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**1987/51.   SLIPCIRC - a GW-BASIC program for Bishop's simplified
             slip circle stability analysis on an IBM-compatible
             micro-computer.**

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Abstract

A slope stability analysis program based on Bishop's simplified method has
been written in GW-BASIC for an IBM-compatible micro-computer. The use of
the program is described and a listing with detailed comments is provided.

INTRODUCTION

Moon (1984) introduced readers to slope stability analysis using a
Hewlett-Packard 41C programmable calculator. His program has been modified
and written in GW-BASIC so as to run on an IBM-compatible micro-computer.
This report comments on the program and enhancements now provided.

The major restraint of the program is that the subsurface cannot be
stratified. The entire earth mass under consideration is assigned one set
of parameters (i.e. density, cohesion and friction) for each particular
analysis.   Pore pressures are considered as the pore pressure ratio (ru =
$\gamma w.h / \gamma d$). There is no limit, apart from available computer memory, on
the number of slices permitted. In reality, only rarely will more than 20
slices be required. The slices are of uniform width for each particular
analysis.

A full listing of the program, including detailed comments, is provided as
Appendix 1. The program may be activated on the Engineering Geology and
Hydrology micro-computer by selecting MODELS and SLIP CIRCLE from the
start-up menu displays.   Alternatively, the GW-BASIC environment may be
invoked and the program SLIPCIRC.BAS loaded from the directory MODELS on
the hard disk.

DATA INPUT

The initial screen display requests a complete set of parameters necessary
to define a slip circle for analysis (fig. 1). Data are entered by typing
the relevant values to a screen prompt.   The back-space, insert and delete
functions may be used to correct mistakes made as the data are being
entered. To complete a data entry, the return key must be depressed. Once
this key is depressed, the particular entry cannot be altered prior to
calculation. It is necessary to complete the data input, allow the
calculation to be made, and the result displayed. The OPTIONS menu will
then be displayed and alterations can be made to any of the input data via
the change data option.

CALCULATIONS

When the last data value has been provided, the program calculates and
displays the new factor of safety. The expression evaluated is:

$$F = \frac{\sum ((c'b + (W - ub) \tan \phi')(1/m\alpha))}{\sum W.\sin \alpha}$$

where   m α = cos   (1 + (tanα.tan$\emptyset'$) / F)
        c' = cohesion
        b   = width of slice
        W   = weight of a slice
        u   = pore pressure ratio
        $\emptyset'$ = friction angle
        α = slope of failure plane
        F   = Factor of Safety

As F appears on both sides of the expression, it is most convenient to solve for F in an iterative manner.

OPTIONS MENU

Immediately the new Factor of Safety has been calculated, the OPTIONS menu will be displayed (fig. 2). An option is selected by typing the first letter of its name. The options are:

Iterate: Entering I or i at the option menu prompt replaces the original factor of safety with the just calculated value. A status message is displayed and the calculation routine is re-entered. The new Factor of Safety will be displayed and program control returns to the options menu.

Change data: A new menu (fig. 3) replaces the options menu when C or c is entered at the option menu prompt. Parameters may be changed by simply typing the first letter of the required parameters name. The existing value is erased and a new value is requested. To complete data entry, the return key must be depressed. As many parameters as desired may be changed before typing O (for Ok to re-calculate). This causes the program to re-enter the calculation routine, display the new Factor of Safety, and returns control to the option menu.

               When changing the number of slices, it is assumed that the end points will not change but that a new ground shape (i.e. Y co-ordinate for the midpoint of each slice) will be needed along with a new Factor of Safety.

               To allow for the modelling of tension cracks, the end points may be changed (new values for each of the two co-ordinate pairs will be requested).

               It is necessary to enter O or o to exit from the change menu.

End: Selecting E or e at the option menu prompt closes any files that may have been opened and returns control to the MS-DOS environment.

Print data: Entering a P or p at the option menu prompt will cause the parameters used in the calculation to be sent to the line printer (provided it is switched on). A status message is displayed during this process. Initially, the ground shape (i.e. the Y co-ordinates for the mid-points of each slice) values are printed followed by each of the other parameters in tabular format. On subsequent print requests, the ground shape data are only printed should they have been changed via the options menu.

A typical print-out is given in Appendix 2.

Save data: Entering a S or s at the options menu prompt will cause all
              the parameters used in the calculation to be written to disk.
              The first time this option is selected, a new screen display
              seeking information about the file specification (fig. 4) is
              presented. Default values for the file specification are
              provided on this screen. The return key need only be
              depressed to accept each of the default values.

              New values may be typed over the defaults.   To complete
              entering a new value, the return key must be depressed. The
              file specification will be displayed briefly before returning
              to the original screen. A status message is displayed as the
              data is written to the disk.   The data is written in comma
              separated ASCII format (i.e. a comma is placed between
              consecutive values).   Program   control is returned to the
              options menu.

