

# PACIFIC SOUTHWEST Forest and Range Experiment Station

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## SIMULATING FOREST PICTURES BY IMPACT PRINTERS

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In the applications of computers to forestry problems, the answers are usually shown in the form of text or tables. If a graphic presentation in hard copy form is needed, a problem arises if only a printer is available. This is particularly true at field locations. The occasional need for graphic output simply does not justify the maintenance of specialized equipment, such as incremental line plotters.

One solution to the hardware problem is to simulate pictures by producing shades of gray with the available printer. This solution is widely used to display remote sensing data. The problem becomes one of selecting the symbols to produce gray levels, from many possibilities. The approach is desirable for a quick look at large volumes of data. Pictorial quality is severely limited, however, since the space between symbols makes streaks in the density patterns.

Another alternative is to acquire a terminal that has both text and graphic capabilities. High-speed ink jet and electrostatic devices with this dual capability require substantial investments. They may be feasible at computer centers, but not field offices. A compromise is a mechanical printer/plotter that resembles a typewriter and costs about four times as much. Although slow, in plot mode it offers fine character positioning which allows removal of space between symbols, giving a smoother gradation of gray scales than a line printer can offer.

This report suggests procedures to generate images with either a line printer or a printer/plotter. It describes applications and offers examples based on the use of elevation data available for the contiguous United States. Methods are emphasized because character fonts are not standard, and some experimentation by the user should be expected.

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1978. *Simulating forest pictures by impact printers*. Gen. Tech. Rep. PSW-25, 11 p., illus. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

Two mechanical devices that are mainly used to print computer output in text form can simulate pictures of terrain and forests. The line printer, which is available for batch processing at many computer installations, can approximate halftones by using overstruck characters to produce successively larger "dots." The printer/plotter, which is normally used as an interactive terminal, permits fine adjustment of the space between characters in the plot mode. This control over blank space improves tonal appearance and permits solid black. The two types of printers have complementary uses. The line printer is best for high volumes of data, while the slower printer/plotter offers a greater range of densities.

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*Retrieval Terms:* mapping systems; computer simulation; pattern recognition; impact printers; gray scale.

Generally the first output device acquired in a batch processing computer system is a line printer. Remote terminals are likely to be low-speed devices similar to a typewriter for hardcopy and perhaps a cathode-ray-tube (CRT), for transitory images. It was realized early that line printers could serve a dual purpose and produce gray-toned pictures by selecting appropriate symbols (Perry and Mendelsohn 1964).

Shaded graphics have diverse forestry applications. Research on pattern recognition by using data from satellites is aided by gray-toned pictures (Heller 1975). Digital terrain data collected by the military services cover the contiguous United States at a resolution of about one point per acre. Instead of contour lines, areas between contour lines can be shaded to indicate relief. A subjective form of relief representation is hill-shading—a laborious cartographic process that can be automated (Yoeli 1965). Recent analytical hill-shading models include subtle atmospheric effects in addition to just changing the sun angle (Brassel 1974). Some problems may require digitizing data from topographic maps or stereo models by using aerial photos. From these data the intervisibility between points can be computed under varied conditions and displayed as shaded patterns. (Travis and others 1975). Slopes or aspects can also be computed from terrain data and displayed by gray level classes (Sharpnack and Akin 1969).

Computer mapping systems based on the uniform grid determined by line printer conventions are widely available. Most systems were developed for urban applications, typically keying census data to alternate density levels forming a choropleth map. Perhaps the best known systems are SYMAP and GRID, developed by the Harvard Laboratory for Computer Graphics (Harvard University 1973). Newer grid systems allow a user to overlay land-use maps before displaying statistics as shades of gray (Federation of Rocky Mountain States 1977, Sinton 1976).

Numerous investigators have studied ways to improve the gray scale attainable with a line printer. Since the process is subjective, it is not surprising that they have reported dissimilar results, and that alternatives are available.

