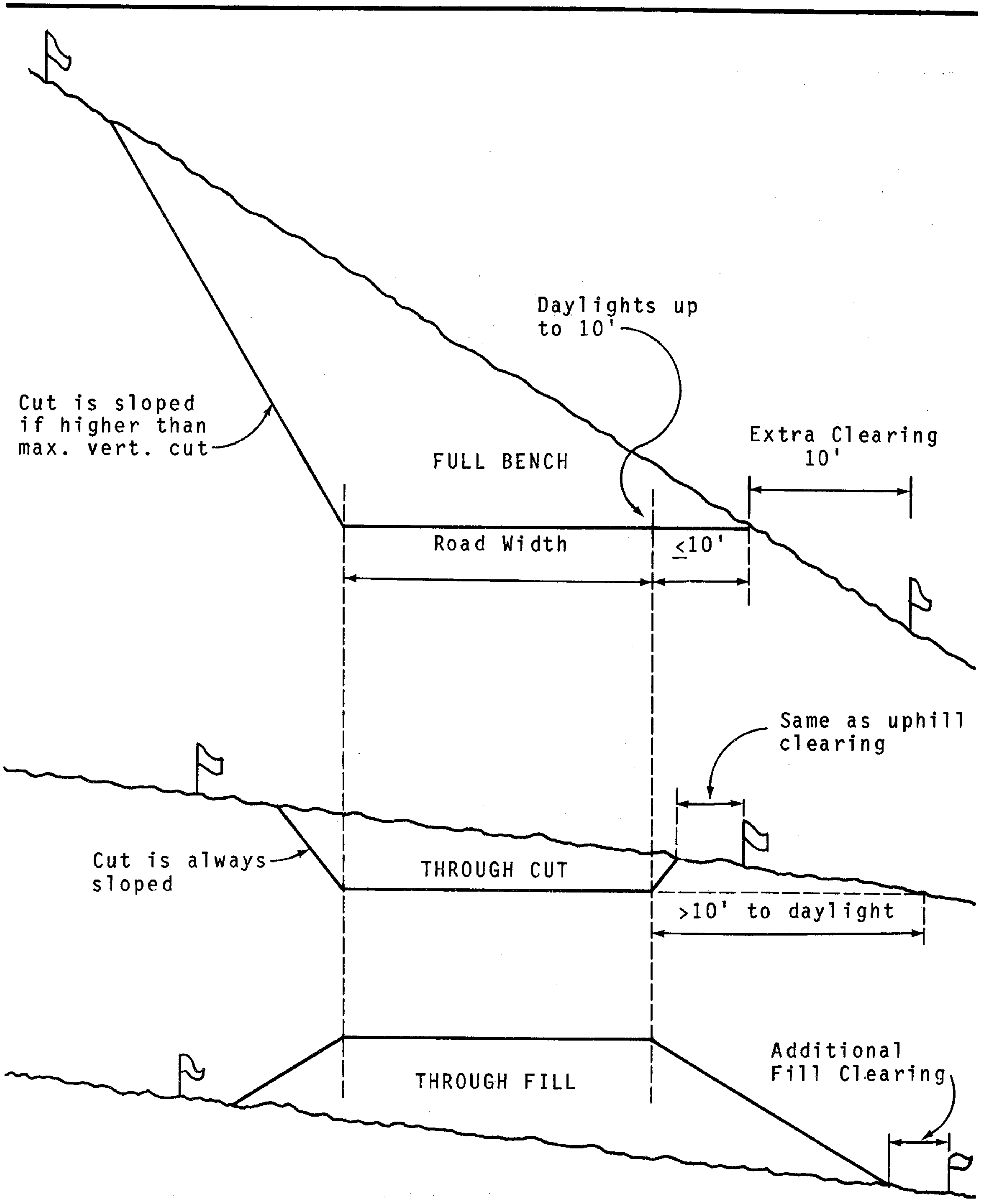


Figure 4. (cont.)--Designing and slope staking with 41-RDADS BALANCE program.

CONCLUSION

The implementation of this system has resulted in a substantial savings in survey, design, and slope-staking cost on the Chattahoochee-Oconee National Forests. It has many details that are not possible to explain in a short article such as this. However, a user's manual is available that describes the programs in greater detail. Readers who have further questions or who are interested in implementing the system on their Forests should contact Dan McReynolds or Randy Warbington at Chattahoochee-Oconee National Forests, 508 Oak Street, Gainesville, Georgia 30501; the phone number is (404) 536-0541.

ROCK CREEK ROAD #124-B   2/25/85

NOTEBOOK

STATION	GROUND EL.	ROAD WIDTH	CL C/F	% SIDE SLP	STAKE C/F	STAKE DIST
.00	500.00	12.0	.0	15.0	.9	6.0
58.50	503.51	12.0	4.0	15.0	5.5	-10.1
104.00	498.05	12.0	-3.5	21.0	-1.7	8.6
147.50	501.97	12.0	3.0	35.0	6.9	11.2
200.00	504.07	12.0	.4	25.0	1.9	6.0
250.00	504.07	12.0	.2	15.0	1.1	6.0

NOTEBOOK SUMMARY

HP-41 FILE NAME	ROCKCR	FILLSLOPE	1.5
ROAD NUMBER	124-B	CUT SLOPE	.75
SURVEYED BY	RLW	ADD. FILL CLEARING	0
SURVEY DATE	022585	ADD. VT. CUT CLRG	3
PERCENT SHRINKAGE	40	ADD. SL. CUT CLRG	3.0
BEGINNING STATION	0	ENDING STATION	250.00
TOTAL MILES	.05		

ROCK CREEK ROAD #124-B   2/25/85

EARTHWORK

STATION	ROAD EL.	ROAD GRADE	EXC. C.Y.	EMB. C.Y.	CUM. EXC.	ADJ. MASS
0.00	500.00					
		-0.8	69.42	3.77		
58.50	499.51				69.42	37.88
		4.5	51.72	58.70		
104.00	501.55				121.14	10.21
		-5.9	40.58	56.12		
147.50	498.97				161.72	-21.56
		9.0	55.71	4.03		
200.00	503.71				217.63	7.83
		0.4	9.94	5.96		
250.00	503.90				227.38	7.83

EARTHWORK SUMMARY

TOTAL EXCAVATION C.Y. = 227.4
TOTAL EMBANKMENT C.Y. = 128.6
ADJUSTED MASS = 7.8

Figure 5.--Output from Data General BALANCE program.

ROCK CREEK ROAD #124-B   2/25/85

CLEARING, SEEDING, AND SURFACING

STATION	CL. WIDTH	CLEAR AREA	CUM. CLEAR	SEED AREA	CUMUL. SEED	SURF WIDTH	SURF TONS
0.00	20.00					12.00	
		0.030		0.003			
58.50	24.23		0.030		0.008	12.00	9.75
		0.027		0.014			
104.00	27.98		0.057		0.022	12.00	17.33
		0.030		0.012			
147.50	32.76		0.037		0.034	12.00	24.58
		0.032		0.007			
200.00	20.00		0.119		0.041	12.00	33.33
		0.023		0.003			
250.00	20.00		0.142		0.044	12.00	41.67

CLEARING, SEEDING, AND SURFACING SUMMARY

TOTAL ACRES SEEDED = .044
TOTAL ACRES CLEARED = .142
TOTAL SURFACING, TONS = 41.67
SURFACING THICKNESS, INCHES = 3.00
SURFACING DENSITY, TONS/CY = 1.5
SEEDING OPTION 1 - CUT AND FILL SLOPES SEEDED

Figure 5. (cont.)--Output from Data General BALANCE program.

Temporal Variations in Traffic Volumes

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Region 6

This article presents three traffic volume variation patterns by hour of day, day of week, and month of year. These patterns were developed from two sets of data collected from the Mount St. Helens National Volcanic Monument area in 1982 and 1984. The purpose of this presentation is to increase the awareness of traffic volume distribution over time. This aspect of traffic characteristics is important to road design and management.

INTRODUCTION

Traffic volume is one of nine variables that are used to define the traffic service level of a road system. The others are flow, vehicle types, critical vehicle, safety, traffic management, user costs, alignment, and road surface. Traffic volume has significant influence on both flow and user costs. Because of its importance, it has been used as a major factor in deciding whether a road should be single- or double-lane (FSH 7709.11). For example, a single-lane road should be selected if projected traffic volumes are less than 100 vehicles per day. On the other hand, a double-lane road should be selected if projected traffic volumes are greater than 250 vehicles per day. In cases where projected traffic volumes fall between these two extremes, other factors, such as social or political concerns, relationship to public road systems, season of use, availability of funds, and traffic management, are used along with traffic volume to determine road size.

Speed is often used as a representative of flow or user costs. The relationship between speed and traffic volume has been reported in other articles, including "Identifying Road Capacity and Traffic

Service Level," <u>Engineering Field Notes</u>, Vol. 16, April-May 1984; "Evaluating Capacities of One-Lane Road with Turnouts," <u>Transportation Research Record</u> 971, 1984; and "Family Curves for Estimating Single-Lane Road Capacities," <u>Engineering Field Notes</u>, Vol. 16, July-August 1985. Traffic volume is the main concern of the present study, and its relationship with speed will not be discussed in this report.

Considering a day to be 10 hours and assuming the majority of traffic to be concentrated in 3 peak hours, a volume of 100 vehicles per day can result in a peak-hour volume of more than 25 vehicles per hour. If a road segment is capable of accommodating 25 vehicles per hour, then the capacity of that road segment is 250 vehicles per day, instead of 100 vehicles per day. However, a road with a capacity of 250 vehicles per day may have peak-hour volumes of 70 vehicles per hour. Therefore a road designed for 100 vehicles per day is one designed for a maximum hourly volume of 25 vehicles per hour, or 70 vehicles per hour in the case of a 250-vehicle-per-day road. If this is true, why not use 25 or 70 vehicles per hour as a standard in selecting single-lane or double-lane roads? For rural highways, AASHTO uses the 30th highest hourly volume of the design year as the design capacity (see "A Policy on Geometric Design for Rural Highways," AASHTO, Washington, D.C., 1965). However, we cannot do so because there is not enough understanding about traffic variation over time. The following discussion, therefore, investigates hourly, daily, and monthly variations in traffic volumes.

SOURCE of DATA

Two sets of data collected from the Gifford Pinchot National Forest were used for analysis. The study area is adjacent to the Mount St. Helens National Volcanic Monument and is shown in figure 1.

The first set of data was collected from 14 study sites from May through November 1982. The duration of data collection for each site varied. As shown in table 1, half the 14 sites were single-lane roads and half were double-lane. Eight of the sites were paved, five were gravel, and one was native. The average daily traffic (ADT) ranged from 156 to 867 vehicles. The majority of the traffic consisted of logging trucks. The road segments were not open to the public during the study period. Most vehicles were equipped with CB radios, which were used to help control the traffic.

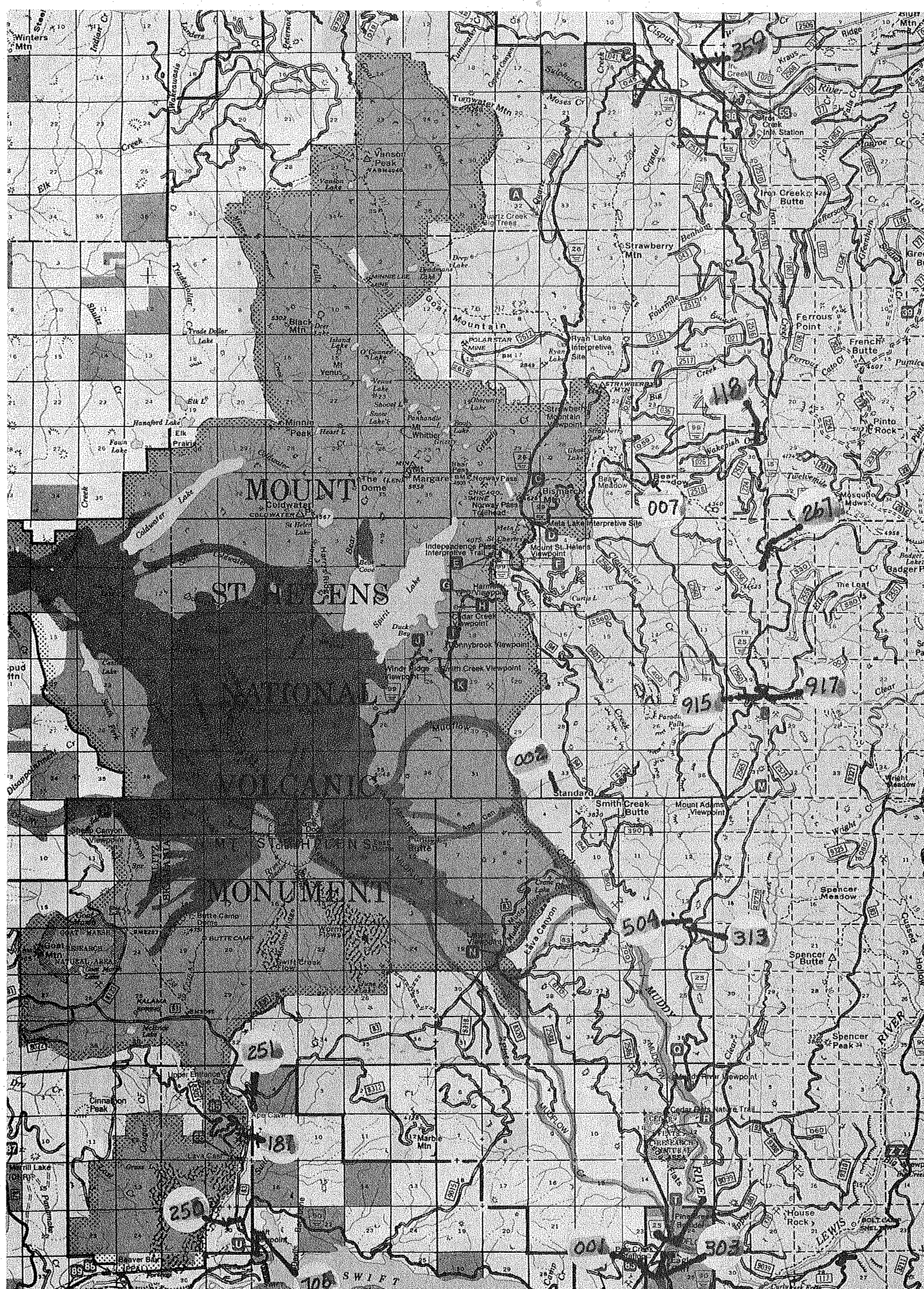

Figure 1.--Location of selected traffic study sites in Mount St. Helens National Volcanic Monument area.

Table 1.--Data characteristics.