Range: Typing a R or r at the options menu prompt will allow the
              user to specify a range of density, pore pressure, cohesion,
              Y circle, or friction for which calculations will be made,
              the results printed, and all parameters written to disk
              automatically. When this option is selected the options menu
              is replaced by the RANGE FOR menu (fig. 5).

              A parameter for range calculations is selected by typing the
              first letter of its name. This causes the range for menu to
              be replaced by the range request menu (fig. 6). The start,
              end and step values are entered, depressing the return key
              after each to accept the value. The step value is the amount
              by which the parameter will be incremented between
              consecutive calculations.

              After entering the step value, a status message will be
              displayed. The start value of the chosen parameter will be
              displayed and the calculation routine entered until the old
              and new Factor of Safety converge on the second decimal
              place. The parameters are then printed to the line printer
              and written to disk. File specification is requested if not
              previously given. The new Factor of Safety is displayed to
              the screen, along with the incremented value of the chosen
              parameter. When calculations have been completed for the
              specified range, the program control returns to the options
              menu.

REFERENCE

MOON, A. T. 1984. Bishop's simplified slope stability analysis with a
    Hewlett-Packard 41C calculator. *Unpubl. Rep. Dep. Mines Tasm.* 1984/51.

[27 October 1987]

STABILITY ANALYSIS: SLIP CIRCLE

END POINTS:		GROUND SHAPE: Slice	Y co-ord
X lhs = 4		1	5.5
Y lhs = 4		2	7.5
X rhs = 24		3	9
Y rhs = 15		4	11.5
Number of Slices = 5		5	14.5
Density (kN/cub m) = 20			
Cohesion (kPa) = 10			
Friction (degrees) = 30			
Ru = .5			
Y Circle (m) = 39			
Safety Factor = 1			

Figure 1.

STABILITY ANALYSIS: SLIP CIRCLE

END POINTS:		GROUND SHAPE: Slice	Y co-ord
X lhs = 4		1	5.5
Y lhs = 4		2	7.5
X rhs = 24		3	9
Y rhs = 15		4	11.5
Number of Slices = 5		5	14.5
Density (kN/cub m) = 20			
Cohesion (kPa) = 10			
Friction (degrees) = 30			
Ru = .5			
Y Circle (m) = 39			
Safety Factor = 1			

New Factor of Safety = 1.15

OPTIONS: Iterate   Print data
            Change data   Save data
            End   Range

        (Enter I,C,P,S,E or R)

Figure 2.

STABILITY ANALYSIS: SLIP CIRCLE

END POINTS:	X lhs = 4	GROUND SHAPE:	Slice	Y co-ord
	Y lhs = 4		1	5.5
	X rhs = 24		2	7.5
	Y rhs = 15		3	9
			4	11.5
Number of Slices = 5			5	14.5
Density (kN/cub m) = 20
Cohesion (kPa) = 10
Friction (degrees) = 30
Ru = .5
Y Circle (m) = 39
Safety Factor = 1.15

CHANGE: Density   End Points
             Cohesion   Number of Slices
             Friction   Ground Shape
             Ru   Safety Factor
             Y Circle   Ok to re-calculate

        (Enter D,C,F,R,Y,E,N,G,S or O)

Figure 3.

PROVIDE DISK DRIVE A:
          path-name \
     and file-name STABIL.DAT

File specification is
A:\STABIL.DAT

Figure 4.

STABILITY ANALYSIS: SLIP CIRCLE

END POINTS:	X lhs = 4	GROUND SHAPE: Slice	Y co-ord
	Y lhs = 4	1	5.5
	X rhs = 24	2	7.5
	Y rhs = 15	3	9
		4	11.5
Number of Slices = 5		5	14.5
Density (kN/cub m) = 20			
Cohesion (kPa) = 10			
Friction (degrees) = 30			
Ru = .5			
Y Circle (m) = 39			
Safety Factor = 1.15			

RANGE FOR: Density   Ru
              Cohesion   Y Circle
              Friction

(Enter D,C,F,R OR Y)

Figure 5.

STABILITY ANALYSIS: SLIP CIRCLE

END POINTS:	X lhs = 4	GROUND SHAPE: Slice	Y co-ord
	Y lhs = 4	1	5.5
	X rhs = 24	2	7.5
	Y rhs = 15	3	9
		4	11.5
Number of Slices = 5		5	14.5
Density (kN/cub m) = 20			
Cohesion (kPa) = 10			
Friction (degrees) = 30			
Ru = .5			
Y Circle (m) = 39			
Safety Factor = 1.15			

Start value of Ru = 0
  End value of Ru = .5
           Calculate in steps of = .1

Figure 6.