### PICTURE SIMULATION WITH LINE PRINTER

The problem of producing a gray-tone image with a line printer involves a binary choice of resolution

and many possible character combinations, called codes. A line has 10 characters per inch. Six lines per inch are considered normal and eight optional. If the input data are equally spaced row- and column-wise, then the output is distorted. If cells are interpolated into each line, the overall map dimensions are preserved, but there is local distortion. Data can be collected at intervals selected to fit the spacing of a particular line printer.

For a particular printer and character set, the objective will largely determine the number of codes used. If the purpose is quantitative such that a gray-tone code can be looked up in a legend regardless of its map position, then the limit is seven or eight (Dickinson 1973, p. 162). Although this number may be conservative, observation of numerous examples in the literature would suggest 10 as an upper limit. If the purpose is relief representation or simply pictorial, then the number of codes may be two or three times greater, or whatever number gives an impression of increasing density to the observer. The impression is only roughly related to the area of ink deposition because less quantifiable factors dominate.

Some considerations affecting ranking for a given font are (a) the number of overprints which affects both density and print time, (b) the effect of multiple ink layers in portions of the overprint, (c) the distribution of ribbon ink and character wear along the print line, and (d) the viewing conditions, particularly distance.

A major consideration is the formation of patches having directional or textural effects which are usually detrimental. Spurious textures are most likely to occur with the lightest shades, where there are few choices of symbols, and a smooth density transition is most difficult. One attempt to avoid distracting patterns led to a set of 37 symbols with up to six overstrikes (Henderson and Tanimoto 1974). Recognizable individual symbols may also distract the observer.

To represent relief, we decided to simulate a conventional graphic process called halftone printing. When enlarged tenfold, newspaper pictures are seen to be actually black dots or squares of different sizes. By constructing star-like dots of graduated sizes, we minimized spurious directional patterns. In halftone printing, neither completely white nor solid black areas occur. Text produced by a line printer also always has some blank space between characters, regardless of the number of overstrikes.

We constructed 16 graduated "dots" using up to eight overstrikes (*fig. 1*). Decreasing the number of

gray levels will raise contrast while increasing the likelihood of creating spurious plateaus or contours. A subset of 8 symbols ending with the penultimate level of the 16 will result in a maximum of 6 overstrikes (*fig. 2*). In addition to the advantage of reduced print time, a subset of eight symbols will be easier to form with diverse character fonts.

Elevation data for the Pyramid Peak quadrangle were assigned 16 gray level "dots," listed and reduced 6.6-fold (*fig. 7*). Another illustration produced using eight gray levels and the same reduction shows the change in contrast (*fig. 8*). Print times were essentially the same at 2 minutes.

Halftone dots are unsuitable for those applications, such as statistical output from computer mapping systems, in which the code must be distinguishable in a map legend as well as provide a separable shade of gray. We constructed two sets of eight codes which seem to us to meet the dual requirements. One set may prove more suitable than the other depending on the particular font available (*figs. 3, 4*). The two seem to give a greater range than a previously published set (Stucki 1969). Stucki's codes, like our two sets, uses a maximum of four overstrikes (*fig. 5*). All three sets were printed by using Pyramid Peak quadrangle data and reducing 6.6-fold (*figs. 9-11*). The subtle differences in appearance change with viewing distance. A spacing of six lines per inch was used. Experiments with eight lines per inch, an option not always available, showed no obvious gain in tonal effect.

### PICTURE SIMULATION WITH PRINTER/PLOTTER

Both a line printer and a printer/plotter can mechanically produce text in an identical format of 10 characters per inch across a line and 6 or 8 lines per inch. Typically a printer/plotter is used as a remote terminal and prints characters individually at about 30 per second. The plotting capability is due to fine bidirectional increments. A solid, curved line can be produced, for example, by producing a string of overlapping periods.