Road number	Site number	Number of lanes	Type of surface	ADT	Majority of traffic	Duration of observation
90	001	double	paved	713	Logging trucks	May 26-Aug. 28, 1982
9200340	002	single	native	156	Logging trucks	June 4-Oct. 20, 1982
99	007	single	gravel	1,033	RV's	July 1-Sept. 15, 1984
99	118	single	paved	379	Logging trucks	June 18-Nov. 8, 1982
				979	RV's	July 1-Sept. 15, 1984
83	181	double[a]	gravel	299	Logging trucks	June 9-Nov. 9, 1982
83	250	double[a]	gravel	284	Logging trucks	June 4-Oct. 22, 1982
83	251	single	gravel	224	Logging trucks	July 2-Nov. 9, 1982
25	267	double	paved	332	Logging trucks	June 10-Oct. 27, 1982
				494	RV's	July 1-Sept. 15, 1984
90	303	double	paved	626	Logging trucks	July 1-Nov. 6, 1982
2573	313	single	gravel	251[b]	Logging trucks	Sept. 2-Nov. 6, 1982
25	359	double	paved	359	Logging trucks	May 11-Oct. 31, 1982
25	504	single	paved	320[b]	Logging trucks	June 10-Nov. 6, 1982
90	706	double	paved	867	Logging trucks	May 5-Nov. 30, 1982
				1,441	RV's	July 1-Sept. 15, 1984
2560	915	single	gravel	356	Logging trucks	June 7-Nov. 8, 1982
25	917	single	paved	381	Logging trucks	June 11-Aug. 28, 1982

[a]Roads with 15- to 16-foot width and are considered to be one and a half lanes.
[b]Traffic flow was managed for one-way traffic.

The second set of data was collected from four sites from July 1 to September 15, 1984. These four sites were composed of a single-lane gravel road; a single-lane paved road; and two double-lane paved roads. Three of these four sites also had been investigated in the 1982 data collection. The majority of the traffic during the second data collection was recreational, with ADT ranging from 494 to 1,441 vehicles per day. No logging traffic traveled on the study sites during the traffic count period.

The 1982 data were collected using induction loops with a 16-channel Stevens tape recorder. The 1984 data were collected with the Tally 74, which is an interactive microprocessor-controlled electronic device. The device is capable of recording traffic count information on specially prepared EPROMS, a memory module.

RESULTS of ANALYSIS

Three types of traffic-volume variations were analyzed with the collected data. Traffic variations in seasons of the year and in days of the week were calculated from the 1982 data, while hourly traffic patterns were derived from the 1984 data.

Season of Year. The seasonal trend in traffic flow for a particular road is developed by plotting the road's traffic volumes according to the month of the year. Figure 2 presents the traffic-volume variations by season of the year for the initial 14 study sites that had different design standards. Figure 2 indicates that four double-lane roads provided services for more than 500 vehicles per day in the 1982 timber-hauling season. The service volume for site number 706 varied from 550 vehicles per day in May to 1,450 vehicles per day in September. The difference in service volume at this site was more than 150 percent. There also was a large variation in service volume at site number 359. The variations in site numbers 001 and 303 were relatively small. For 10 sites with traffic volume less than 600 vehicles per day, the ADT variations were smaller than those of the four double-lane, paved roads. However, the monthly difference for two sites, numbers 118 and 504, amount to 300 percent. Figure 2 also indicates that high traffic volumes occurred in the study area during August and September.

Site number 002 is a native road that is considered a typical local road. Its service volume was

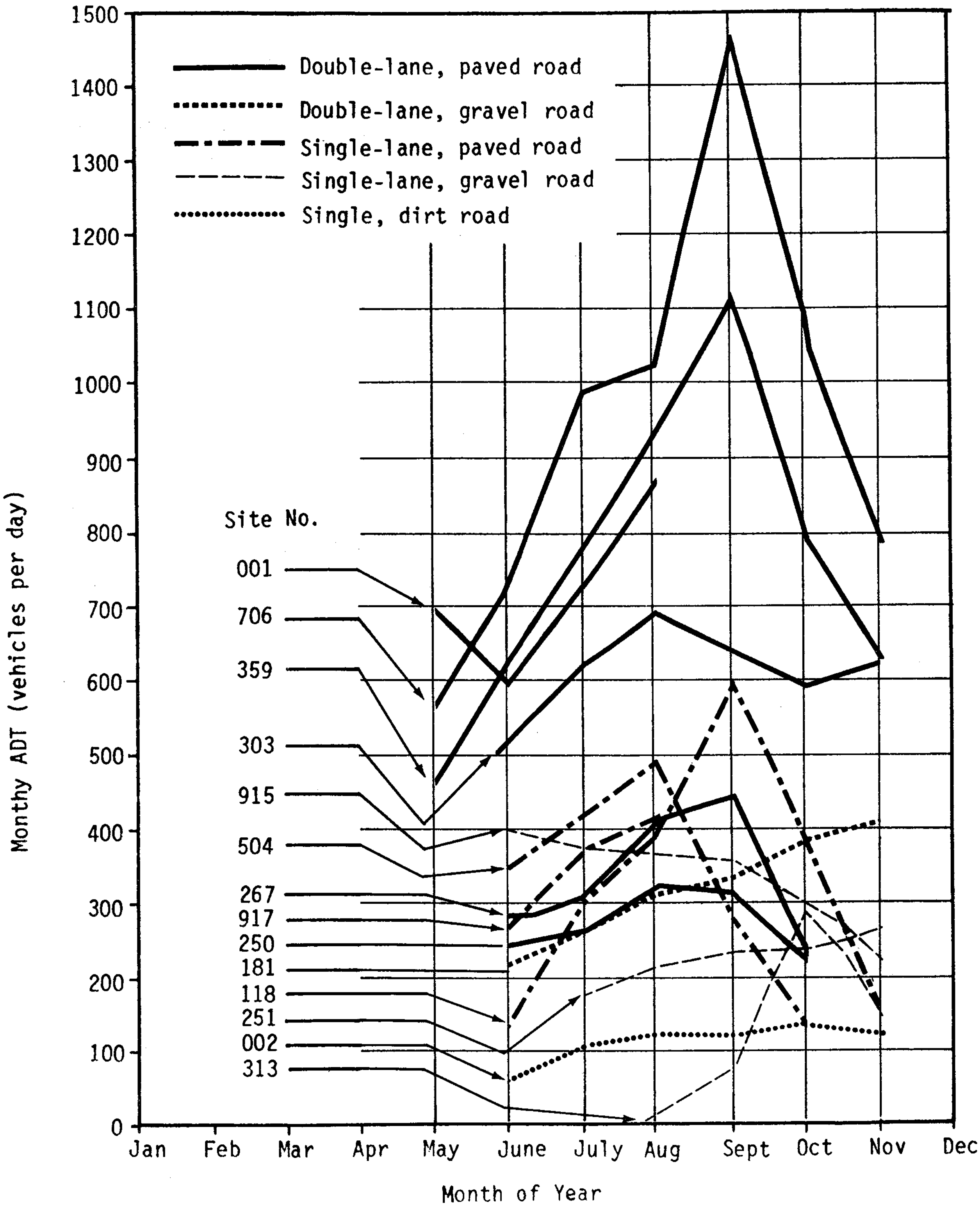

Figure 2.--Monthly variation in traffic volume for road segments having different design standards.

relatively stable, with ADT ranging from 60 to 120 vehicles per day. It is important to point out that six single-lane roads, gravel or paved, each accommodated an ADT of more than 250 vehicles per day in 1982.

Day of Week. Data from site numbers 706, 267, and 002 were used to analyze the daily variation of traffic movement on a site. Figure 3 presents three histogram plots of daily traffic for a 2-week period from August 8 to September 15, 1982, for the three sites. The three sites represent three classes of road systems--arterials, collectors, and local roads. Site number 706 is a double-lane, paved road; 267 is a single-lane, paved road; and 002 a single-lane, dirt road.

At both site numbers 706 and 267, weekend traffic volumes exceeded weekday volumes. As was expected, the variation of daily traffic volume for site number 706, which is an arterial road, was relatively small compared to that of site 267, which is a collector road. Traffic flow in arterials is more stable than in collectors. On the other hand, the weekend traffic volumes for site number 002 were lower than weekday volumes, which is a typical traffic pattern for local roads.

Hour of the Day. Hourly distributions of traffic volumes often describe the peak demands for service on Forest Service transportation facilities. Figure 4 presents typical hourly distributions for a week from Friday to Thursday on site number 706, a double-lane, paved road. The vehicles per day during the week ranged from 1,239 vehicles on Monday to 1,598 vehicles on Sunday.