APPENDIX 1

Program SLIPCIRC

```
10 REM SLIPCIRC: a slip circle stability analysis based on BISHOP'S method
20 '
30 '              version #3.0     APRIL 87    B D WELDON
40 '
50 '
60 '
70 SCREEN 0,0,0,0                            :' set screen 0 as active
80 KEY OFF                                   :' turn function key display off
90 CLS                                       :' clear screen display
100 COLOR 1,0                                :' set back/fore-ground colors
110 LOCATE 1,20                              :' find line 1, col 20 on screen
120 PRINT "STABILITY ANALYSIS: SLIP CIRCLE"  :' display title to screen
130 COLOR 7,0:LOCATE 3,1:PRINT "END POINTS:" :' display to screen
140 J =1:K=11                                :' set counter start/stop values
150 GOSUB 1020                               :' DATA INPUT
160 DIM Y(NS),TH(NS),U(NS),W(NS)             :' dimension up arrays
170 PT=0:AC=0:TX=0                           :' set flag values
180 LOCATE 3,39                              :' set screen position
190 PRINT "GROUND SHAPE: Slice    Y co-ord" :' display to screen
200 VP=4:HP=55:J=1:K=NS                      :' set screen/counter parameters
210 GOSUB 1290                               :' get GROUND SHAPE values
220 GOSUB 1400                               :' calculate SAFETY FACTOR
230 '
240 ' ***********************************
250 ' DISPLAY CALCULATED FACTOR OF SAFETY
260 ' ***********************************
270 '
280 LOCATE 16,4:COLOR 7,0                    :' set screen display parameters
290 PRINT "New Factor of Safety = ";        :' display to screen
300 PRINT USING "#.##";FS                    :' display formatted result
310 '
320 ' ***********
330 ' CHECK FLAGS
340 ' ***********
350 '
360 IF AC=0 THEN GOSUB 2020                  :' check flags, display OPTIONS
370 IF AC=1 AND ACC=1 THEN 6380              :' check flags, data PRINTed
380 IF AC=1 AND ACC=0 THEN 6400              :' check flags, data SAVEd
390 '
400 ' ***********************
410 ' CHECK KEYBOARD RESPONSE
420 ' ***********************
430 '
440 GOSUB 2160                               :' check keyboard for response
450 AN%=INSTR("IiCcPpSsEeRr",AN$)            :' valid response range
460 IF AN%<1 OR AN%>12 THEN 410              :' check validity of response
470 ON AN% GOTO 2240,2240,2360,2360,3020,3020
              ,4020,4020,5020,5020,6020,6020 :' goto selected response
480 '
490 ' *********
500 ' DATA BANK
510 ' *********
520 '
530 DATA "X lhs = ","###.#",3,19             :' DATA BANK
540 DATA "Y lhs = ","###.#",4,19
550 DATA "X rhs = ","###.#",5,19
560 DATA "Y rhs = ","###.#",6,19
570 DATA "Number of Slices = ","##",8,8
580 DATA "Density (kN/cub m) = ","##.#",9,6
590 DATA "Cohesion (kPa) = ","##.#",10,10
600 DATA "Friction (degrees) = ","##.#",11,6
610 DATA "Ru = ","#.##",12,22
620 DATA "Y Circle (m) = ","###.#",13,12
630 DATA "Safety Factor = ","#.##",14,11
1000
```

```
1010 '    **********
1020 '    DATA INPUT                                          :'
1030 '    **********
1040 '
1050 FOR I=J TO K                                             :' start counting parameters
1060    READ VN$,PU$,VP,HP                                    :' read data
1070    LOCATE VP,HP:PRINT VN$;:INPUT "",VV                   :' request value
1080    ON I GOSUB 1160,1170,1180,1190,1200,
              1210,1220,1230,1240,1250,1260                   :' assign input to parameter
1090 NEXT I                                                   :' next parameter
1100 RETURN                                                   :' finished here
1110 '
1120 ' **************************
1130 ' ASSIGN PARAMETER TO INPUT
1140 ' **************************
1150 '
1160 XL=VV:RETURN                                             :' X lhs
1170 YL=VV:RETURN                                             :' Y lhs
1180 XR=VV:RETURN                                             :' X rhs
1190 YR=VV:RETURN                                             :' Y rhs
1200 NS=VV:RETURN                                             :' Number of Slices
1210 GA=VV:RETURN                                             :' Density
1220 CO=VV:RETURN                                             :' Cohesion
1230 PH=VV:RETURN                                             :' Angle of Internal Friction
1240 RU=VV:RETURN                                             :' Pore Pressure Ratio
1250 YC=VV:RETURN                                             :' Y Circle
1260 F1=VV:RETURN                                             :' Factor of Safety