Fine positional control enables the printer/plotter to remove the blank space between characters. This capability gives it three advantages over the line printer. First, the dark end of the gray scale is extended by diminishing or exactly removing the blank areas between symbols. Second, a greater diversity of codes is obtainable with a given number of over-

strikes. Finally, flexibility is gained for computer mapping systems using a fixed grid. Both input and output grid cells may be square, thereby avoiding interpolation or distortion. Discrete-scale changes are also possible, with the exact multiple uniquely determined by the output device selected.

For example, our Diablo<sup>1</sup> daisy-wheel printer/plotter has an incremental movement resolution of 1/48th inch between lines and 1/60th inch between characters. With four line feeds and five horizontal spaces, a 1/12-inch square grid is attainable. The elevation data collected at 200-foot contour intervals were digitized from maps with a representative fraction of 1 to 250,000 at a map distance of 0.01 in. or 208.3 feet on the ground.<sup>2</sup> When these data are converted to gray level codes and printed at a 1/12-inch resolution, the scale of the shaded map is 1 to 30,000 or close to 2 inches per mile, which is a common scale used in forestry (California State Cooperative Soil-Vegetation Survey 1958).

The printer/plotter offers so many combinations of character symbols, positions, and spacings that grid cell size must be determined before selection begins. At a 1/12-inch resolution, there are 20 (4 X 5) print positions. A period could be printed at any one of the matrix positions, giving a very general capability of forming symbols. This choice is impractical because of time consumed and physical wear on the period. Instead, the darker areas can be formed more rapidly with larger symbols.

We decided upon 10 gray levels for relief representation. These levels can be illustrated in a legend (*fig. 6*). The northeast quarter of the Pyramid Peak quadrangle was printed and reduced 3.3-fold for comparison with the line printer images. Print time was 2 hours, 10 minutes or 31 sq. in. per hour (*fig. 12*). The cost in dollar terms is more elusive because the hardware configuration we used is not rented. The Pyramid Peak illustration cost about \$7 to \$8, assuming a 5-year depreciation period, maintenance, and one-shift use.

Some experimentation may be necessary to reproduce the appearance of the illustrations in this report.

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<sup>1</sup>Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

<sup>2</sup>Elevation data are available from the National Cartographic Information Center, U.S. Geological Survey, 507 National Center, Reston, Virginia 22092.

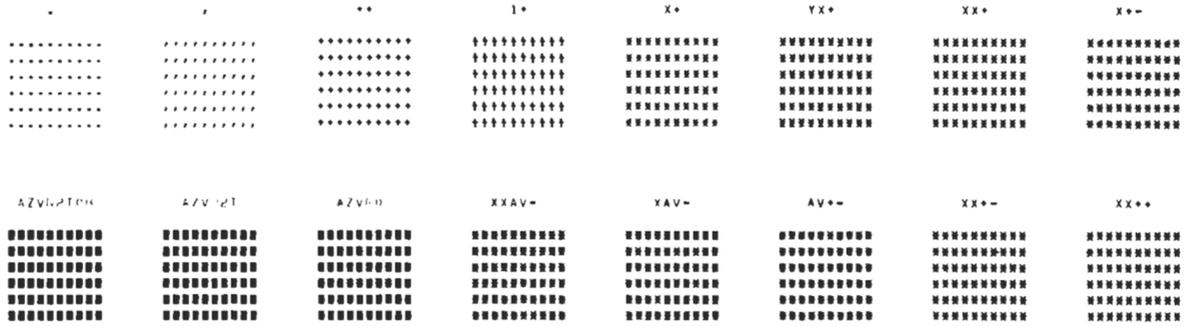


Figure 1—A set of 16 symbols for a halftone display, not including blank.

