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ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC. F/G 20/4
H6123 - CONJUGATE DEPTH IN EITHER A TRAPEZODIAL, TRIANGULAR, OR--ETC(U)
JUN 78 M T HEBLER

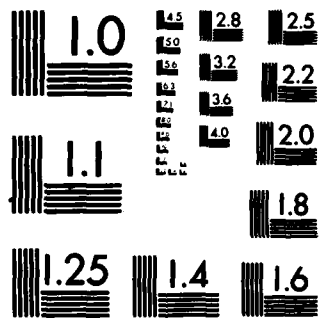
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ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM H6123 - Conjugate Depth in Either a Trapezoidal, Triangular, or Rectangular Open Channel **PROGRAM NUMBER** 722-F3-RO-6AI

PREPARING AGENCY Hydraulic Analysis Division, Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, MS, 39180

AUTHOR(S) 10 Martin T. Hebler	DATE PROGRAM COMPLETED Nov 1973	STATUS OF PROGRAM	
<i>The purpose of this</i>	Documented June 78	PHASE Origin	STAGE Operational

A. PURPOSE OF PROGRAM 13 705
To compute the conjugate depth at a hydraulic jump in either a trapezoidal, triangular, or rectangular open channel.

References: (1) Chow, Ven Te, Open Channel Hydraulics, McGraw-Hill, 1959 pp 53-56
(2) Schied, Francis, Numerical Analysis, Schaum's Outline Series, McGraw-Hill, 1968, pp 315-317.

B. PROGRAM SPECIFICATIONS

SEE FOLLOWING PAGE

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C. METHODS

The program is written in G635 time-share series, FORTRAN IV, and is part of a Conversationally Oriented Real-Time Program-Generating System (CORPS). The program consists of a main program and three subroutines. The main program handles all I/O requirements with the subroutines handling the computation.

D. EQUIPMENT DETAILS

The program was developed and is operational on the WES G635, Vicksburg, MS. It is also operational on HIS 66/80, Macon, GA, and Boeing CDC, Seattle, WA.

E. INPUT-OUTPUT

The required inputs which are entered at execute time are: discharge, cfs, bottom width, ft, (0 if tria sect.), side slope (0 if rect sect), number of flow depths and the flow depths, ft. Output includes the type of cross section and the given data, plus the conjugate depth, ft.

F. ADDITIONAL REMARKS

Complete documentation of this program is available from the Engineer Computer Programs Library, Technical Information Center, WES.

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Distribution Unlimited

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B. PROGRAM SPECIFICATIONS:

Language: ANSI FORTRAN (FORTRAN IV)

Solution Requirements: The run command

RUN WESLIB/CORPS/H6123, R

and the inputs defined in (E).

Method of Analysis: Solves the momentum equation for the conjugate depth by application of Newton's Tangent Method.

Core Requirements G635: 11 K words

External Storage: None

Restrictions: Velocity distribution is uniform across the flow section and the invert slope is small (i.e., < 10 degrees).

General Equation:

$$A_1 \bar{y}_1 + \frac{Q^2}{gA_1} = A_2 \bar{y}_2 + \frac{Q^2}{gA_2}$$

where Q is discharge (cfs), g is acceleration of gravity (32.2 ft/sec²), A₁ and A₂ are the respective cross-section areas (ft²) for flow depth and conjugate depth, and \bar{y}_1 and \bar{y}_2 are the distances (ft) of the centroids of the respective areas A₁ and A₂ below the water surface.

Range of Quantities: Unlimited for practical application

Accuracy: Governed by accuracy of input data; conjugate depth computed to + 0.001 ft.

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	Special	Avail and/or	Distribution/	NTIS CP:SI
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				500-100-1000

REF: ER 1110-1-10 - ENGINEERING AND DESIGN - Engineering Computer
Program Library Standards and Documentation, Appendix B

PART I: ENGINEERING DESCRIPTION

1. PROGRAM NUMBER: 722-F3-RO-6AI
2. TITLE: H6123 - Conjugate Depth in Either a Trapezoidal, Triangular, or Rectangular Open Channel.
3. REVISION LOG: N/A
4. PURPOSE OF PROGRAM: To compute the conjugate depth at a hydraulic jump in either a trapezoidal, triangular, or rectangular open channel.

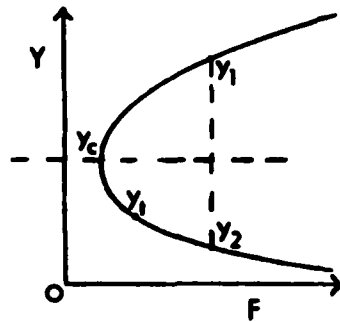
References:

- a. Chow, Ven Te, Open Channel Hydraulics, McGraw-Hill, 1959, pp 53-56.
- b. Schied, Francis, Numerical Analysis, Schaum's Outline Series, McGraw-Hill, 1968, pp 315-317.