1270 '
1280 '    **********************
1290 '    GROUND SHAPE DATA INPUT
1300 '    **********************
1310 '
1320 FOR I=J TO K                                             :' start counting slices
1330    LOCATE VP,HP:PRINT I                                  :' display slice number
1340    LOCATE VP,HP+10:INPUT "",Y(I)                         :' request Y co-ordinate
1350    VP=VP+1                                               :' increment screen line counter
1355    IF I=20 THEN VP=4
1360 NEXT I                                                   :' next slice
1370 RETURN                                                   :' finished here
1380 '
1390 '    ************
1400 '    CALCULATIONS
1410 '    ************
1420 '
1430 XA=(XL+XR)/2:YA=(YL+YR)/2:XD=XL-XR:YD=YL-YR:' calculate geometry
1440 XC=XA-(YC-YA)*YD/XD                                      :'
1450 CI=SQR((XC-XL)*(XC-XL)+(YC-YL)*(YC-YL))                  :'
1460 DF=0:RF=0:U=0:W=0:J=1:K=NS                               :' initialise accumulators
1470 FOR I=J TO K                                             :' start counting slices
1480    T1=(XR-XL)/NS:T2=I-.5:T3=XL-XC:
         T4=360/(2*3.141593):T5=2*3.141593/360                :' calculate forces
1490    TH=(T1*T2+T3)/CI:TEMP=TH/SQR(1-TH*TH)                 :'
1500    TH(I)=ATN(TEMP)*T4                                    :'
1510    W(I)=((Y(I)+(CI*COS(TH(I)*T5)))-YC)*GA                :'
1520    W=W+SIN(TH(I)*T5)*W(I)                                :'
1530    DF=DF+SIN(TH(I)*T5)*W(I)                              :'
1540    U(I)=(1-RU)*W(I)*TAN(PH*T5)+CO                        :'
1550    V=(SIN(TH(I)*T5)*TAN(PH*T5)/F1)+
              COS(TH(I)*T5)
1560    RF=RF+(U(I)/V)                                        :'
1570 NEXT I                                                   :' next slice
1580 FS=RF/DF                                                 :' calculate Factor of Safety
1590 RETURN                                                   :' finished here
2000 '
2010 '    **********
2020 '    OPTION MENU
```

```
2030 '    ***********
2040 '
2050 LOCATE 18,5:COLOR 1,0:PRINT "OPTIONS:"        :' display OPTIONS menu
2060 LOCATE 18,16:COLOR 4,6:PRINT "I":
     LOCATE 18,17:COLOR 7,0:PRINT "terate"         :' iterate
2070 LOCATE 18,35:COLOR 4,6:PRINT "P":
     LOCATE 18,36:COLOR 7,0:PRINT "rint data"      :' print data
2080 LOCATE 19,16:COLOR 4,6:PRINT "C":
     LOCATE 19,17:COLOR 7,0:PRINT "hange data"     :' change data
2090 LOCATE 19,35:COLOR 4,6:PRINT "S":
     LOCATE 19,36:COLOR 7,0:PRINT "ave data"       :' save data to disk
2100 LOCATE 20,16:COLOR 4,6:PRINT "E":
     LOCATE 20,17:COLOR 7,0:PRINT "nd"             :' end session
2110 LOCATE 20,35:COLOR 4,6:PRINT "R":
     LOCATE 20,36:COLOR 7,0:PRINT "ange"           :' range of data for auto-calc
2120 LOCATE 22,18:COLOR 3,0:
     PRINT "(Enter I,C,P,S,E or R)"                :' display valid responses
2130 RETURN                                        :' finished here
2140 '
2150 '    ****************
2160 '    KEYBOARD RESPONSE
2170 '    ****************
2180 '
2190 AN$=INKEY$                                    :' assign keyboard response
2200 IF AN$="" THEN 2190                           :' check keyboard for response
2210 RETURN                                        :' finished here
2220 '
2230 '    **************
2240 '    ITERATE OPTION
2250 '    **************
2260 '
2270 LOCATE 22,16:COLOR 7,0:PRINT SPC(34)          :' clear prompt line from screen
2280 LOCATE 22,18:COLOR 7,0:
     PRINT "RE-CALCULATING"                        :' display status message
2290 F1=FS                                         :' re-assign Factor of Safety
2300 LOCATE 14,26:COLOR 7,0:PRINT SPC(24)          :' remove old value from screen
2310 LOCATE 14,27:PRINT USING "#.##";FS            :' display new value to screen
2320 GOSUB 1400                                    :' now re-calculate FS
2330 GOTO 250                                      :' and display to screen
2340 '
2350 '    ******************
2360 '    CHANGE PARAMETER(S)
2370 '    ******************
2380 '
2390 HD=1                                          :' set flag for header print
2400 FOR I=16 TO 23:LOCATE I,1:PRINT SPC(50):
     NEXT I                                        :' erase part of screen display
2410 LOCATE 18,3:COLOR 1,0:PRINT "CHANGE:"         :' display CHANGE menu
2420 LOCATE 18,13:COLOR 4,6:PRINT "D":
     LOCATE 18,14:COLOR 7,0:PRINT "ensity"         :' density