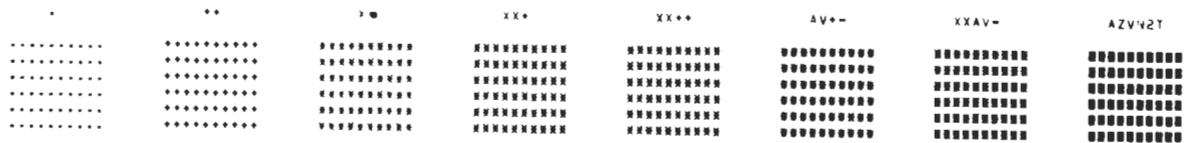


Figure 2—Eight halftone symbols from the above set of 16 (every odd-numbered symbol).

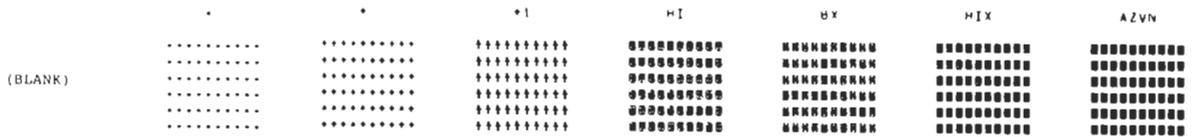


Figure 3—This set of eight gray tone symbols can be distinguished in a legend accompanying an illustration.

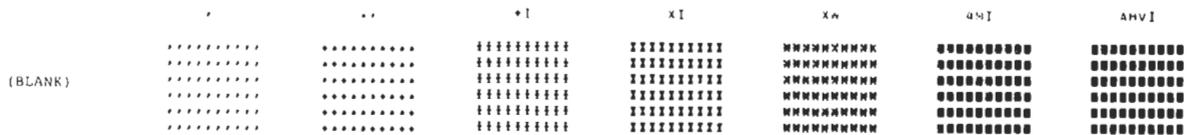


Figure 4—This set of eight separable gray codes may be more suitable with some line-printer character fonts.

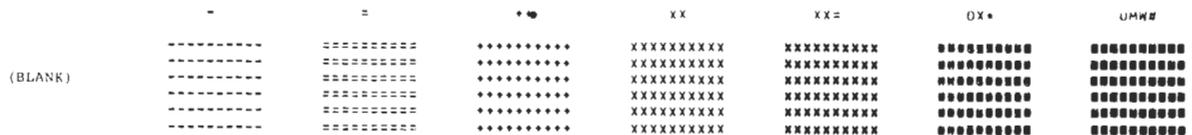
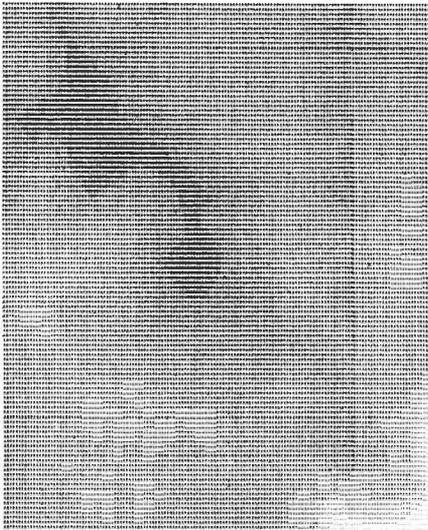


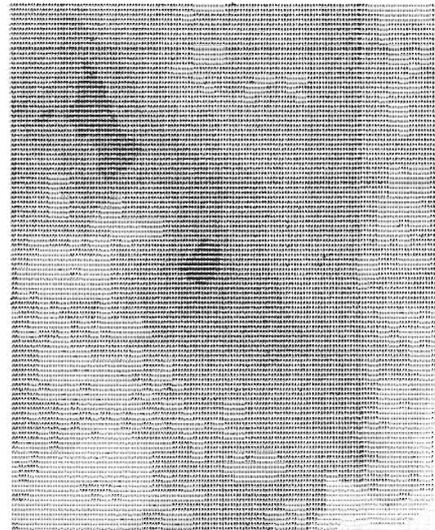
Figure 5—Stucki's set of eight gray level codes uses four overstrikes (Stucki 1969).