When the hourly traffic distribution patterns were plotted in the same diagram, two general patterns appear--one for weekdays and one for weekends (see figure 5). There were two peak-hour periods on weekdays, but only one on weekends. The morning and midday peak-hour movements on weekdays occurred from 4 a.m. to 6 a.m. and from 11 a.m. to 3 p.m., respectively. However, the morning peak-hour traffic volumes were only about 50 percent of the midday peak-hour traffic volumes. Weekend peak-hour volumes occurred between 11 a.m. and 5 p.m. Most morning peak-hour traffic on weekdays consisted of logging-related vehicles, while approximately one-third of the midday peak-hour traffic consisted of

```
                        Site 706 with Double-lane, Paved Condition

DAY    DATE              0                                                 VPD

SUN  8 / 8 /    1982 I************************************             1126
MON  8 / 9 /    1982 I*******************************                  966
TUE  8 / 10 /   1982 I**********************************               1077
WED  8 / 11 /   1982 I************************************             1112
THU  8 / 12 /   1982 I******************************                   960
FRI  8 / 13 /   1982 I****************************                     890
SAT  8 / 14 /   1982 I******************************************       1282
SUN  8 / 15 /   1982 I*****************************************        1263
MON  8 / 16 /   1982 I************************************             1113
TUE  8 / 17 /   1982 I**********************************               1071
WED  8 / 18 /   1982 I************************************             1111
THU  8 / 19 /   1982 I************************************             1113
FRI  8 / 20 /   1982 I**************************************           1184
SAT  8 / 21 /   1982 I******************************************** 1453

                        Site 267 with Single-Lane, Paved Condition

SUN  8 / 8 /    1982 I***********************************              491
MON  8 / 9 /    1982 I***********************                          308
TUE  8 / 10 /   1982 I****************************                     374
WED  8 / 11 /   1982 I****************************                     371
THU  8 / 12 /   1982 I*************************                        327
FRI  8 / 13 /   1982 I***********************                          306
SAT  8 / 14 /   1982 I***********************************              471
SUN  8 / 15 /   1982 I******************************************** 647
MON  8 / 16 /   1982 I***************************                      356
TUE  8 / 17 /   1982 I****************************                     370
WED  8 / 18 /   1982 I*******************************                  417
THU  8 / 19 /   1982 I*******************************                  418
FRI  8 / 20 /   1982 I******************************                   401
SAT  8 / 21 /   1982 I******************************************       578

                        Site 002 with Single-Lane, Dirt Condition

SUN  8 / 8 /    1982 I************                                     48
MON  8 / 9 /    1982 I*******************************************      174
TUE  8 / 10 /   1982 I*********************************                136
WED  8 / 11 /   1982 I*******************************************      173
THU  8 / 12 /   1982 I***************************************          158
FRI  8 / 13 /   1982 I*******************************                  128
SAT  8 / 14 /   1982 I**********                                       42
SUN  8 / 15 /   1982 I***********                                      45
MON  8 / 16 /   1982 I*******************************************      175
TUE  8 / 17 /   1982 I*******************************************      175
WED  8 / 18 /   1982 I******************************                   125
THU  8 / 19 /   1982 I**************************                       110
FRI  8 / 20 /   1982 I************************************             149
SAT  8 / 21 /   1982 I********************                             82
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Figure 3.--Histogram plots for daily traffic.

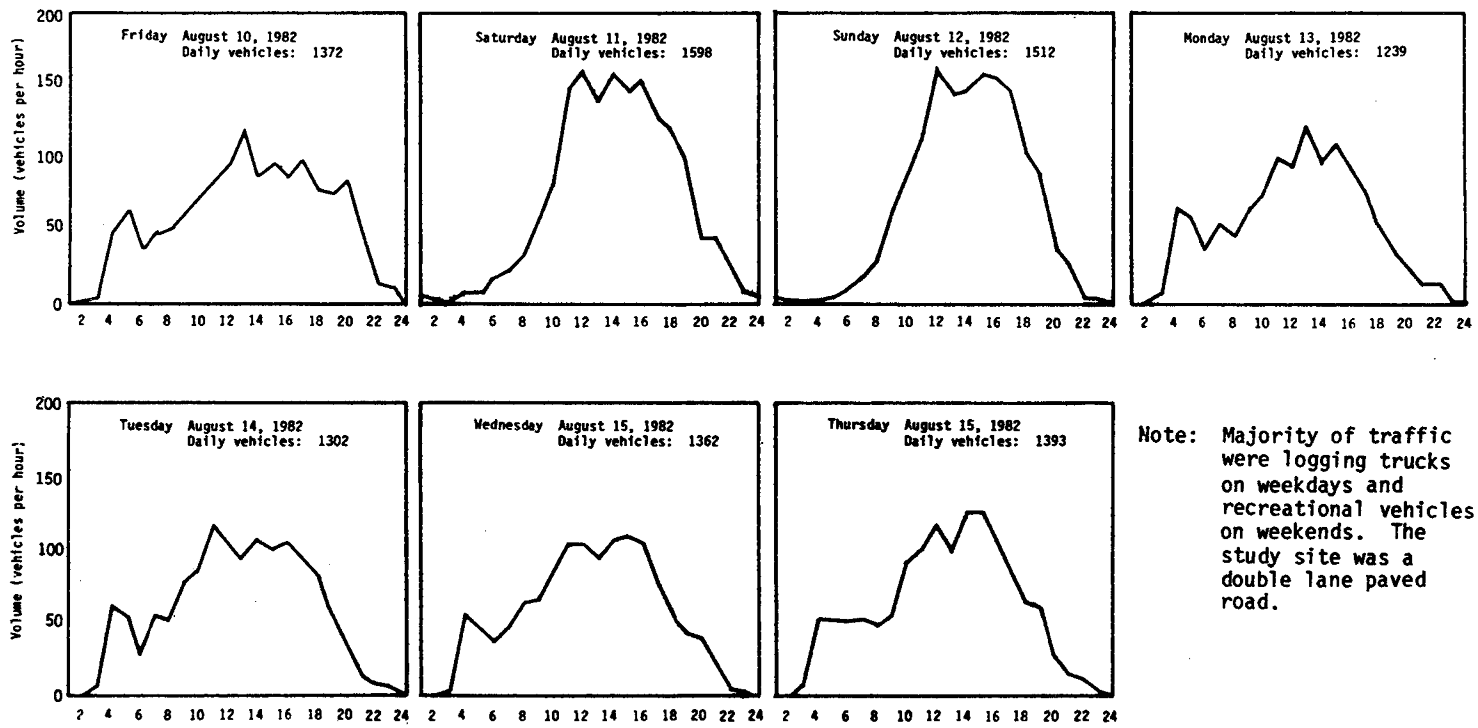

Figure 4.--Hourly traffic volume variations on site number 706 of Road 90 in Gifford Pinchot National Forest, August 10 through 16, 1982.

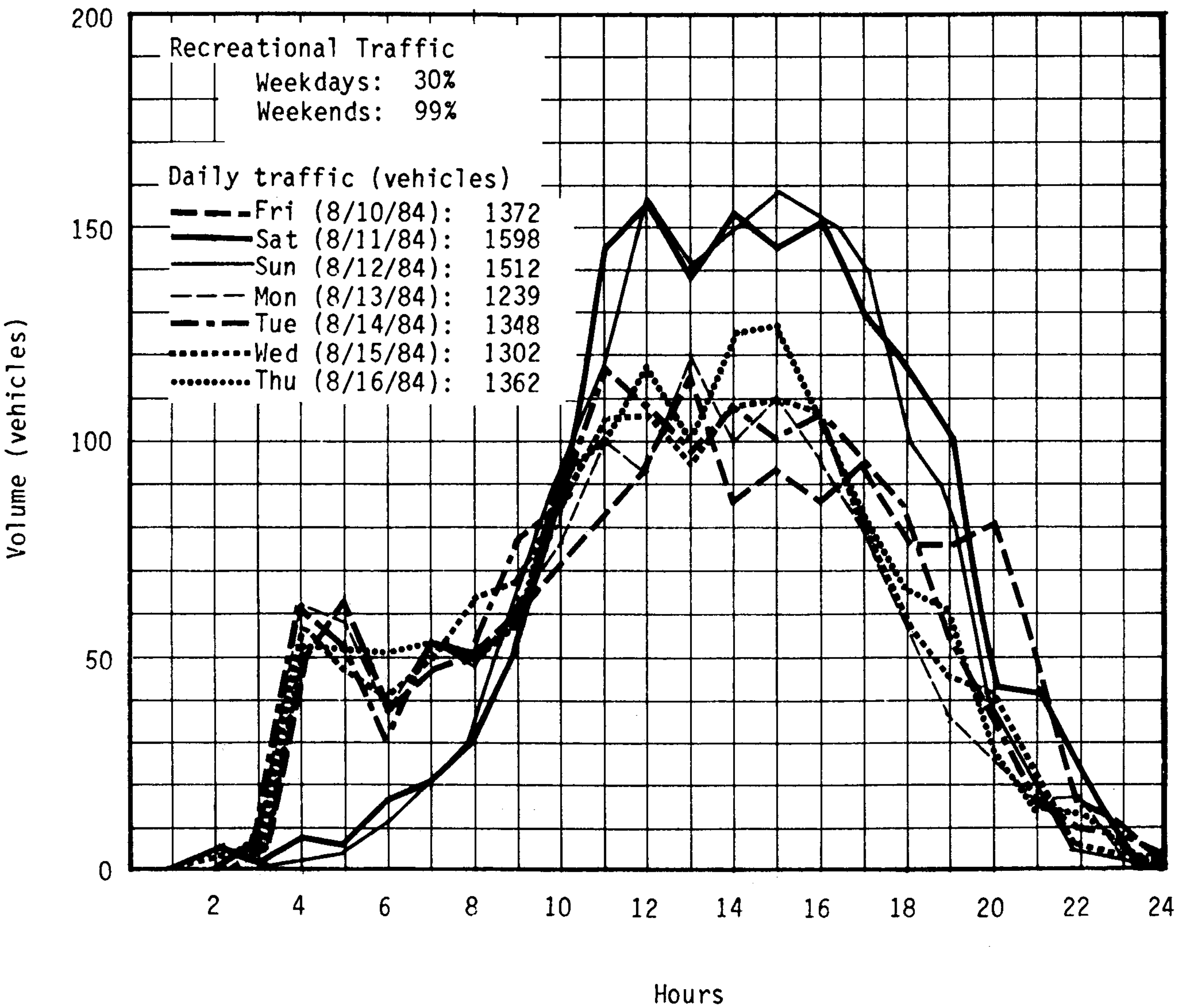

Figure 5.--Hourly traffic volume variations on site number 706 of Road 90 in Gifford Pinchot National Forest, August 10 through 16, 1984.

recreational vehicles. There were no morning peak hours on weekends, and most weekend traffic consisted of recreational vehicles. The midday peak hours for both weekdays and weekends occurred approximately at the same time of the day, from 10 a.m. to 5 p.m.

Figures 6, 7, and 8 present hourly traffic volume variations on site numbers 267, 118, and 007. Traffic counts for these sites took place in August 1984 and included the Labor Day holiday. Recreational vehicles accounted for more than 95 percent of the total traffic. Figure 6 indicates unusually high traffic volume on the Monday on which Labor Day fell. Figures 7 and 8 show that two single-lane roads accommodated peak-hour volumes of more than 300 vehicles per hour for a duration of 3 to 5 hours on weekends. Although there was no record of the traffic flow when these traffic counts took place, the observation indicates that the flow would probably be bumper-to-bumper traffic and that both ditches of the roadway would be used to accommodate two-way traffic. Figure 7 surprisingly reveals that a single-lane road can handle more than 400 vehicles per hour.

It is important to be cautious in interpreting these traffic patterns for use in choosing road designs. Since the traffic flow was unknown, the results of this analysis do not suggest that 400 vehicles per hour is a desired hourly volume for single-lane roads. However, this study does strongly indicate that peak-hour volume may be a better road design criterion than daily volume. For example, at site number 118 (shown in figure 7), the daily volume for Sunday, September 2, 1984, was 2,972 vehicles. Based on a 10-hour day, the average hourly volume was about 300 vehicles per hour. But, in fact, the peak-hour volume exceeded 400 vehicles per hour. For site number 007 shown in figure 8, the daily volume for Saturday, August 4, 1984, was 1,925 vehicles. Calculated from this, the average hourly volume would be nearly 200 vehicles per hour, but the peak-hour volume actually reached 350 vehicles per hour. Peak-hour volumes exceeded daily volume design for single-lane roads.

SUMMARY & CONCLUSIONS

This study has analyzed variations in traffic volumes with time based on data collected in the Mount St. Helens National Volcanic Monument area in 1982 and 1984. Fifteen study sites provided information on traffic patterns on an hourly, daily, and

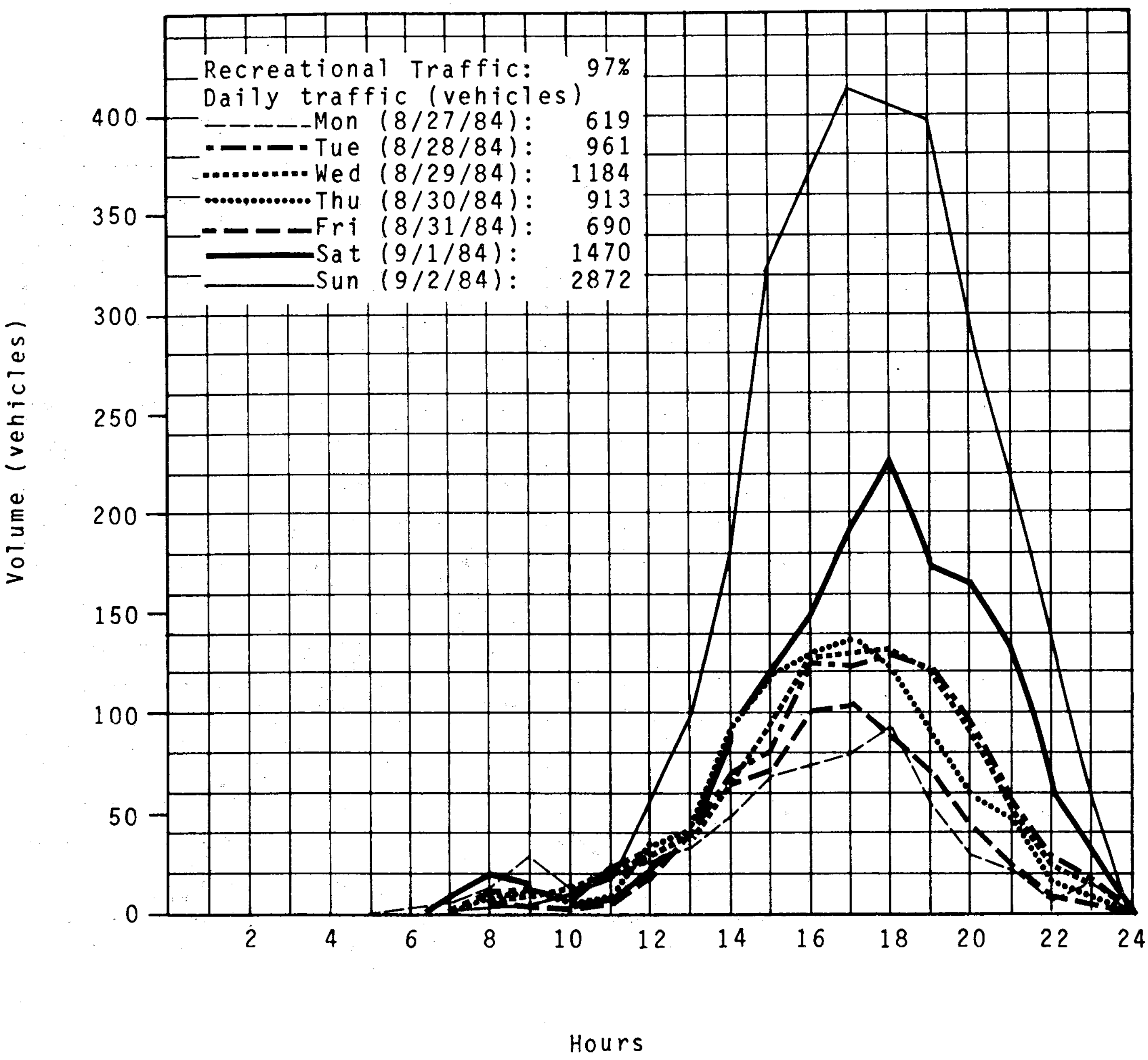

Figure 6.--Hourly traffic volume variations on site number 267 of Road 25 in Gifford Pinchot National Forest, August 30 through September 5, 1984.

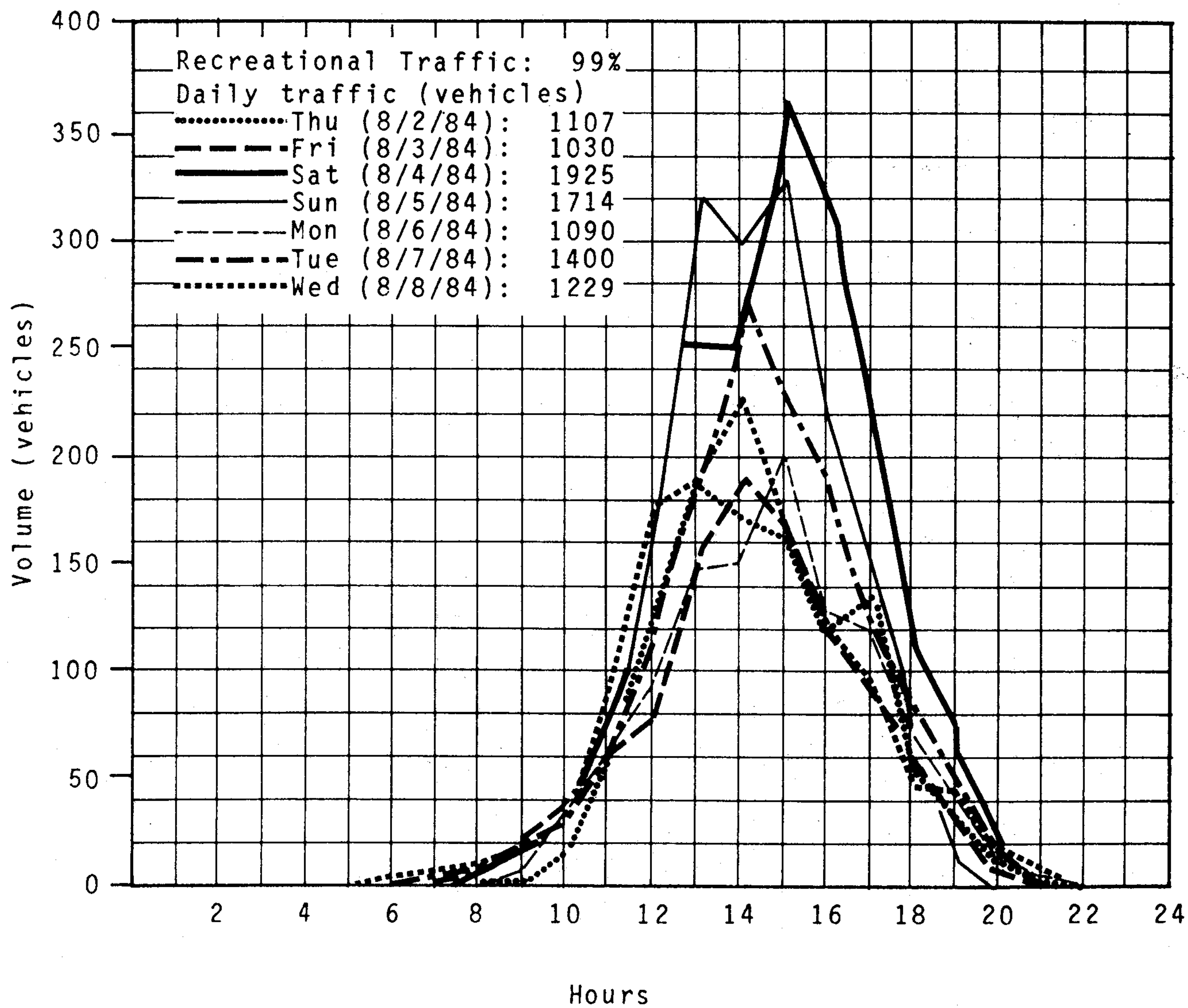

Figure 7.--Hourly traffic volume variations on site number 118 of Road 99 in Gifford Pinchot National Forest, August 27 through September 2, 1984.

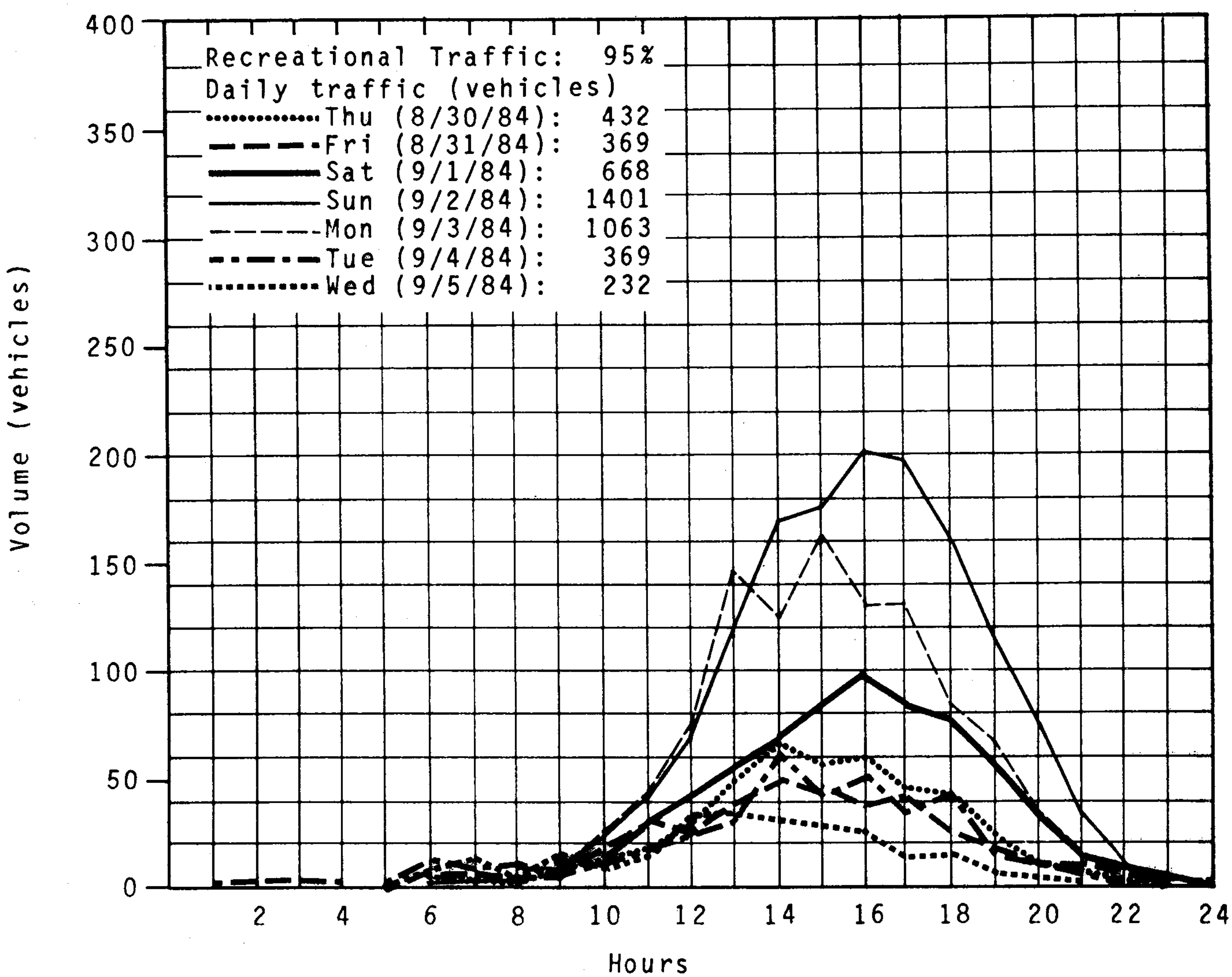

Figure 8.--Hourly traffic volume variations on site number 007 of Road 99 in Gifford Pinchot National Forest, August 2 through 8, 1984.

monthly or seasonal basis. These sites covered a whole spectrum of Forest road systems, including arterials, collectors, and local roads. Road segments ranged from single- to double-lane roads and from native to paved surfacing. The observed traffic included traffic generated by logging and recreational activities.

The specific findings of this study are as follows:

(1) High log-hauling traffic occurred in August and September.

(2) From largest to smallest, the order of seasonal traffic volume variations on road types was arterials, collectors, and local roads; the order based on day of week was local roads, collectors, and arterials.

(3) There was more demand for arterials and collectors on weekends than on weekdays. On the other hand, local roads not open to the public for recreational travel were underused on weekends.

(4) Logging-related traffic had both morning and midday peak-hour periods, while recreational traffic had only midday peak-hour periods. The morning traffic peak hours occurred from 4 a.m. to 6 a.m. and was about half of the volume of the midday peak-hour period. Midday peak hours occurred from 10 a.m. to 5 p.m.

(5) For single-lane roads, during bumper-to-bumper travel conditions in which both ditches of roadway are used as road surface, recreational traffic may exceed 300 vehicles per hour.

(6) Hourly volume may be a better road design criterion than daily volume because there is a significant difference between peak-hour and nonpeak-hour traffic, which is not reflected in averages based on daily volume rates. To do so, however, hourly volume for a particular duration needs to be defined.

(7) For traffic controlled by CB radios when a road is not open to public, the ADT of single-lane roads reached 250 vehicles per day, with the majority of traffic consisting of logging trucks.

It should be noted that this traffic volume study was based on data from the Mount St. Helens Monument area, and, therefore, any interpretation of traffic patterns beyond the controlled base condition would require verification of local data samples.

Evaluation of Computer-Aided Drafting & Design for Architectural & Structural Engineering

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Chief Facilities Engineer
Washington Office

This is the first of several articles on the subject of computer-aided drafting and design systems. Subsequent articles will be provided for general interest to field personnel as additional information becomes available.