2430 LOCATE 18,33:COLOR 4,6:PRINT "E":
     LOCATE 18,34:COLOR 7,0:PRINT "nd Points"      :' end points
2440 LOCATE 19,13:COLOR 4,6:PRINT "C":
     LOCATE 19,14:COLOR 7,0:PRINT "ohesion"        :' cohesion
2450 LOCATE 19,33:COLOR 4,6:PRINT "N":LOCATE
     19,34:COLOR 7,0:PRINT "umber of Slices"       :' number of slices
2460 LOCATE 20,13:COLOR 4,6:PRINT "F":
     LOCATE 20,14:COLOR 7,0:PRINT "riction"        :' friction
2470 LOCATE 20,33:COLOR 4,6:PRINT "G":
     LOCATE 20,34:COLOR 7,0:PRINT "round Shape"    :' ground shape
2480 LOCATE 21,13:COLOR 4,6:PRINT "R":
     LOCATE 21,14:COLOR 7,0:PRINT "u"              :' Ru
2490 LOCATE 21,33:COLOR 4,6:PRINT "S":
     LOCATE 21,34:COLOR 7,0:PRINT "afety Factor"   :' Safety Factor
2500 LOCATE 22,13:COLOR 4,6:PRINT "Y":
     LOCATE 22,14:COLOR 7,0:PRINT " Circle"        :' Y circle
```

```
2510 LOCATE 22,33:COLOR 4,6:PRINT "O":
     LOCATE 22,34:COLOR 7,0:
     PRINT "k to re-calculate"                    :' re-calculate now
2520 LOCATE 24,13:COLOR 3,0:
     PRINT "(Enter D,C,F,R,Y,E,N,G,S or O)";      :' display valid responses
2530 GOSUB 2160                                   :' get keyboard response
2540 AN% = INSTR("DdCcFfRrYyNnEeGgSsOo",AN$)      :' valid responses
2550 IF AN%<1 OR AN%>20 THEN 2530                 :' check validity of response
2560 LOCATE 24,13:COLOR 7,0:PRINT SPC(37)         :' clear prompt line
2570 ON AN% GOTO 2580,2580,2590,2590,2600,2600,
        2610,2610,2620,2620,2630,2630,2670,2670,
        2740,2740,2860,2860,2870,2870             :' goto selected response
2580 VP=9:HP=27:GOSUB 2940:GOSUB 1210:GOTO 2520   :' change density
2590 VP=10:HP=27:GOSUB 2940:GOSUB 1220:GOTO 2520: ' change cohesion
2600 VP=11:HP=27:GOSUB 2940:GOSUB 1230:GOTO 2520: ' change friction
2610 VP=12:HP=27:GOSUB 2940:GOSUB 1240:GOTO 2520: ' change Ru
2620 VP=13:HP=27:GOSUB 2940:GOSUB 1250:GOTO 2520: ' change Y circle
2630 VP=8:HP=27:L=NS:GOSUB 2940:GOSUB 1200        :' change number of slices
2640 ERASE Y,TH,U,W                               :' erase old arrays
2650 DIM Y(NS),TH(NS),U(NS),W(NS)                 :' dimension up new arrays
2660 GOTO 2740                                    :' now get new ground shape
2670 VP=3:HP=27:J=1:K=4                           :' set parameters
2680 FOR I=J TO K                                 :' start counting end points
2690     GOSUB 2940                               :' re-fresh screen display
2700     ON I GOSUB 1160,1170,1180,1190           :' assign new end point values
2710     VP=VP+1                                  :' increment screen line counter
2720 NEXT I                                       :' next end point
2730 GOTO 2520                                    :' finished! display prompt line
2740 VP=4:HP=65:J=1:K=NS:PT=0                     :' set parameters
2750 FOR I=J TO L                                 :' start counting old slices
2760     LOCATE VP,HP-12:PRINT SPC(24)            :' erase old ground shape value
2770     VP=VP+1                                  :' increment screen line counter
2775     IF I=21 THEN I=L
2780 NEXT I                                       :' next old slice
2790 VP=4                                         :' re-set screen line display
2800 FOR I=J TO K                                 :' start counting new slices
2810     LOCATE VP,HP-10:PRINT I                  :' display slice number
2820     GOSUB 2940                               :' remove old value and get new
2830     Y(I)=VV                                  :' assign new value for slice
2840     VP=VP+1                                  :' increment screen line counter
2845     IF I=20 THEN VP=4
2850 NEXT I                                       :' nex new slice
2860 VP=14:HP=27:GOSUB 2940:GOSUB 1260:
     GOTO 2520                                    :' change safety factor
2870 FOR I=18 TO 24                               :' start counting screen lines
2880     LOCATE I,1                               :' goto screen position
2890     PRINT SPC(50)                            :' erase portion of line
2900 NEXT I                                       :' next screen line
2910 GOTO 220                                     :' calculate safety factor
2920 '
2930 '  ***********************
2940 '   REFRESH SCREEN DISPLAY
2950 '  ***********************
2960 '
2970 LOCATE VP,HP:PRINT SPC(10)                   :' erase existing value
2980 LOCATE VP,HP:INPUT "",VV                     :' request a new value
2990 RETURN                                       :' finished here