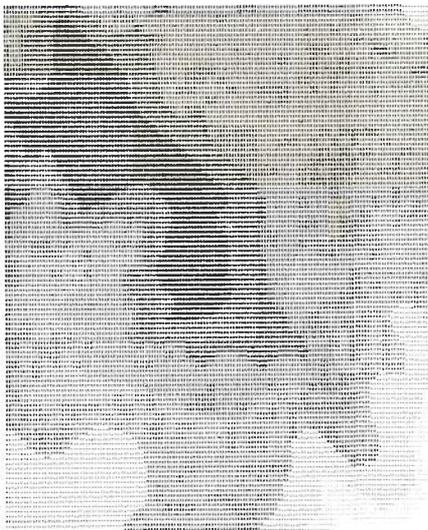
Figure 6—A printer/plotter set of 10 gray tones can be used in a map legend.



**Figure 7**—Digital elevation data spanning 4000 feet give an impression of relief when transformed into halftones.



**Figure 8**—Reducing the number of halftone “dots” from 16 to 8 increases contrast.



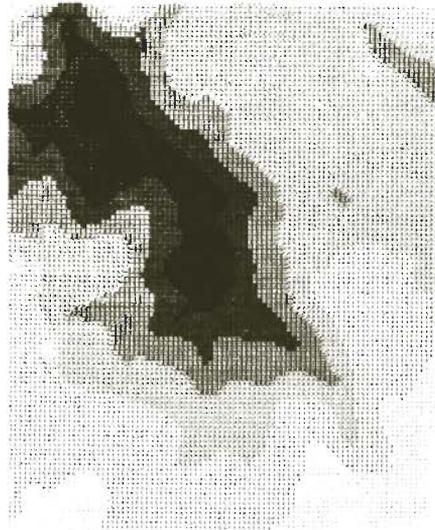
**Figure 9**—These terrain data were produced by the eight symbols of *figure 3*.



**Figure 10**—The same terrain illustrated in *figure 9* is pictured by using the eight symbols in *figure 4*.



**Figure 11**—The same Pyramid Peak data using Stucki’s set of eight symbols (Stucki 1969).



**Figure 12**—A printer/plotter representation of relief can be compared to the figures produced by line printer.

The character and overstrike patterns used to illustrate the terrain data (figs. 7-12) are shown in figures 1-6:

Symbols shown in these figures:	Were used to produce these figures:
1	7
2	8
3	9
4	10
5	11
6	12

In programming and operating a printer/plotter, we found several small ways to improve performance which may apply to like mechanical devices. We found the quality of an illustration to be strongly affected by the choice of ribbon. In most cases, film ribbon is preferable to cloth. Print time can be reduced about 5 percent just by printing in a zig-zag (boustrophedonic) fashion. In addition to the carriage return time saved, print quality is improved, which is attributed to reduced vibration. Print time can be reduced at the cost of additional programming. The data can be searched in advance of printing for blank lines or segments to skip over using the print suppression and tabbing features available.

Two versions of a sample subroutine (PATT) for reading and processing data into a gray-scale representation are reproduced in the *Appendix*. These listings will reduce development time by prospective users. Subroutine PATT can be called by a simple FORTRAN main program. PATT reads unblocked records from tape but other formats and storage media can be used with slight program modifications.

The first version was developed on a NOVA 2 with a DTC printer/plotter. The corresponding UNIVAC version includes horizontal expansion of the data to compensate for line printer distortion. The eight print symbols for the line printer are those of *fig. 3*, but other sets may be substituted readily.

## CONCLUSIONS

The two types of printers are not alternatives since they differ greatly in output speed. They can complement each other. The line printer provides a "quick-look" at, say, a large volume of remote sensing print-out. The precise positioning ability of the printer/plotter is best used for presentation where appearance is more important. Line printers are widely available and standardized in many respects. Some modification of character sets may still be required because of

differences in fonts, inking methods, and wear. The gray-level symbols that we have provided should save time in finding the best set for simulating pictures on other printers.