For this series of articles, micro- and minisystems are differentiated by both size and cost. Usually, microsystems have less than 1.5 megabyte internal memory and cost less than $40,000 installed, while minisystems have greater than 1.5 megabyte internal memory and a price range between $75,000 and $200,000. Both are stand-alone hardware/software systems dedicated to a specific application. And, because of internal memory size, the capabilities of the two are usually different.

In addition, two acronyms--CAD and CADD--are used in these articles. These and additional acronyms are discussed in the article "A Review of Micro- and Mini-CADD Systems." These acronyms are used interchangeably. CADD means both drafting and design are included in the system. CAD normally refers to systems in which only drafting is included.

The Washington Office Engineering Staff is coordinating a four-part evaluation of computer-aided drafting and design (CADD) systems and their potential cost-effective use in Forest Service architectural and structural engineering design. Although there are some exceptions, most structural engineering and architectural design is done at the Regional Offices. Our evaluation focuses on what configurations of hardware and software might be shared or coordinated between the architecture and structural engineering disciplines both within the Region and inter-Regionally.

We have no doubt that automated drafting and design will be cost effective. The purpose of the Service-wide evaluation is to investigate and optimize potential savings and other benefits of CADs. At present, a wide assortment of commercial CAD systems, capabilities, and costs are available. The competitiveness of the CADD market is improving users' opportunities monthly. However, the appropriate level of needs, capabilities, and investments must be identified before implementing major changes in work practices. Installation and use of uniform CAD systems will enhance the shape and transfer of detailed technology and project data in usable form among Regions. The opportunity also exists for inter-Regional design and review teams.

Although current funding levels are limited and contracting for work is being emphasized, a concerted effort is being made to identify the magnitude of facility needs and recommend more realistic program levels. Contracting for design work is not cost effective for small projects. The advent of CAD systems could increase Staff productivity and reduce overall cost considerably.

During fiscal years 1984 and 1985, the following four separate but complementary efforts were undertaken.

MAINFRAME TIME-SHARE SYSTEMS (COMPLETED)

A time-share contract that ran from May through September 1984 with the Control Data Corporation revealed that most large mainframe programs are complex enough to require an indepth training program and knowledge of systems far in excess of Forest Service design needs. Telecommunication problems were encountered, user support was inadequate, and quality transmission was unreliable.

The general conclusion was that mainframe time-share systems are less feasible than available stand-alone systems for the Forest Service.

Articles that further analyze this evaluation appear in this issue of <u>Engineering Field Notes</u>--see "Computer-Aided Design" and "Final Evaluation Report: Internal Application and Evaluation of Control Data Corporation's CD2000 Computer-Aided Design/Drafting System."

DESIGN WORKLOAD/ SYSTEM NEEDS ANALYSIS (95-PERCENT COMPLETE-5/1/85)

This effort is being conducted by an A/E contractor. Lee Wan and Associates, Incorporated, a suburban Atlanta design firm, has compiled data received from all Regions, has reviewed various micro- and mini-CADD systems, and has provided its final report. A copy has been sent to each Region and Station for information. A future Engineering Field Notes article will discuss the findings. Some discussion from the report is included in the article "A Review of Micro and Mini CAD Systems" included in this issue.

MICROCOMPUTER-LEVEL CADD SYSTEM (UNDERWAY)

Three IBM-PC (hardware)/PCAD software systems were installed in Region 8 in November 1984. These are currently being evaluated. First production (project level) drawings were completed in January. Additional projects are under way to test the system in a "real world" environment.

MINICOMPUTER-LEVEL CADD SYSTEMS (PENDING)

We orginally proposed to install a two-station minicomputer CADD system in Region 5 for Service-wide evaluation. This effort now has been designed to evaluate the practicality and costs of manual integration design with automated drafting systems in a micro-environment. The rationale for this change is discussed in the article "A Review of Micro- and Mini-CAD Systems."

Originally, the evaluations of micro- and mini-CAD systems were to be separate but parallel, generic efforts. Two complete CAD workstations, with supporting peripheral equipment, were proposed for each test Region. These Regions would have two to three trained designers proficient in producing design drawings. These hands-on efforts would give the designers sufficient knowledge to compare other systems. While quality hardware/software systems were to be installed, the evaluation was not intended to test the selected system but to permit a comparison of it with other systems within the same generic level of a CAD system.

Although the minisystem evaluation has been modified, the results of the microsystem evaluations will be merged for use in acquisition. Inter-Regional committees are planned for (1) writing performance specifications and evaluation criteria for acquisition, and (2) developing system guidelines to ensure the sharing of graphic and textual data bases and project drawings (that is, developing an in-Service user group).

Computer-Aided Design

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Civil Engineer
& Fong L. Ou
Engineer, Systems Analysis & Development
Washington Office

This article describes the application of a computer-aided design system provided by Control Data Coporation (CDC) to develop a structural analysis of a complicated three-dimensional structure. A three-dimensional analysis provides designers with a better understanding of the interrelationship of stresses and strains between members within a structure than is possible with a two-dimensional analysis. Based on such an analysis, the designer will be able to select the most efficient members and connections for the complete structure with consideration of overall safety factors. This article has been prepared for publication in Engineering Field Notes to increase awareness of the potential of the latest technology for improving structural analysis. The CDC system is available through a time-sharing contract.

INTRODUCTION

Computer-aided design (CAD) increasingly is becoming a major tool for structural engineers in designing engineering structures. The benefits of using a CAD system include increased productivity, greater accuracy, efficiency in making changes, time saved in redesign work, and reductions in project development time.

The Forest Service designs and builds 150 to 300 bridges and about 100 buildings every year. Nearly 40 personnel are assigned to carry out this work. The size of the task suggests that a CAD system could greatly improve the efficiency of these professionals in structural analysis. In light of this potential, the Washington Office sponsored the use of CDC's CAD software for a trial period.

The main purpose of this trial period was to gain hands-on experience with the computer graphics technology and its ability to reduce time and costs for Forest Service designers. The Washington Office Technical Application Engineer and System Analysis Engineers participated in this application and evaluated the potential use of a CAD system for structural analysis.

The CDC CADD SYSTEM

CDC provided a Computer-Aided Design and Drafting (CADD) System including CD2000, UNISTRUC, and GTSTRUDL programs. CD2000 is an automated design and drafting programming system. It provides basic geometric definitions, such as a point, line, circle, and arc, for use in creating designs of two- and three-dimensional parts. UNISTRUC is an interactive graphics preprocessor and postprocessor program that automatically prepares the input for the finite element routines in GTSTRUDL from the drawings of the structure developed on the CRT screen. It also automatically interprets the results of the analysis from GTSTRUDL for CRT viewing. The CD2000 also can be used to generate the structural model. This input is used by GTSTRUDL for the structural analysis. GTSTRUDL is a general purpose finite element structural analysis program that has been adapted from the original Massachusetts Institute of Technology ICES/STRUDL by the Georgia Institute of Technology. The output shows the stresses and the strains on each member and the moments at all connections.

APPLICATION

To illustrate this design and finite element analysis application, a two-story structure with a first floor of 50 feet by 40 feet and a second floor of 24 feet by 20 feet was chosen. In this example, all of the floor truss, roof truss, and walls were combined into a single rigid-frame structure model for analysis. This is a very large finite element model and does require a large computer for analysis in a reasonable period of time.

Drafting by CD2000. The analysis is begun by showing the structure with lines that represent the centerline of each member. This drafting started with the selection of the origin point of the drawing. Based on the origin, four corner points of a basic panel of floor truss were created, as shown in figure 1(a). Then, four lines were drawn by connecting four pairs of points, as shown in figure 1(b). Through entity manipulation, figure 1(b) was duplicated and translated nine times, as shown in figure 1(c). Duplicating figure 1(c) once and rotating it 180 degrees resulted in figure 1(d).