3000 '
3010 '  *************
3020 '   PRINT OPTION
3030 '  *************
3040 '
3050 LOCATE 22,1:PRINT SPC(50):LOCATE 22,18       :' delete prompt line
3060 COLOR 3,0:PRINT "PRINTING DATA"              :' display status message
3070 PT=PT+1:IF PT>1 THEN 3080 ELSE 3090          :' check printer flag
3080 IF HD=1 THEN 3170 ELSE 3200                  :' check if header required
```

```
3090 LPRINT :LPRINT                                     :' advance printer two lines
3100 LPRINT "GROUND SHAPE: Slice       Y co-ord"        :' print header information
3110 J=1:K=NS                                           :' set parameters
3120 FOR I=J TO K                                       :' start counting slices
3130     LPRINT SPC(16);:LPRINT USING "##";I;           :' print slice number
3140     LPRINT SPC(7);                                 :' print seven spaces
3150     LPRINT USING "###.#";Y(I)                      :' print Y co-ordinate
3160 NEXT I                                             :' next slice
3170 LPRINT                                             :' advance printer 1 line
3180 LPRINT " Xlhs   Ylhs   Xrhs   Yrhs NS Gamm";       :' print header information
3190 LPRINT " Cohs   Phi    Ru     Yc    F1    FS"      :'
3200 RESTORE:J=1:K=11                                   :' set parameters
3210 FOR I=J TO K                                       :' start counting parameters
3220     READ VN$,VU$,VP,HP                             :' read data
3230     ON I GOSUB 3330,3340,3350,3360,3370,
              3380,3390,3400,3410,3420,3430             :' goto appropriate parameter
3240     LPRINT USING VU$;VV;:LPRINT SPC(1);            :' print parameter
3250 NEXT I                                             :' next parameter
3260 LPRINT USING "#.###";FS                            :' print Factor of Safety
3270 HD=0:GOTO 360                                      :' return to main menu
3280 '
3290 '    ***********************
3300 '    PROVIDE PARAMETER VALUE
3310 '    ***********************
3320 '
3330 VV=XL:RETURN                                       :'
3340 VV=YL:RETURN                                       :'
3350 VV=XR:RETURN                                       :'
3360 VV=YR:RETURN                                       :'
3370 VV=NS:RETURN                                       :'
3380 VV=GA:RETURN                                       :'
3390 VV=CO:RETURN                                       :'
3400 VV=PH:RETURN                                       :'
3410 VV=RU:RETURN                                       :'
3420 VV=YC:RETURN                                       :'
3430 VV=F1:RETURN                                       :'
4000 '
4010 '    ****************
4020 '    SAVE DATA OPTION
4030 '    ****************
4040 '
4050 TX=TX+1: IF TX>1 THEN 4060 ELSE GOSUB 4250         :' check for file specification
4060 LOCATE 22,1:COLOR 7,0:PRINT SPC(50)                :' delete prompt line
4070 LOCATE 22,16:COLOR 3,0:PRINT "SAVING DATA"         :' display status message
4080 OPEN FILESPEC$ FOR APPEND AS #1                    :' open file, append mode
4090 PRINT #1,USING "###.#,";XL,YL,XR,YR,YC;            :' write to disk XL,YL,XR,YR,YC
4100 PRINT #1,USING "##";NS;:PRINT #1,",";              :' write to disk NS
4110 PRINT #1,USING "##.#,";GA,CO,PH;                   :' write to disk GA,CO,PH
4120 PRINT #1,USING "#.##,";RU,F1,FS;                   :' write to disk RU,F1,FS
4130 FOR I=1 TO NS                                      :' start counting slices
4140     PRINT #1,USING "###.#,";Y(I);                  :' write to disk Y co-ord
4150 NEXT I                                             :' increment counter
4160 PRINT #1, CHR$(13)                                 :' write carriage return to disk
4170 CLOSE #1                                           :' close file
4180 LOCATE 22,1:PRINT SPC(50)                          :' delete status message
4190 GOTO 360                                           :' return to OPTIONS MENU
4200 '
4210 '    ******************
4220 '    FILE SPECIFICATION
4230 '    ******************
4240 '
4250 DDRIVE$="A:"                                       :' set default drive
4260 DPATH$="\"                                         :' set default path
4270 DFILE$="STABIL"                                    :' set default file-name
4280 DEXTENSION$=".DAT"                                 :' set default extension
4290 SCREEN 0,0,1,1                                     :' select screen 1 as active
```