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## APPENDIX

### Subroutine PATT—Version for NOVA 2/DTC 1200 printer/plotter

```

PARAMETER NOG=10
SUBROUTINE PATT(BUF,LEL,IEL,IC,JC,IR,JR,NCOL)
C PRINTS SQUARE BLOCKS, 1/12 INCH X 1/12 INCH, ON THE DTC 1200.
C ASSEMBLY LANGUAGE ROUTINE 'OUTC' FEEDS EACH CHARACTER
C   TO THE PRINT BUFFER.
C EACH BLOCK CONTAINS 5 HORIZONTAL AND 4 VERTICAL PRINT POSITIONS.
C THERE ARE 13 PATTERNS OF 5 CHARACTERS EACH. EACH BLOCK IS MADE
C   UP OF 4 OF THESE PATTERNS. THERE ARE 10 POSSIBLE SETS OF
C   PATTERNS TO PRINT BLOCKS GIVING 10 GREY SCALES.
C BUF IS THE ARRAY TO RECEIVE DATA FROM INPUT FILE.
C LEL IS THE LOWEST VALUE IN THE DATA.
C IEL IS THE HIGHEST VALUE IN THE DATA.
C IC IS THE BEGINNING POSITION TO BE PRINTED FROM EACH DATA
C   RECORD, JC IS THE ENDING POSITION.
C IR IS THE FIRST DATA RECORD TO BE USED, JR IS THE LAST.
C NCOL IS THE TOTAL NUMBER OF WORDS IN EACH INPUT RECORD.
COMMON/A/IPAT(5,13),ISQ(4,NOG),INH80(3),ISP(2)
INTEGER LINE(1450),BUF(NCOL)
DATA IPAT/40K,40K,40K,40K,40K, 40K,40K,47K,40K,40K,
: 40K,40K,54K,40K,40K, 40K,40K,40K,54K,40K, 40K,40K,40K,73K,40K,
: 40K,56K,40K,40K,40K, 40K,72K,40K,40K,40K, 111K,40K,53K,40K,111K,
: 111K,53K,111K,53K,111K, 72K,72K,72K,72K,72K, 73K,73K,73K,73K,73K,
: 40K,53K,40K,53K,40K, 111K,111K,111K,111K,111K/
DATA ISQ/1,1,1,1, 1,1,1,2, 3,1,1,1, 4,6,1,1, 5,6,1,1,
: 5,7,1,1, 1,1,8,1, 1,1,9,1, 1,12,13,12, 1,10,11,1/
DATA INH80/-1,2,40000K/
DATA ISP/40K,10K/
C IZIG CONTROLS DIRECTION OF PRINTING, TO AVOID UNNECESSARY
C   CARRIAGE RETURNS.
IZIG=1
INVL=(IEL-LEL)/NOG
C OPEN PRINT FILE.
CALL OPEN(10,'$TTO',INH80,IER10)
IF(IER10.NE.1) GO TO 90
C OPEN DATA FILE.
CALL OPEN(2,'EVEL',0,IER2,175)
IF(IER2.NE.1) GO TO 90
C PUT PRINT FILE IN PLOT MODE.
TYPE "<6>"
C OUTER LOOP FOR PRINTING STRIPS.
DO 39 MA=IC,JC,145
WRITE(10,1000)
MB=MIN0(MA+144,JC)
C LTOT=TOTAL CHARACTER POSITIONS PER LINE.
LTOT=(MB-MA+1)*5
C IF IR IS NOT FIRST RECORD, SKIP RECORDS 1 THROUGH KR.
IF(IR.EQ.1) GO TO 23
KR=IR-1
DO 24 J=1,KR
READ (2,2000,END=90,ERR=90) (BUF(I),I=1,NCOL)
24 CONTINUE
C PROCESS RECORDS.
23 DO 80 IREC=IR,JR