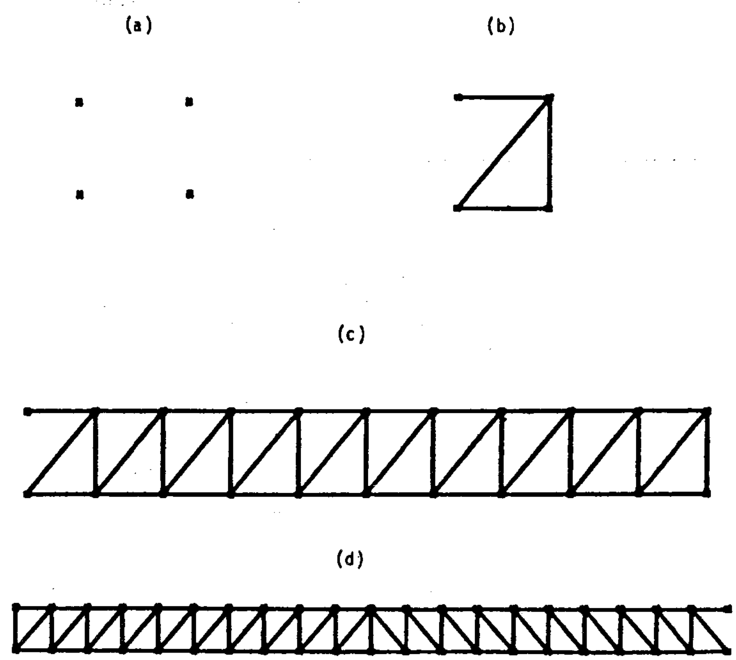

Figure 1.--Process for creating a floor truss.

The roof truss was developed by locating five points at member intersections and connecting these points with lines, as shown in figure 2(a). The design of the roof truss for the first floor, shown in figure 2(b), was completed by duplicating figure 2(a) once and rotating it 180 degrees.

As shown in figure 3, figure 2(b) was duplicated and translated five times in each case 2 inches apart. Figure 3 was duplicated and translated once, thus completing the design for the portions with one level. Figure 4 illustrates the truss for one level.

The truss figure 2(b) for the one-floor structure was modified for the portion of the model with two stories. Figure 5 shows the modified truss. The design of the two-story portion was completed by duplicating figure 5 and translating it thirteen times, as figures 6 and 7 show. Figure 8 displays the portion of truss above the floor. Figure 8 also shows a 72-inch by 82-inch door and two 72-inch by 50-inch windows. These are included to demonstrate the advantage of a three-dimensional analysis in analyzing the effects of removing parts of several truss frames. Figure 9 shows both front and right views of the structure with their dimensions.

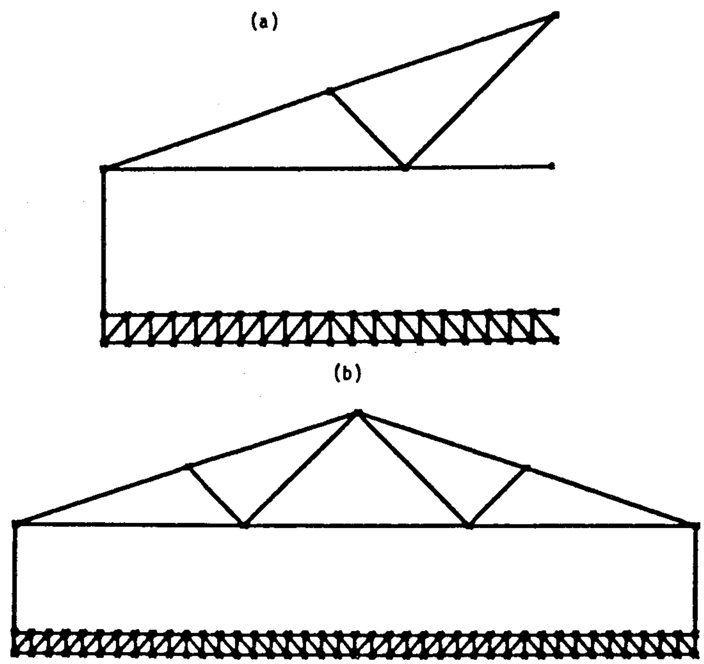

Figure 2.--Truss for one-floor section.

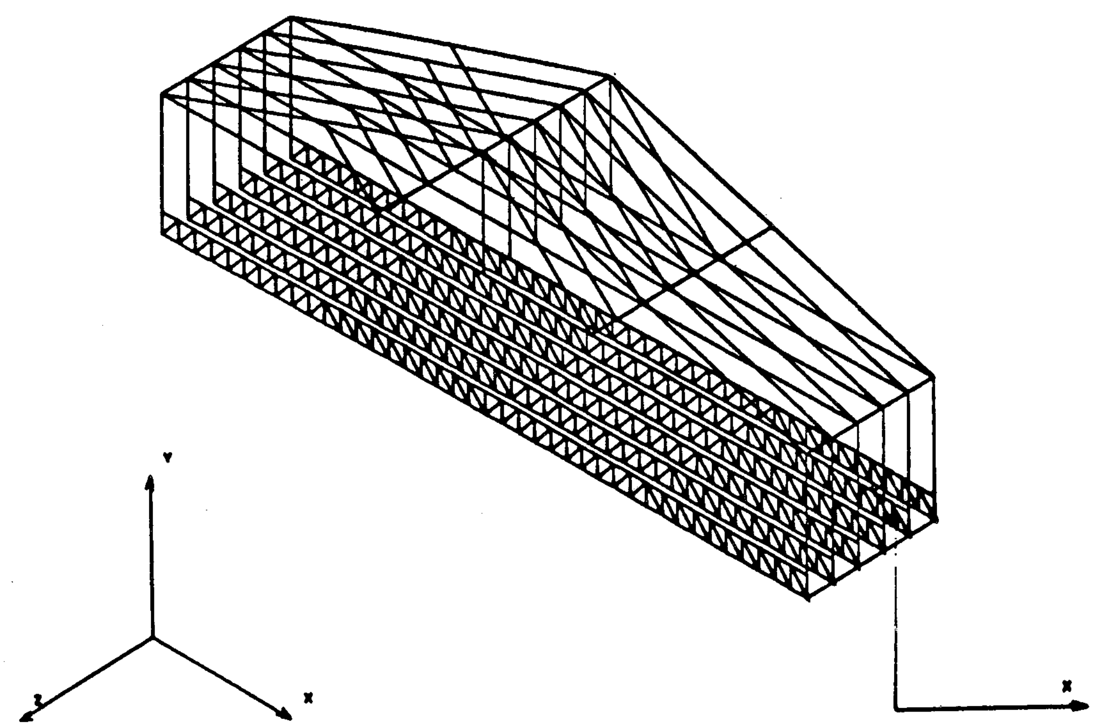

Figure 3.--Truss for one-floor section.

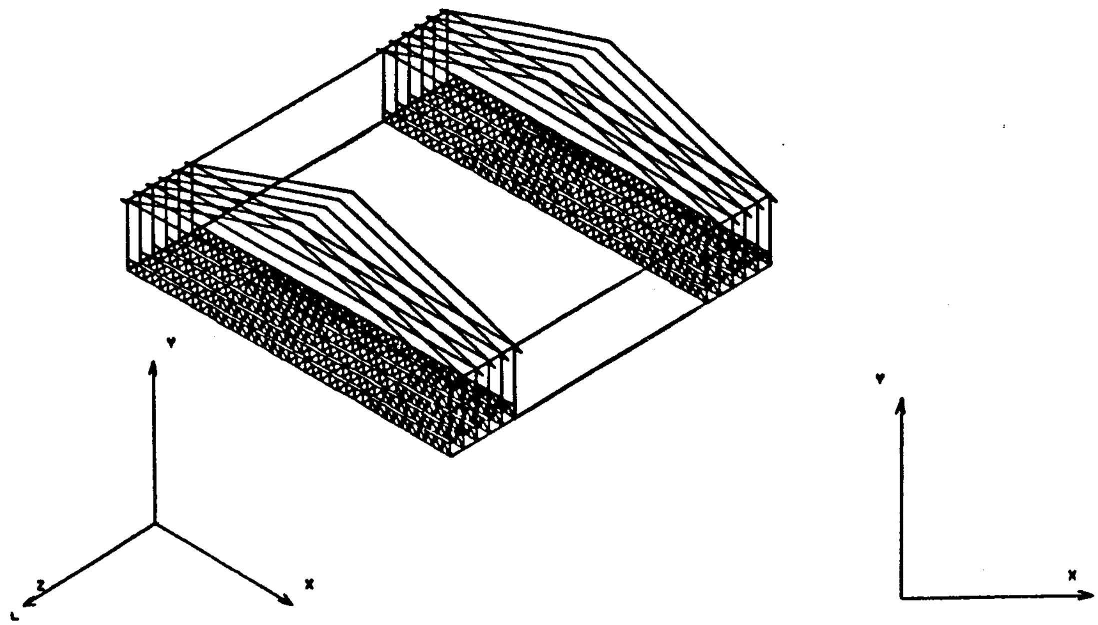

Figure 4.--Two ends of structure with one floor.

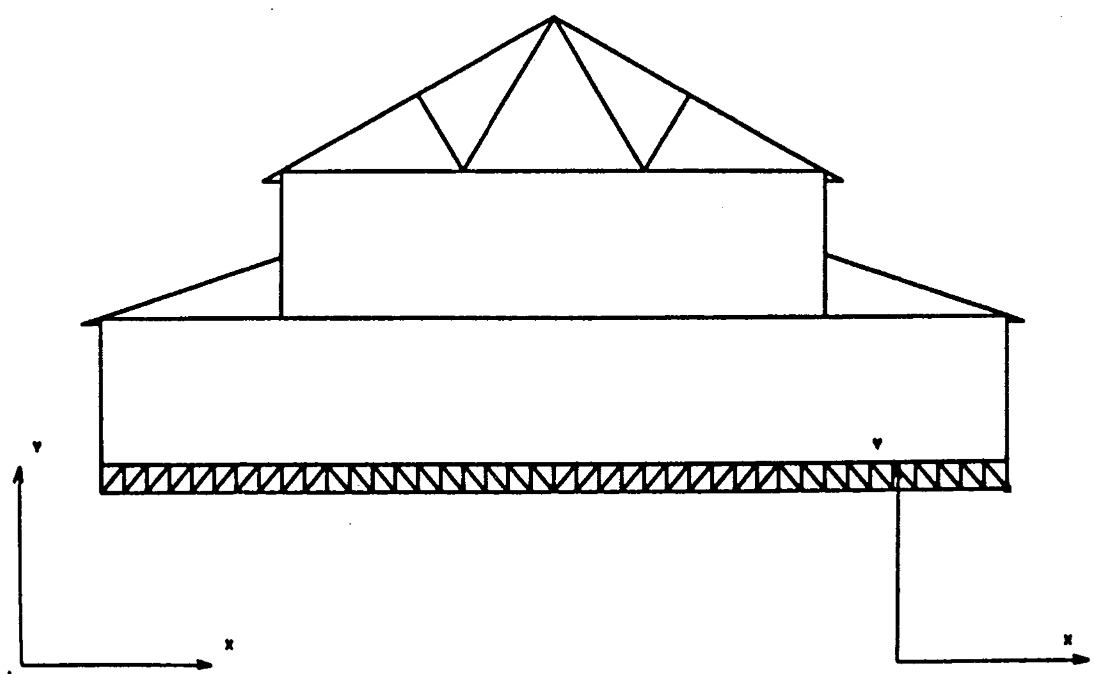

Figure 5.--Truss for two-floor section.

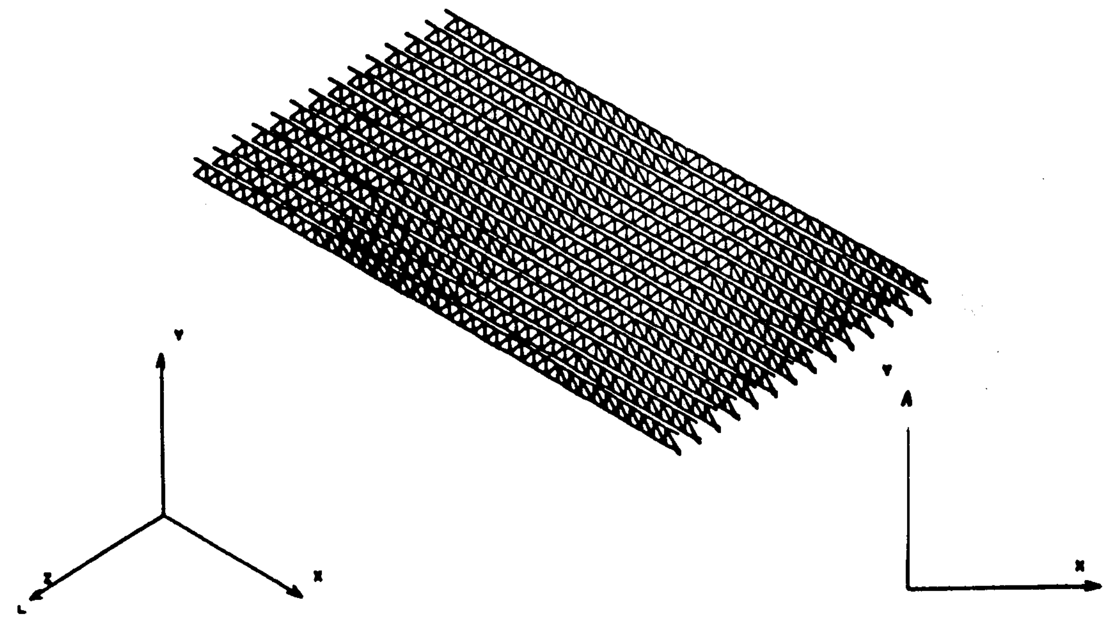

Figure 6.--Floor truss for two-story section.

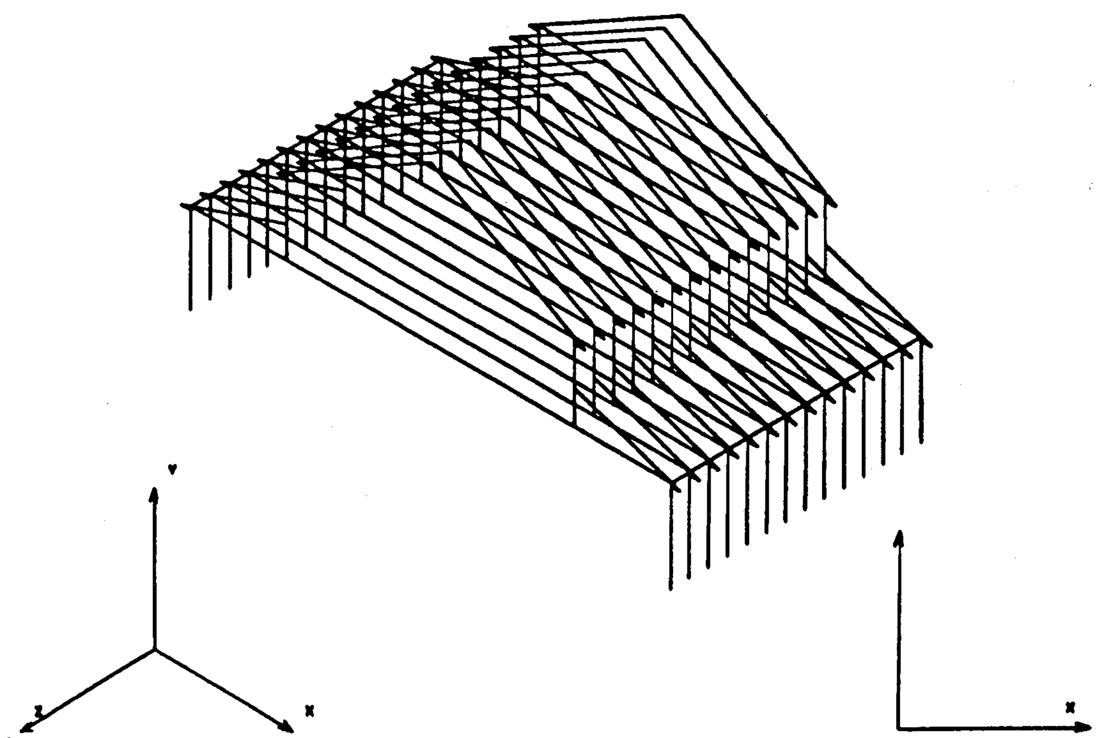

Figure 7.--Portion of structure with two stories.

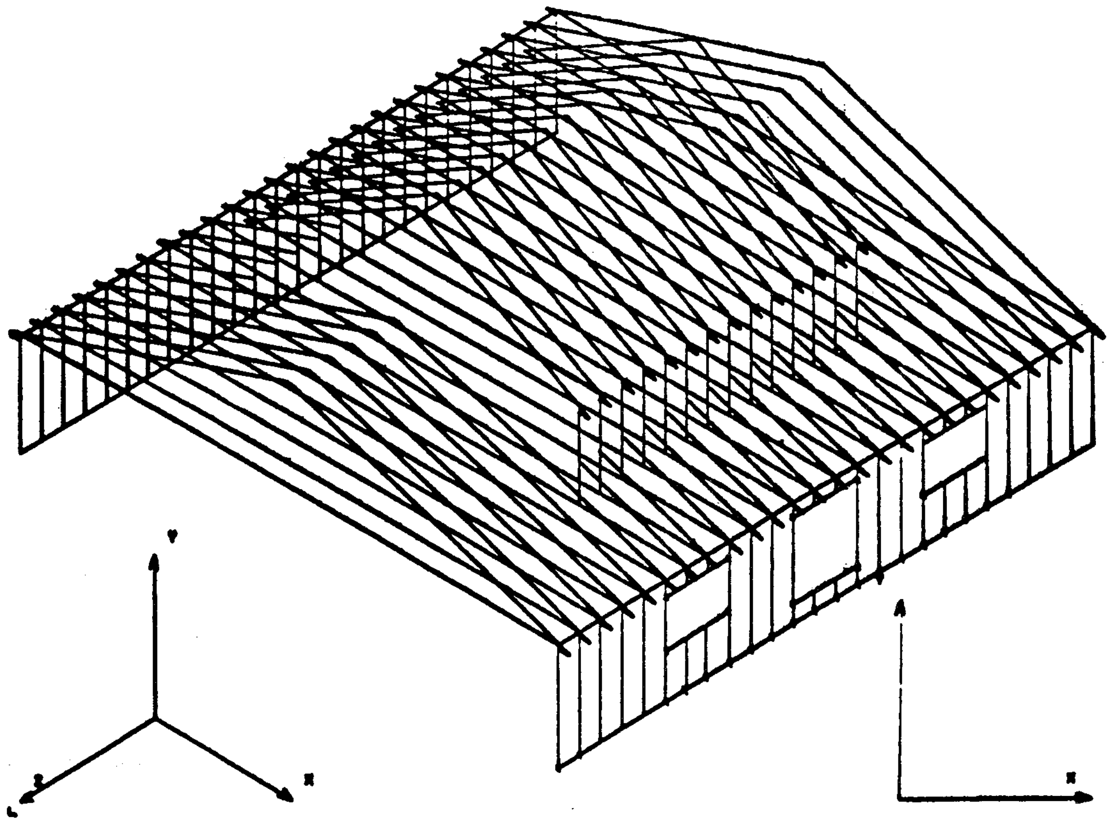

Figure 8.--Structure truss above the floor.

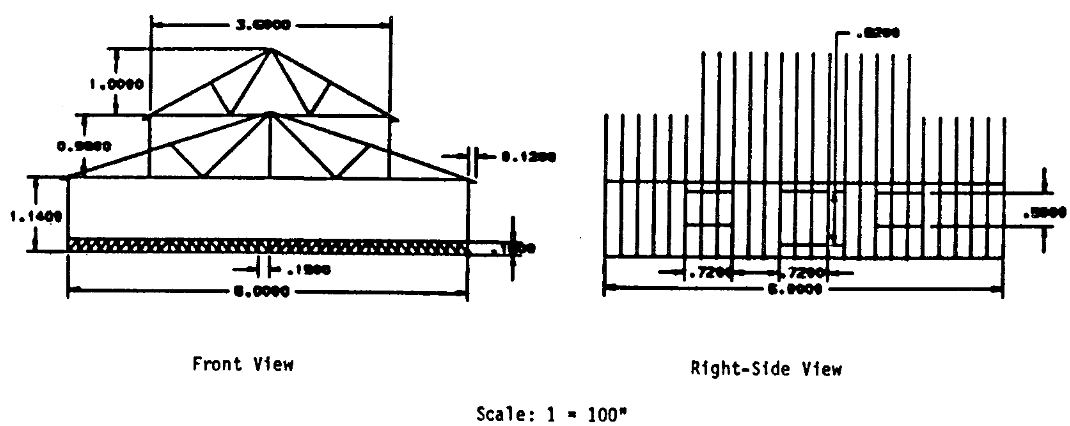

Figure 9.--Front and right-side views.

Generating a Finite Element Model With UNISTRUC. Using the geometric data from the previous step, a finite element model was generated with UNISTRUC. The model is shown in figure 10. Figure 11 displays a zoomed portion of the truss with node numbers.

The finite element model, a section of which appears in figure 12, was submitted to GTSTRUDL for analysis. The results of this analysis are discussed in the following section.

Structural Analysis by GTSTRUDL. In this application, the entire three-dimensional space frame finite element model was included in the structural analysis. X, Y, and Z forces, as well as moments about the X, Y, and Z axes, were developed at each node point. A GTSTRUDL run was made based on the assumptions that the combination of live and dead loads is 25 pounds per square foot; the module of elasticity equals 0.12×10^7 pounds per square inch for wood framing materials; and the size of member ranges from 2 inches by 4 inches to 2 inches by 6 inches.

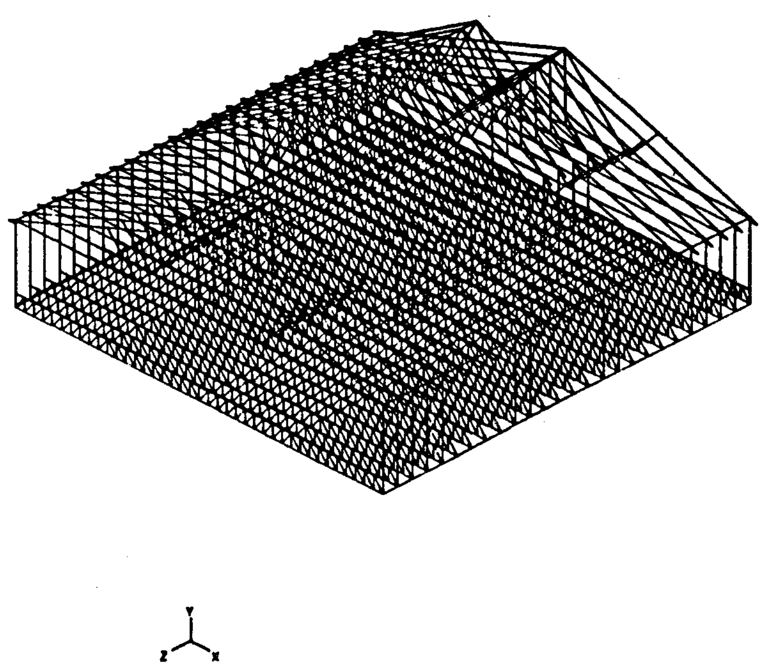

Figure 10.--Finite element model of the building.

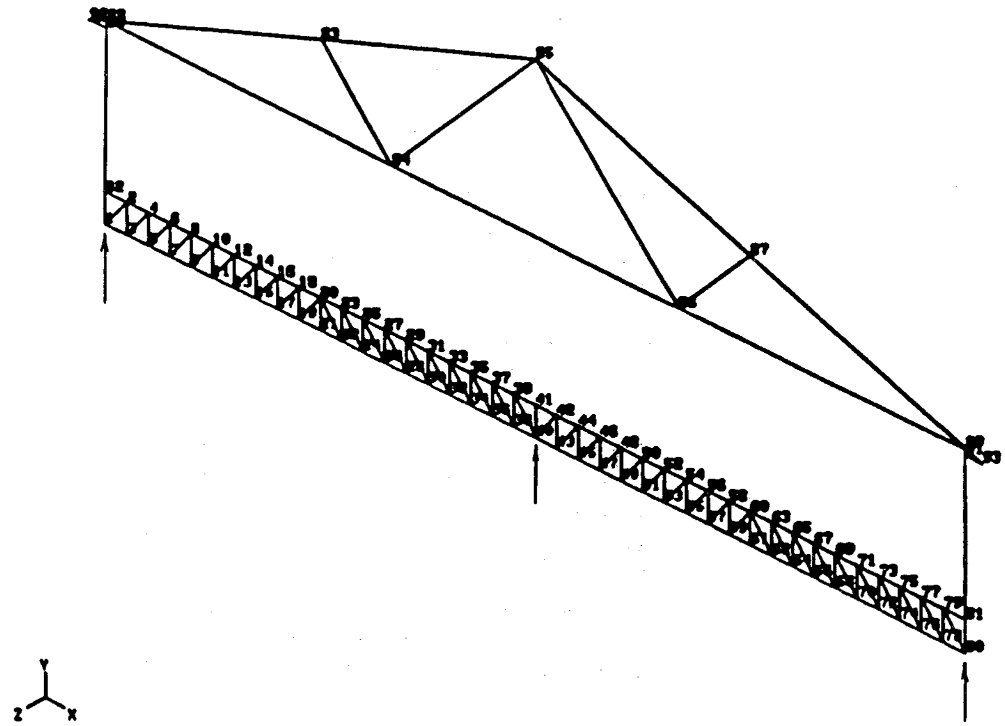

Figure 11.--Zoomed portion of finite element model.

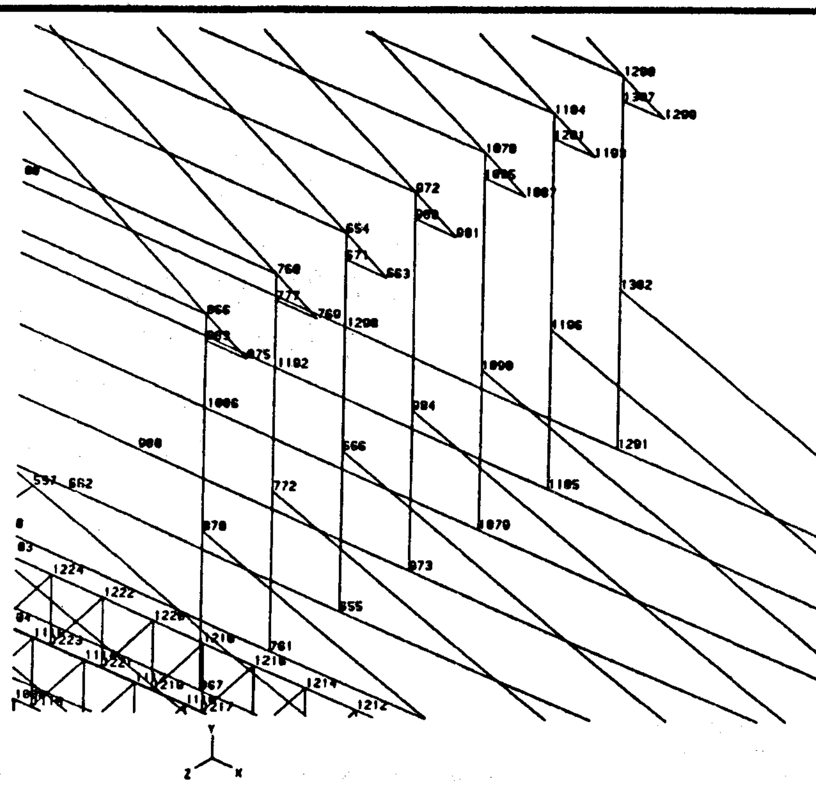

Figure 12.--Section of finite element model.

The first part of the output contains the input information. The second part of the output presents the analysis results, a portion of which are summarized in four tables. Table 1 shows the member forces in axial and shear y, and in moment z. Table 2 depicts the joint displacements in both x and y coordinates and the rotation of the z coordinate. Table 3 presents the joint loads for supports. Finally, Table 4 shows the member stress in terms of axial, y shear, z shear, y bending, z bending, maximum normal, and minimum normal. The members with incorrect or insufficient properties for stresses were denoted by STRUDL errors.

Details. A CADD system is capable of drawing various detailed aspects of a structure. For simplicity, only a portion of roof overhangs is illustrated in this article. Figure 13 shows a two-dimensional roof overhang, while Figure 14 shows a three-dimensional display of the same overhang.

LEARNING CURVES

The Washington Office evaluation period took less than 3 weeks. This is too short a time period to understand fully this complex system without sufficient support from the vendor. However, based on this experience it seems that a user could acquire considerable proficiency quickly if sufficient support from the vendor is available, if the hardware is satisfactory, and if the system is used continuously. For example, with no assistance from CDC it took 5 days to learn how to create the truss in figure 8. After learning the procedure, it took only 30 minutes to develop the same truss the second time. For creating a three-dimensional roof overhang, the first trial took 2 days, but the second took only 1 hour.

After finally obtaining adequate support, the drafting shown in figures 3 through 12 was completed in 3 hours with the immediate assistance of a CDC specialist, and the conversion to a finite element model was almost instantaneous.

CONCLUSIONS

This paper has shown the application of CDC's CAD system to a structurally complicated space frame structural analysis using finite elements for a hypothetical two-story building. The experiment indicates that considerable savings could be achieved using CAD as a structural analysis tool. An experienced user could do the work shown here in a few hours with high confidence in its accuracy. The savings in structural analysis costs would be

Table 1.--Member forces.

RESULTS OF LATEST ANALYSES

PROBLEM - NONE TITLE - NONE GIVEN

ACTIVE UNITS FEET KIP RAD DEGF SEC

MEMBER FORCES

MEMBER	LOADING	JOINT	FORCES: AXIAL	FORCES: SHEAR Y	FORCES: SHEAR Z	MOMENTS: TORSION	MOMENTS: MOMENT Y	MOMENTS: MOMENT Z
1								
	DEAD	1	.1282301	0.0000000				0.0000000
		2	-.1263401	0.0000000				0.0000000
	LIVE	1	2.3006932	0.0000000				0.0000000
		2	-2.3006932	0.0000000				0.0000000
2								
	DEAD	1	-.1278767	.0028833				.0000000
		3	.1278767	.0005601				.0020202
	LIVE	1	-3.7736675	.0445186				.0000000
		3	3.7736675	-.0445186				.0774237
3								
	DEAD	1	.1698153	.0010957				.0000000
		4	-.1679253	.0010957				.0000000
	LIVE	1	4.9833937	-.0000000				0.0000000
		4	-4.9833937	.0000000				-.0000000
4								
	DEAD	2	-.0035195	.0200913				.0241560
		4	.0035195	-.0166479				.0037911
	LIVE	2	-.1022786	.7006932				.0182287
		4	.1022786	-.3528671				.0979107
5								
	DEAD	3	-.1205265	0.0000000				0.0000000
		4	.1224165	0.0000000				0.0000000
	LIVE	3	-3.4082771	0.0000000				0.0000000
		4	3.4082771	0.0000000				0.0000000
6								
	DEAD	3	-.2602778	.0043236				-.0020202
		5	.2602778	-.0008801				.0065451

Table 2.--Joint displacements.

PROBLEM - NONE TITLE - NONE GIVEN

ACTIVE UNITS FEET KIP RAD DEGF SEC

RESULTANT JOINT DISPLACEMENTS SUPPORTS

JOINT		LOADING	DISPLACEMENT: X DISP.	DISPLACEMENT: Y DISP.	DISPLACEMENT: Z DISP.	ROTATION: X ROT.	ROTATION: Y ROT.	ROTATION: Z ROT.
1	GLOBAL							
		DEAD	0.0000000	0.0000000				-.0011329
		LIVE	0.0000000	0.0000000				-.0332214
47	GLOBAL							
		DEAD	.0017297	0.0000000				.0011329
		LIVE	.0507708	0.0000000				.0332209

RESULTANT JOINT DISPLACEMENTS FREE JOINTS

JOINT		LOADING	DISPLACEMENT: X DISP.	DISPLACEMENT: Y DISP.	DISPLACEMENT: Z DISP.	ROTATION: X ROT.	ROTATION: Y ROT.	ROTATION: Z ROT.
2	GLOBAL							
		DEAD	.0016177	-.0000214				-.0010445
		LIVE	.0474948	-.0003867				-.0309407
3	GLOBAL							
		DEAD	.0000159	-.0019631				-.0011222
		LIVE	.0004679	-.0576174				-.0329472
4	GLOBAL							
		DEAD	.0016182	-.0019427				-.0011273
		LIVE	.0475075	-.0570445				-.0331345
5	GLOBAL							
		DEAD	.0000481	-.0038900				-.0010884
		LIVE	.0014214	-.1141698				-.0319328
6	GLOBAL							
		DEAD	.0016028	-.0038719				-.0010885
		LIVE	.0470522	-.1136653				-.0319272
7	GLOBAL							
		DEAD	.0000953	-.0057343				-.0010297
		LIVE	.0028114	-.1682696				-.0301967
8	GLOBAL							
		DEAD	.0015709	-.0057179				-.0010309
		LIVE	.0461114	-.1678158				-.0302373

Table 3.--Joint loads supports.

PROBLEM - NONE   TITLE - NONE GIVEN

ACTIVE UNITS FEET KIP RAD DEGF SEC

RESULTANT JOINT LOADS SUPPORTS

JOINT	LOADING		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
1	GLOBAL							
		DEAD	.0000000	.2428540				.0000000
		LIVE	.0000000	5.6000000				.0000000
47	GLOBAL							
		DEAD	-.0000000	.2428540				-.0000000
		LIVE	-.0000000	5.6000000				-.0000000

Table 4.--Member normal stress.

PROBLEM - NONE   TITLE - NONE GIVEN

ACTIVE UNITS FEET KIP RAD DEGF SEC

INTERNAL MEMBER RESULTS

MEMBER NORMAL STRESS

MEMBER 1

DISTANCE FROM START	AXIAL	Y SHEAR	Z SHEAR	Y BENDING	Z BENDING	MAX NORMAL	MIN NORMAL
LOADING DEAD							
0.000 FR	-3.5171681	0.0000000	0.0000000	0.0000000	0.0000000	-3.5171681	-3.5171681
.500	-3.4912481	0.0000000	0.0000000	0.0000000	0.0000000	-3.4912481	-3.4912481
1.000	-3.4653281	0.0000000	0.0000000	0.0000000	0.0000000	-3.4653281	-3.4653281
LOADING LIVE							
0.000 FR	-63.1047276	0.0000000	0.0000000	0.0000000	0.0000000	-63.1047276	-63.1047276
.500	-63.1047276	0.0000000	0.0000000	0.0000000	0.0000000	-63.1047276	-63.1047276
1.000	-63.1047276	0.0000000	0.0000000	0.0000000	0.0000000	-63.1047276	-63.1047276

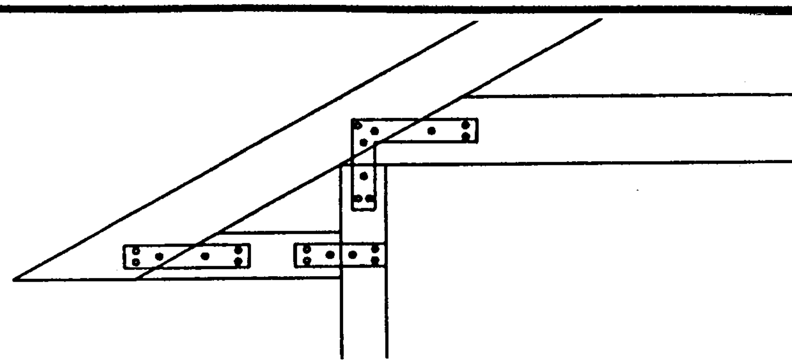

Figure 13.--Roof overhangs in two dimensions.

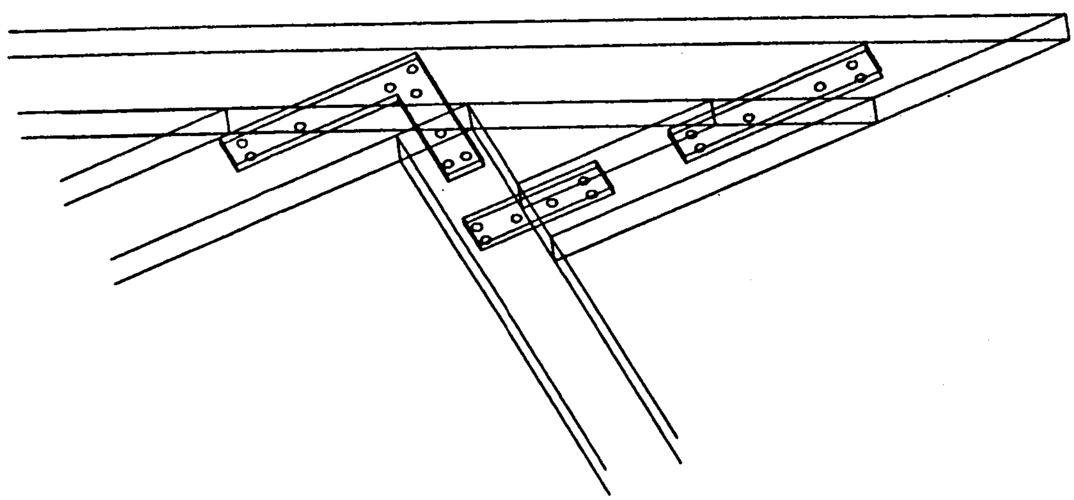

Figure 14.--Roof overhangs in three dimensions.

appreciable compared to the costs of an analysis by any other method. It should be noted, however, that a sophisticated CAD structural analysis may not be justifiable for building structures using light framing (2 inches by 4 inches, 2 inches by 6 inches, and so forth) because the savings in construction costs resulting from increased knowledge of actual stresses and strains will not save sufficient material to compensate for the additional structural analysis cost. Instead, this type of analysis would be useful for reducing the cost of bridges and towers.