51-12

```
4300 CLS:LN=12:CN=20:FG=7:BG=0:FC=3:BC=0            :' set screen parameters
4310 LOCATE LN,CN:COLOR FG,BG:
        PRINT "PROVIDE DISK DRIVE "                 :' display to screen
4320 LOCATE LN,CN+20:COLOR FC,BC:
        PRINT DDRIVE$                               :' display default disk drive
4330 LOCATE LN,CN+20:COLOR FG,BG:
        INPUT "",DRIVESPEC$                         :' request disk drive
4340 LOCATE LN+1,CN+9:COLOR FG,BG:
        PRINT "path-name"                           :' display to screen
4350 LOCATE LN+1,CN+20:COLOR FC,BC:
        PRINT DPATH$                                :' display default path
4360 LOCATE LN+1,CN+20:COLOR FG,BG:
        INPUT "",PATHSPEC$                          :' request path-name
4370 LOCATE LN+2,CN+5:COLOR FG,BG:
        PRINT "and file-name"                       :' display to screen
4380 LOCATE LN+2,CN+20:COLOR FC,BC:
        PRINT DFILE$+DEXTENSION$                    :' display default filename
4390 LOCATE LN+2,CN+20:COLOR FG,BG:
        INPUT "",FILENAME$                          :' request file-name
4400 IF LEN(DRIVESPEC$)=0
        THEN DRIVESPEC$=DDRIVE$                     :' default drive required
4410 IF LEN(DRIVESPEC$)=1 AND DRIVESPEC$<>":"
        THEN DRIVESPEC$=DRIVESPEC$+":"             :' colon(:) required
4420 IF LEN(PATHSPEC$)=0
        THEN PATHSPEC$=DPATH$                       :' default path required
4430 IF RIGHT$(PATHSPEC$,1)<>"\"
        THEN PATHSPEC$=PATHSPEC$+"\"               :' backslash required
4440 IF LEFT$(PATHSPEC$,1)<>"\"
        THEN PATHSPEC$="\"+PATHSPEC$               :' backslash required
4450 L%=LEN(FILENAME$):
        IF L%=0 THEN 4460 ELSE 4470                :' determine length of filename
4460 FILENAME$=DFILE$:GOTO 4550                     :' default filename required
4470 FOR I=1 TO L%                                  :' start counting characters
4480    IF RIGHT$(LEFT$(FILENAME$,I),1)="."
        THEN NEWFILE$=LEFT$(FILENAME$,I-1)
        ELSE 4530                                   :' check for extension delimiter
4490    IF LEN(NEWFILE$)>8
        THEN NEWFILE$=LEFT$(NEWFILE$,8)            :' limit filename to 8 chars
4500    NEWEXTN$=RIGHT$(FILENAME$,L%-I)            :' rest is extension
4510    IF LEN(NEWEXTN$)>3
        THEN NEWEXTN$=LEFT$(NEWEXTN$,3)           :' limit extension to 3 chars
4520    FILENAME$=NEWFILE$+"."+NEWEXTN$:
        GOTO 4560                                   :' assemble filename
4530 NEXT I                                         :' next character
4540 IF LEN(FILENAME$)>8
        THEN FILENAME$=LEFT$(FILENAME$,8)          :' limit filename to 8 chars
4550 FILENAME$=FILENAME$+DEXTENSION$               :' assemble file name
4560 FILESPEC$=DRIVESPEC$+PATHSPEC$+FILENAME$      :' assemble file specification
4570 LOCATE LN+7,CN:COLOR FG,BG:
        PRINT "        File specification is"       :' display to screen
4580 LOCATE LN+8,CN+10:COLOR FC,BC:
        PRINT FILESPEC$                             :' display file specification
4590 FOR J=1 TO 1500:NEXT J                         :' time delay for display
4600 SCREEN 0,0,0,0                                 :' return to screen 0
4610 RETURN                                         :' finished here
5000 '
5010 '  **********
5020 '   END OPTION
5030 '  **********
5040 '
5050 COLOR 7,0:CLOSE:SYSTEM                         :' turn function keys on, clear
                                                       screen and end program
6000 '
6010 '  ******************************
6020 '   AUTO-RANGE CALCULATION OPTION
6030 '  ******************************
```

```
6040  '
6050  HD=1                                              :' set flag for header print
6060  FOR I=16 TO 22                                    :' start counting line numbers
6070      LOCATE I,1:COLOR 7,0:PRINT SPC(50)            :' delete line from screen
6080  NEXT I:AC=1                                       :' next line number, set flag
6090  LOCATE 18,3:COLOR 1,0:PRINT "RANGE FOR:"          :' request parameter name
6100  LOCATE 18,16:COLOR 4,6:PRINT "D":
      LOCATE 18,17:COLOR 7,0:PRINT "ensity"             :' display Density
6110  LOCATE 18,35:COLOR 4,6:PRINT "R":
      LOCATE 18,36:COLOR 7,0:PRINT "u"                  :' display Ru
6120  LOCATE 19,16:COLOR 4,6:PRINT "C":
      LOCATE 19,17:COLOR 7,0:PRINT "ohesion"            :' display Cohesion
6130  LOCATE 19,35:COLOR 4,6:PRINT "Y":