```

Subroutine PATT--Version for NOVA 2/DTC 1200 printer/plotter (continued)

```
      READ(2,2000,ERR=90,END=90)(BUF(I),I=1,NCOL)
2000  FORMAT(1X,25I4)
C FIND PATTERN SET FOR EACH DATA VALUE.
  DO 26 I=MA,MB
    26  BUF(I)=MIN0(((BUF(I)-LEL)/INVL)+1,NOG)
C STORE AND PRINT CHARACTERS AND SPACING FOR EACH LINE.
  DO 60 IR=1,4
    IL=0
    DO 50 IH=MA,MB
      M=BUF(IH)
      IF(M.GT.NOG) GO TO 91
      IF(M.LT.1) GO TO 91
      K=ISQ(IR,M)
      DO 40 L=1,5
        IL=IL+1
        IF(IL.GT.1450) GO TO 91
        LINE(IL)=(IPAT(L,K))
        IF(LINE(IL).EQ.ISP(1)) GO TO 38
        IL=IL+1
        IF(IL.GT.1450) GO TO 91
      38  LINE(IL)=ISP(IZIG)
      40  CONTINUE
      50  CONTINUE
C SKIP DIRECTLY TO LINE FEED IF LINE IS ALL BLANKS.
      IF(IL.EQ.LTOT) GO TO 60
      IF(IZIG.EQ.2) GO TO 56
      DO 55 L=1,IL
        55  CALL OUTC(LINE(L))
        GO TO 58
      56  DO 57 I=1,IL
        57  CALL OUTC(LINE(IL-I+1))
      58  IZIG=3-IZIG
      60  CALL OUTC(12K)
      80  CONTINUE
      REWIND 2
      89  CONTINUE
C LEAVE PLOT MODE.
      TYPE "<33><6>"
      WRITE(10,1000)
1000  FORMAT(1H1)
      RETURN
C ERROR MESSAGES.
      90  TYPE "<33><6>"
      WRITE(10,9000),IER10,IER2,IREC
9000  FORMAT('0FILE ERROR, IER10=',I4,6X,' IER2=',I4,6X,' IREC=',I4)
      RETURN
      91  TYPE "<33><6>"
      WRITE(10,9001),MA,MB,IH,M,IL
9001  FORMAT('0BAD SUBSCRIPT FOR ISQ OR LINE: MA,MB,IH,M,IL=',5I8)
      RETURN
      END
*>
```

Subroutine PATT—Version to run on UNIVAC 1108 (Exec. 8) with standard line printer

```

C OVERPRINTS ZERO TO FOUR CHARACTERS TO GIVE EIGHT GREY SCALES, USING A
C   UNIVAC 1108 WITH STANDARD LINE PRINTER OF 10 CHARACTERS/INCH AND
C   6 LINES/INCH. TO CORRECT FOR OVERALL DISTORTION, FOUR OUT OF
C   EACH SIX HORIZONTAL CHARACTERS ARE PRINTED TWICE.
C KUF IS THE ARRAY TO RECEIVE DATA FROM INPUT FILE.
C LEL IS THE LOWEST VALUE IN THE DATA.
C IEL IS THE HIGHEST VALUE IN THE DATA.
C IC IS THE FIRST POSITION TO BE PROCESSED FROM EACH DATA RECORD,
C   JC IS THE LAST.
C IR IS THE FIRST DATA RECORD TO BE USED, JR IS THE LAST.
C NCOL IS THE TOTAL NUMBER OF WORDS IN EACH INPUT DATA RECORD.
      PARAMETER NOG=8, NL=130
      INTEGER BUF(NL),KUF(NCOL)
      INTEGER LINE(NL)
      INTEGER CHARS(4,NOG)
C OUR #, SET 1.
      DATA (CHARS(1,I),I=1,NOG)/1H ,1H.,1H+,1H+,1HH,1HB,1HH,1HA/
      DATA (CHARS(2,I),I=1,NOG)/1H ,1H ,1H ,1H1,1HI,1HX,1HI,1HZ/
      DATA (CHARS(3,I),I=1,NOG)/1H ,1H ,1H ,1H ,1H ,1H ,1HX,1HV/
      DATA (CHARS(4,I),I=1,NOG)/1H ,1H ,1H ,1H ,1H ,1H ,1H ,1HW/
      INVL=(IEL-LEL)/NOG
C NC IS THE MAXIMUM NUMBER OF HORIZONTAL CHARACTERS THAT CAN BE EXPANDED
C   BY 4/6 AND FIT IN A PRINT LINE OF 130 SPACES.
      NC=(6*NL)/10
C OUTER LOOP FOR PROCESSING STRIPS.
      DO 89 MA=IC,JC,NC
      MB=MIN(MA+NC-1,JC)
      PRINT 1000
1000 FORMAT(1H1)
C IF IR IS NOT THE FIRST RECORD, SKIP RECORDS 1 THROUGH IR-1.
      IF(IR.EQ.1) GO TO 5
      KR=IR-1
      DO 4 IREC=1,KR
      CALL NTRAN(10,2,NCOL,KUF,L)
      CALL NTRAN(10,22)
4 CONTINUE
C PROCESS RECORDS.
5 DO 80 IREC=IR,JR
      CALL NTRAN(10,2,NCOL,KUF,L)
      CALL NTRAN(10,22)
      IF(L.NE.NCOL) GO TO 800
C EXPAND EACH 6 VALUES TO 10.
      W=.05
      L=0