Direct questions regarding this paper to C. Swarthout or Fong Ou at FTS 235-2376/235-3119 or (703) 235-2376/(703) 235-3119.

Final Evaluation Report—Internal Application & Evaluation of Control Data Corporation's CD2000 Computer-Aided Design/Drafting System

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Structural Engineer
& Robert LeCain
Architect
Region 1

The following report presents Region 1's evaluation of the Washington Office's contract with Control Data Corporation (CDC) in fiscal year 1984 for time-share service with CDC's computer-aided design/drafting system. The purpose of the contract was to allow the Forest Service to evaluate the CADD system. Robert LeCain and Frank Muchmore from Region 1, Nelson Hernandez from Region 5, and Dick Smith and Bill Grabner from Region 6 attended a 1-week training session in Rockville, Maryland, from May 7 to May 11, 1984.

While attending the training, we realized that a digitizer tablet would be absolutely necessary for efficient use of the CD2000 system. Tablets were not contemplated in the original plan, so the implementation was delayed while they were being procured by the Washington Office. CDC did loan a tablet to Region 1, which was installed on July 9. The tablet purchased by the Washington Office was delivered and became operational on August 7, after which the CDC tablet was returned to the Washington Office.

Region 1 evaluated the CADD system during the months June through September 1984.

EVALUATION CRITERIA

The "Plan for Internal Application and Evaluation of Computer-Aided Drafting/Design System" outlines the criteria used for this evaluation. Each item is analyzed below.

(1) Ease of data entry and modification. Very difficult at first. CD2000 is very complex because of its versatility and multiple possibilities for use. Many proper responses must be made to enter data or to change previously entered data. Obviously, as with any learning

process, once a function is thoroughly learned it no longer seems difficult or complicated; however, retaining that learning efficiency requires constant use, which does not seem likely with this program.

(2) The reliability of the system for phone connection to the vendor's computer system. Very poor! Rarely did it function 100 percent. Problems varied from occasional "blips" (unwanted characters or lines) to complete loss of work in progress.

(3) Internal application results are accurate and complete. We have made no internal applications. Because of the problems of data entry and system reliability, as well as other problems, we did not seriously attempt any production work. However, CD2000 certainly allows accurate and complete results provided data are entered completely and accurately.

(4) Operating costs are reasonable for the following functions:

(a) Training:

Training materials are sufficient to both quality and quantity--Generally this was true. Adequacy of the CD2000 user's manual varied greatly. Some areas were logical and understandable and some were not.

Availability of troubleshooting assistance after initial training is completed--CDC was cooperative and tried to be helpful. However, because of the large size and specialization in their organization, it was sometimes difficult and time consuming to get to the proper person for assistance.

(b) Data collection--This item was more appropriate to the structural analysis programs, which Region 1 did not evaluate.

(c) Data preparation--This item was more appropriate to the structural analysis programs, which Region 1 did not evaluate.

(d) Data analysis--This item was more appropriate to the structural analysis programs, which Region 1 did not evaluate.

(e) Computer process--The log-on process was cumbersome and seemed to be a carryover from the old punch-card days. The process definitely was not user friendly.

(f) Communications--The phone link to the computer ranged from quite good to terrible. At worst, the system was totally unusable, with so much "garbage" appearing on the screen that communication with the system was impossible. Time-share does not seem to be the way to handle a production situation.

(5) User's satisfaction with the performance of the system.

(a) Architect's comments--"I was intrigued by the versatility and complexity of the system. However, this same versatility made it difficult to learn and use. A program that does much less but that is user friendly would be much more appropriate to our needs."

(b) Structural Engineer's comments--"This system [CD2000] is extremely powerful and flexible, which makes it necessarily very complex. For the type of applications we have, it is far too complex. Probably 80 to 90 percent of the system's capabilities are not needed at all for our drafting. A much simpler and more user-friendly system would be far more useful to us."

(6) Functions of the system that may be performed in a cost-effective manner. For standard drawings, a CADD system would be quite useful. For any one-time-only drawing, however, manual methods would be faster. The computer obviously can change scales, and so forth, very easily; however, that is relatively unimportant in developing a set of architectural or structural drawings.

(7) System-generated reports are readable and easily understood by users. Not applicable to the drafting functions, which is all that we tested.

(8) Reasonable protection from data loss. Seemed to be; but only if one performed "pack and file" often. Line disturbances or the phone link, which caused "garbage" to appear on the screen, increased data loss.

(9) System-identified data errors or difficulties are easily located. This depended on the drafting function being used. It varied from the obvious to the impossible.

(10) Calculations and analytical procedures are an integral component of the system. Yes! But of little or no importance for drafting functions, which was our primary area of interest for this evaluation.

GENERAL COMMENTS

The speed of screen repainting was very slow on the Techtronix 4014 terminal. As the drawing becomes more complex, repainting time becomes significant. This interrelates with the following:

(1) Menus covered the drawing rapidly, which required frequent repainting of the drawing. Menus on a separate screen would seem to be a significant advantage.

(2) Some functions, such as dimensioning, required a lot of "zooming" (for instance, zoom up to pick up an entity, zoom down to pick up another area of drawing, zoom up to pick up the next entity, and so forth). This zooming required a great deal of repainting, which was cumbersome. A scroll feature that allows moving back and forth and up and down without changing scale would be useful. Moving the center of the screen did this to a very limited degree but required screen repainting at each move.

(3) Cancelling repainting (Control T) in midpaint because of entry error or other problems often resulted in loss of an entire program (CD2000), which of course, required starting over, and resulted in loss of work that was in process.

The ergonomics of the terminal were very bad. When using the digitizing tablet, there was no good place to put the tablet. The keyboard should be separate from the screen display (like FLIPS) so that the keyboard and tablet can be arranged in a comfortable manner. Also, it was time consuming having to gather your user's manual and other materials and go from the third floor to the basement where the terminal was located. All of these are Forest Service problems, not CDC problems.

It was difficult to enter points, lines, and so forth, close enough. There was no practical rough scale. There was a grid, but repainting the screen with the grid turned on was unacceptably slow.

"Shading" choices were very limited and difficult to control. Even very simple software architectural programs for personal computers have many more shading choices.

Automatic dimensioning and entry of dimensions functions were only in inches or metric; in other words, no measurements were in feet and inches. This is impractical for architectural or structural work.

Plotters in Region 1 were not comptabile with CD2000 for direct link. To obtain a plot, it would have been necessary to have CDC make the plot and mail it or make a tape and send it to Region 1. This would be completely unacceptable for production work. Although equipment to allow CD2000 to control Region 1 plotters is undoubtedly available, such equipment might be quite costly or otherwise difficult to obtain.

Training time needed to become proficient on CD2000 seems to be excessive for our purposes. Because of the complexity of the system, there is no easy way to become trained in its use. For example, Rockwell International (as reported in Design Graphics World, July 1984, page 17), uses CD2000 and the CDC design and analysis programs in their space shuttle division. They require each engineer to be trained for 10 weeks in the basic applications and do not certify their people as qualified until after they log about 200 hours on the terminal. They claim a 2-to-1 productivity gain over conventional methods after that time. However, until that skill level is attained, they find that the learner is still quite vulnerable and may find snags, make excuses, and go back to his or her old ways! We cannot afford that much training, either in terms of time or money.

RECOMMENDATIONS

CD2000 is not the CADD system that we need.

For the kinds of work we do, we see less need or potential for a computer-aided design system than for a computer-aided drafting system that will allow preparation and revision to working drawings.

Because drafting is only a part-time function with us, the system must be easy to learn and use and must be relatively inexpensive, both in terms of initial cost and use cost.

To maintain state-of-the-art capability, the primary hardware must be of a general purpose type that allows software to be updated.