      LOCATE 19,36:COLOR 7,0:PRINT " Circle"            :' display Y circle
6140  LOCATE 20,16:COLOR 4,6:PRINT "F":
      LOCATE 20,17:COLOR 7,0:PRINT "riction"            :' display Friction
6150  LOCATE 22,18:COLOR 3,0:
      PRINT "(Enter D,C,F,R OR Y)"                      :' display valid responses
6160  GOSUB 2160                                        :' check keyboard for response
6170  AN%=INSTR("DdCcFfRrYy",AN$)                       :' check validity of response
6180  IF AN%<1 OR AN%>10 THEN 6160                      :' if invalid go again
6190  FOR I=16 TO 22                                    :' start counting screen lines
6200      LOCATE I,1:COLOR 7,0:PRINT SPC(50):           :' erase portion of line
6210  NEXT I                                            :' next screen line
6220  ON AN% GOSUB 6470,6470,6480,6480,
               6490,6490,6500,6500,6510,6510            :' goto desired response
6230  READ VN$,PU$,OVP,HP                               :' read data
6240  LOCATE 18,5:COLOR 7,0:
      PRINT "Start value of "VN$;:
      INPUT "",SV                                       :' request range starting value
6250  LOCATE 19,5:COLOR 7,0:
      PRINT "  End value of "VN$;:
      INPUT "",EV                                       :' request range end value
6260  LOCATE 20,15:COLOR 7,0:
      INPUT "  Calculate in steps of = ",INCR           :' request increment value
6270  LOCATE 22,10:COLOR 3,0:
      PRINT "AUTO-RANGE CALCULATIONS IN PROGRESS":
      AC=1                                              :' display status message,
6280  FOR IV=SV TO EV STEP INCR:VV=IV                   :' start counting range increm.
6290      ON AN% GOSUB 1210,1210,1220,1220,
           1230,1230,1240,1240,1250,1250                :' get appropriate data
6300      LOCATE OVP,27:PRINT SPC(10)                   :' erase old value
6310      LOCATE OVP,27:PRINT USING PU$;VV              :' display current value
6320      GOSUB 1400                                    :' now for calculations
6330      IF INT(F1*100)<>INT(FS*100)
          THEN 6340 ELSE 6370                           :' check for convergence
6340      LOCATE 22,1:COLOR 7,0:PRINT SPC(50)           :' clear prompt line
6350      LOCATE 22,10:COLOR 3,0:PRINT
          "AUTO-RANGE CALCULATIONS IN PROGRESS"         :' display status message
6360      F1=FS:GOTO 6320                               :' not yet converged, go again
6370      ACC=1:GOTO 3020                               :' converged, print results
6380      ACC=0:GOTO 4020                               :' save data to disk
6390      LOCATE 14,27:COLOR FC,BC:
          PRINT SPC(10)                                 :' erase old safety factor
6400      LOCATE 14,27:COLOR FC,BC:
          PRINT USING "#.##";FS                         :' display new safety factor
6410      F1=1:FS=1                                     :' re-set FS to unity
6420  NEXT IV                                           :' next range increment
6430  FOR I=16 TO 22:LOCATE I,1:COLOR 7,0               :' start counting screen lines
6440      PRINT SPC(50)                                 :' erase screen line
6450  NEXT I                                            :' next screen line
6460  AC=0:GOTO 330                                     :' return to OPTIONS MENU
6470  RESTORE 580:RETURN                                :' read data
6480  RESTORE 590:RETURN
6490  RESTORE 600:RETURN
6500  RESTORE 610:RETURN
6510  RESTORE 620:RETURN
```

APPENDIX 2

```
GROUND SHAPE: Slice      Y co-ord
                 1         5.5
                 2         7.5
                 3         9.0
                 4        11.5
                 5        14.5
```

Xlhs	Ylhs	Xrhs	Yrhs	NS	Gamm	Cohs	Phi	Ru	Yc	F1	FS
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.00	39.0	1.90	1.904
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.10	39.0	1.76	1.762
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.20	39.0	1.61	1.618
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.30	39.0	1.47	1.475
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.40	39.0	1.33	1.333
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.50	39.0	1.18	1.188

Xlhs	Ylhs	Xrhs	Yrhs	NS	Gamm	Cohs	Phi	Ru	Yc	F1	FS
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.50	24.0	1.00	0.969
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.50	24.0	0.97	0.962
4.0	4.0	24.0	15.0	5	20.0	10.0	30.0	0.50	24.0	0.96	0.961