```

Subroutine PATT—Version to run on UNIVAC 1108 (Exec. 8) with standard line printer (continued)

```

      K=0
      DO 10 J=MA,MR
      K=K+1
10    KUF(K)=((KUF(J)-LEL)/INVL)+1
      DO 15 J=1,K
      D=J
      D=D/6.
13    IF(W.GT.D) GO TO 15
      L=L+1
      W=W+.1
      BUF(L)=MIN(KUF(J),NOG)
      GO TO 13
15    CONTINUE
C NR INDICATES MAXIMUM NUMBER OF OVERSTRIKES FOR ALL CHARACTERS IN
C   PRINT LINE.
      NR=1
      DO 52 K=1,L
      NF=BUF(K)
      NR=MAX(NR,NF)
52    LINE(K)=CHARS(1,NF)
      NR=NR/2
C SKIP TO NEXT RECORD IF THIS ONE WOULD BE ALL BLANKS.
      IF(NR.LT.1) GO TO 80
      PRINT 1001,(LINE(J),J=1,L)
1001  FORMAT(1H ,130A1)
      IF(NR.LT.2) GO TO 80
C PRINT OVERSTRIKES.
      DO 54 ICR=2,NR
      DO 53 K=1,L
      NF=BUF(K)
53    LINE(K)=CHARS(ICR,NF)
      PRINT 1002,(LINE(J),J=1,L)
1002  FORMAT(1H+,130A1)
54    CONTINUE
80    CONTINUE
      CALL NTRAN(10,10)
      CALL NTRAN(10,22)
89    CONTINUE
      GO TO 900
800  PRINT 8000,L,IR
8000  FORMAT('OREAD ERROR=',I3,' AT ROW',I4)
900  RETURN
      END

```

### The Authors

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are assigned to the Station's research unit investigating measurement and analysis techniques for management planning, with headquarters in Berkeley, Calif. **ELLIOT L. AMIDON** is in charge of the measurement and analysis techniques research unit. He earned a bachelor's degree in forest management at Colorado State University (1954) and a master's degree in agricultural economics at the University of California, Berkeley (1961), and was assigned to production economics research at the Station until he assumed his present position in 1971. **E. JOYCE DYE**, a computer programmer, earned a bachelor's degree in geography (1973) at the University of California, Berkeley. She joined the Station staff (Support Services) in 1961 after nine years on National Forests in Oregon. She has been in her present assignment since 1970.