The equipment must be located within the work area of the people using it and be primarily a single-purpose use. If the machine is not readily available for use, it will not be used, particularly during the learning phase.

A paper germane to the subject was presented by Joseph E. Bowles on October 4, 1984, at the American Society of Civil Engineers Convention in San Francisco. Bowles discussed the micro- and mini-computer systems and the additional power and usability of these new units.

A Review of Micro- & Mini-CADD Systems

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Chief Facilities Engineer
Washington Office

Author's Note: Although the original CAD evaluation action plan proposed both mini- and microlevel evaluations, it became increasingly apparent that the differences in costs and capabilities would have to be justified to conduct both evaluations. A review was made that led to the recommendation to cancel the minilevel evaluation and to add a second micro-CADD evaluation. The review provided an excellent opportunity to make a side-by-side comparison of several systems, and to discover some aspects of CAD systems vital to potential users. The following report was made and submitted to the Directors of the Engineering Staff and Computer Science and Telecommunications Staff in June 1985.

EXECUTIVE SUMMARY

The past 12 to 15 months have been devoted to studying CADD systems, their capabilities, and potential benefits to the Forest Service. The majority of this effort has been to review the potential of micro- and minilevel stand-alone CADD systems. A micro-CAD system has been purchased and is undergoing evaluation in Region 8.

Enough information has been gathered to form some conclusions with regard to present day mini-CADD systems and to recommend revising near-term evaluation actions.

While there are major capability differences between present day micro- and minilevel CADD systems, it is becoming increasingly apparent that, for architectural and structural engineering design in the Forest Service, the microlevel CADD systems offer sufficient capabilities and are more cost effective than the more expensive, more highly integrated minicomputer CADD systems. The micro-CADD system market is very dynamic, with better products being offered every few months. This situation will continue for some time, and the present differences in capabilities between micro- and minisystems may soon be history.

RECOMMENDATIONS

(1) The hands-on evaluation of minilevel CADD systems should be held in abeyance until further notice. Efforts should continue to stay abreast of CADD market development in the minilevel field.

(2) Acquire additional but separate micro-CADD system software for further evaluation. Use IBM-AT hardware. Expand the evaluation test to use IBM-compatible engineering design software and evaluate the practicality of manual integration of computer-aided drafting and design.

(3) Consider minisystems only after the implementation of CADD and the demonstration of a need for more than five workstations per office. Require the use of Initial Graphics Exchange Specification (IGES) formatted software to allow projects to be shared between Regions.

(4) Evaluate and determine system requirements and features on a "must have versus want" basis for the acquisition of CADD systems in fiscal year 1986 and beyond.

DISCUSSION

During the past 12 to 15 months, considerable Staff effort has been devoted to becoming more familiar with CADD systems and to develop an indepth understanding of the capabilities of both CADD hardware and software and their applicability to architectural and structural engineering disciplines.

Concurrent with these efforts, Region 8 has begun its evaluation and production drawings using a micro-CADD system, and the contractor Lee Wan and Associates, Incorporated, has been working on its review of micro- and mini-CADD systems. Much of our time has been spent in viewing demonstrations, reading, pricing systems, and discussing CADD systems with several individuals both inside and outside of the agency. The following is a digest of our findings from a host of sources.

<u>What's in an Acronym?</u>

What do we mean when we say CADD? With many buzz words, meanings change, people read in new meanings, and so forth. CADD is no different. CADD (computer-aided drafting and design), CAD (computer-aided drafting or computer-aided design), CAD/CAM (. . . computer-aided manufacturing), CAE (computer-aided engineering), CAEAD (computer-aided engineering and architectural design), CAE/CAM (computer-aided engineering and manufacturing), CASD/M (computer-aided space design and management, and CIM (computer-integrated manufacturing) have a common thread--computer-assisted. We have been using computer systems for 25 years; so--what's new?

Perhaps the attribute common to the acronyms presented is the use of graphic displays and interactive graphics. Without a doubt, graphics are desirable for solving many types of problems. For architectural and structural design, graphics is a language for communications. Designs are usually a graphical depiction of a desired product. Can graphics or computer aids be used all the time for design? The answer is "no!" Holguin Associates, a software firm, estimates that, considering the level of graphics used in problem solving, while almost 100 percent of drafting activities can be automated, only abut 60 percent of architectural activities and 30 percent of engineering activities can be automated.

What It Is & Isn't

CAD/CADD. These names are frequently used interchangeably. Expressed separately, the first "D" in CADD is drafting, the second "D" is design. This is an important distinction.

Micro/Mini. These are generic computer hardware terms. The former usually has less than 1.5 megabytes (but increasing daily) internal memory and costs less than $40,000. The latter has a larger internal memory and costs considerably more. As expected, the larger the capacity, the larger the price.

Hardware/Software. While magazine articles and numerous advertisements tout the attributes of one system or another, considerable care is needed when investigating systems. Some softwares are little more than electronic pencils ranging in price from $500 to $50,000. Others vary by their degree of integration. Integration might be best explained by an example. In a highly integrated architectural CADD system, a number of operations occur with the recall of a standard detail from the data base. Specifications are outlined, quantities are counted, finish schedules are developed, and, when the detail is placed with the design, all views and sections are correctly oriented and labeled.

Generally, the comparatively higher price of minis over micros can be attributed to the degree of integration of both drafting and design, the required size of data base, and the internal memory needed. Thus, with micros, you get CAD; with minis, you can get CADD.

"Roots," in the sense of what the software was developed for, are extremely important. We recently attended a demonstration of GRAFTEX software. This is a very powerful three-dimensional drafting program capable of both wire-frame and solids modeling in more than 300 colors. The program was written by and for mechanical engineers for tool and die design. While technically adaptable, the program, as written, is not practical for producing architectural working drawings and other contract documents. The best softwares are those written by and for applications within a given discipline. Software selection must be on that basis as well.

Driving Forces/Costs-Benefits

When considering a CAD/CADD system, the dominant issue is software capability. Hardware is normally selected to operate the software efficiently. Software programs will have various degrees of capabilities and will integrate data base systems. Heavily integrated drafting and design programs usually require minilevel computers. However, several highly integrated drafting programs are available in the microcomputer market.

The differences in cost between an integrated CAD system (a good drafting program with a high level of geometric, data storage, and integration capabilities), and CADD (a fully integrated drafting and design program) is about $75,000 to $150,000. Several firms advertise micro- and mini-CAD systems for under $15,000 and $50,000, respectively. These prices normally do not include all the hardware and software necessary for production of construction documents. For instance, multipen drum plotters range from $7,500 to $20,000 each. These are priced separately. Once an office has common support hardware and software, the costs of the next CAD workstation are closer to the advertised prices.

Although one would expect an increase in benefits with a more fully integrated program, this is not necessarily the case. Many features cannot be fully used. Minilevel design programs often include far more design capability than is needed. Because of their integration and their being generally more complete (that is, structural engineering from simple beam analysis to finite element analysis), minilevel design programs may cost 8 to 10 times as much as microlevel systems. The micro-CAD market has several excellent integrated drafting programs, which, while lacking some features, such as three dimensions, modeling, and so forth, are sufficient for most Forest Service work. The item missing in most micro-CAD systems is the ability to directly integrate design (structural analysis, HVAC, electrical circuit analysis, hydraulics) into the drafted project. In both micro- and minilevel programs, good drafting and design programs exist.

Finally, the opportunity to capture potential benefits is directly related to frequency of use. Relatively noncomplex analysis is all that is necessary with most Forest Service facilities. Lee Wan and Associates, Incorporated, has concluded that most design analysis required by the Forest Service can be accomplished using small individual microlevel programs with "manual" integration. Generally, manual integration involves moving the drafted project to a file, loading a design program in the computer, and calling up sections of data from the file for analysis. Drafting is completed after the design analysis is completed. While this is not automatic, the consultant has suggested that we would probably be unable to fully amortize the larger investment necessary for full drafting and design integration.

Marketplace Realities

Although the present software market is expanding, most vendors target particular segments of the CADD market. This targeting is associated with the "roots" discussion earlier. GRAFTEX Corporation has stated that its goal is to serve the largest segment of the market. According to its market surveys, mechanical engineering (machine) design is the largest, electronics and electrical design is second, and civil engineering is third. By comparison, the civil engineering design market is 5 to 6 times smaller than mechanical engineering design. All other design fields, including architecture, were less than one-tenth of the mechanical design market.

While there are several firms writing software programs for segments of the smaller design market, the scale of the market, the popularity, increasing availability, and use of microbased programs for similar work is apparently causing major divisions in marketing strategy. Considerably more activity is occurring in the microbased than in the minibased CADD industry. Microcomputer firms are, in effect, leap-frogging their competition with newer, better software, and expanded capabilities with each new program introduced. This situation is being accelerated by the introduction of the super micros (for instance IBM-AT). With larger internal memory, increased computer speed, and other features at lower comparative prices, it is almost certain that the differences in integration of drafting and design, system capabilities, and cost between present day micros and minis will disappear in the next 5 years.

FACTORS SHAPING the EVALUATION of the MINI-COMPUTER CADD SYSTEM for REGION 5

Consistent with the original evaluation proposal, we investigated several options to acquire a mini-CADD system for use and evaluation by Region 5. Because this is a generic evaluation effort, several criteria were used to compare system options. These were:

(1) <u>Obtain a Cost-effective Evaluation of Minilevel CADD</u>.

(a) Because of the learning curve associated with minis, we determined that this would require an evaluation period of at least 1 year. (Lost production could be recouped during a 1-year period).

(b) Staff size was considered. Sufficient staff is needed to dedicate time to the evaluation without seriously interrupting production.

(c) Need to keep costs reasonable. Because the price of a fully integrated system could be significant, we were particularily interested in what was available generically before full commitment to minicomputer evaluation.

(2) <u>Salvage</u>.

(a) Because we recognized that minis would be potentially costly to evaluate, we considered leasing. The normal breakeven point--lease to purchase--was 15 to 18 months. Vendors were not too interested in leasing. In one instance, leasing for 1 year would cost about 11 percent more than the purchase price.

(b) The most viable salvage option was to consider Data General hardware (MV 4000) or Lot 7 (HP 9020 series) for potential reuse in other existing Forest Service systems.

(c) A third option was to consider only systems with standard components. (Intergraph Corporation has a very good CADD system. However, Intergraph significantly modifies standard DEC/VAX equipment so that only Intergraph programs can be used).

(3) Need to evaluate both drafting and design capabilities. Originally, only integrated systems were considered. After discussions with several vendors regarding capabilities and cost of both basic software and specific design applications, this criterion was modified. It appeared that the second "D" in CADD would be extremely expensive.

Criterion 1--evaluation of a mini-CADD--was easily satisfied by assignment. For both architectural and structural engineering, only Regions 5 and 6 were considered for the mini. Region 5 expressed strong interest in participation and was, therefore, selected.

Criterion 2--salvage--was difficult to compare but did limit the wide choice of equipment. Choosing systems based on hardware rather than software does violate a principal tenet of system selection. However, because the evaluation was generic rather than specific concerning software, matching acceptable softwares for a selected support hardware was considered prudent. (The concept of our generic evaluation was to use a good system and become proficient enough to intelligently evaluate other systems in the same general level through vendor/user discussions, reading, demonstrations, and so forth.)

Criterion 3--evaluation of drafting and designing--was accomplished to the extent practical with a side-by-side comparison. The results appear in table 1. Because the features of each system were somewhat different, this analysis is an approximation.

CONCLUSIONS

While there are some well-developed commercial CADD systems that provide integrated drafting and design, very little is available below $150,000. Vendors

Table 1.--Mini-CADD evaluations.

Item	Sys Comp/DG	Intergraph	Holguin/ HP1000[a]	ICM/ HP9000 (9020)[a] or (9050)	GRAFTEX/ HP9000
Hardware:					
Costs					
1st Work Stat.	109,700	129,000	57,000	68,000	68,000
complete 2nd Work Stat.	23,000	48,000	15,000	23,800	23,800
Software:					
Basic Integrated Drafting Package (Added option)	65,000	20,000 (20,000)	15,200	30,000	50,000
Capability	3D	3D	2D	3D	3D
Design Analysis	Unknown (extra)	16,000 (22,500)	None	25,000	25,000
Training (3 persons)	20,000	6,000	2,600	?	est. 3,000
Est. Cost	217,000	219,000	89,800	146,800	169,800
User Numbers	Few	Many	Many	Unknown	Recent Issue

[a]Hewlett Packard (HP) representatives recommended that should "good" drafting and design analysis both be desired, both systems (hardwares and softwares) should be purchased. The estimated cost of one station is $197,000. HP recommended a less expensive option, the GRAFTEX/HP System. This, however, did not provide the type of integration capabilities for the disciplines being considered.

Commentary:

Sys Comp/DG--Sys Comp is one of four third-party vendors providing CADDs written for Data General hardware and offers perhaps the best software of this group. Regions 1 and 5 Engineering Staffs have reviewed Sys Comp's EASINET program. Several applications need updating. Limited users. Has mechanical engineering origin. Not architecturally integrated.

Intergraph--Very good architectural drafting program with some related engineering design applications. Good update potential. Software modules are expensive. Additional work stations are very expensive.

Holguin/HP1000--Good architectural drafting package. No structural design analysis available. Good update potential.

ICM/HP9000--Poor drafting package. Good modeling/design analysis.

GRAFTEX/HP9000--Very good drafting and design programs for tool and die manufacturing. No architectural integration. No vendor support planned for architectural users.

with programs compatible to hardware that could be integrated with existing Forest Service hardware offer very limited choices. The lowest priced mini-level system offered by Hewlett Packard is the Holguin/HP1000 combination. The HP1000 will not operate the road design graphics program currently run on the Hewlett Packard Model 9020 (Lot 7). The Sys Comp EASINET program is costly and has limited architectural integration capabilities.

Lee Wan and Associates, Incorporated, under contract to evaluate needs and recommend cost-efficient systems, has indicated that the Forest Service should focus on the expanding microcomputer field. Engineering design applications can be run on the same hardware but in a nonintegrated process. In the consultant's opinion, it would be diffcult to justify and amortize the investment of a fully integrated drafting and design system over functionally similar, but less sophisticated, micro-CAD systems.

Lee Wan and Associates viewed several microsystems and evaluated three of the more highly qualified micro-CADD systems: AUTO-CAD, PCAD, and Versa CAD. Of these three, the consultant recommended that we consider Versa CAD. It based this determination on its analysis of the Regional Office design workloads, types and complexity of designs, and a comparison of CAD features appropriate for Forest Service design automation. In addition, Versa-CAD is written with the Graphics Exchange Specification file structure. This allows a computer to process data from another computer almost directly. Lee Wan and Associates suggested that five workstations per office would be an approximate cost breakeven point for separate micros in one office. Above that number, a compatible minisystem with appropriate software could be considered. The consultant's recommendaton for a minisystem is the Holguin/HP1000 system. The IGES-based softwares of both would enable inter-Regional exchange of project files.

Based on the findings of our review of the minicomputer CAD market (with salvage potential) and the consultant's recommendations, I recommend that we abandon the minicomputer evaluation in favor of the microsystems. While Region 8 is currently reviewing a microsystem (PCAD/IBM-PC), it is not conducting design analysis. I recommend expanding the evaluation of micros using Versa CAD/IBM-AT or a similar quality system and testing the practicality of using an integrated drafting system and nonintegrated engineering design.

The IBM-PC/AT or compatible hardware is readily salvageable, and a wide variety of third-party A/E design and general application software is available.

Engineering Technical Information System

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