5. STEP SOLUTION:

- a. Enter inputs:
 - (1) Discharge (Q), cfs
 - (2) Channel bottom width (b), ft (0 if triangular section)
 - (3) Channel side slope (z), expressed as the cotangent (0 if rectangular section)
 - (4) Flow depth (y_1), ft
- b. Computational steps:
 - (1) Critical depth (y_c) using subroutine H6140
 - (2) Specific force (F_1) at y_1 using subroutine H6124
 - (3) Determine trial conjugate depth (y_t)

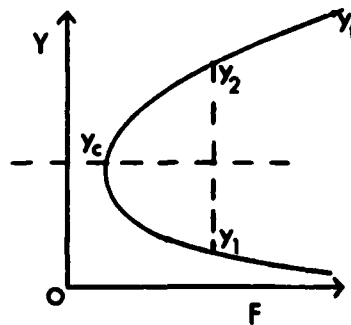
If $y_c < y_1$, then $y_t = \frac{y_c}{2}$



SPECIFIC FORCE CURVE

If $y_c = y_1$, then the conjugate depth (y_2) is equal to y_c ; y_2 is returned to the main program. If $y_c > y_1$, then

$$y_t = \frac{y_c^2}{y_1}$$



SPECIFIC FORCE CURVE

- (4) Specific force (F_t) and area (A_t) at y_t using subroutine H6124
- (5) Define function $F(y_t)$ to be used for Newton's Tangent Method

$$F(y_t) = F_t - F_1$$

- (6) First derivative of $F(y_t)$ with respect to y_t

$$\frac{d}{dy_t} F(y_t) = A_t - \frac{Q^2(b + 2zy_t)}{gA_t^2}$$

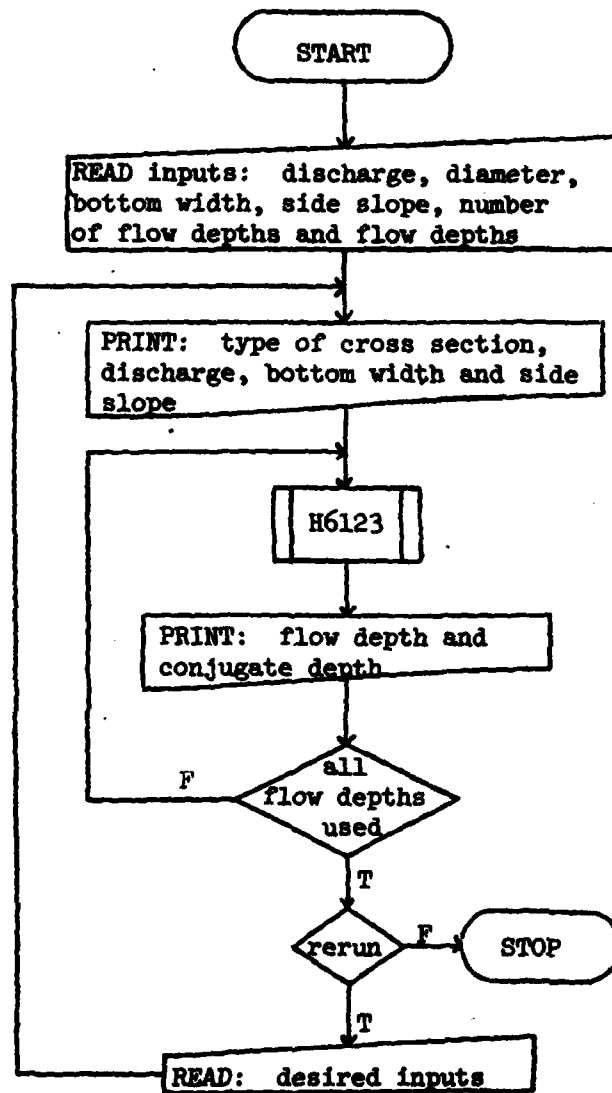
- (7) Conjugate depth (y_2) is calculated using Newton's Tangent Method
- (8) If $y_2 \leq 0.0$, then $y_t = \frac{y_c}{2^m}$, where $m = 2, 3, \dots$, depending on the number of times the condition $y_2 \leq 0.0$ occurs. Transfer is to step (4) and the process is repeated until $y_2 > 0.0$. Step (9) is then entered.
- (9) If $|y_2 - y_t| \geq .001$, then $y_t = y_2$ and the procedure returns to step (4) and is repeated until $|y_2 - y_t| < .001$. The value of y_2 is returned to the main program.

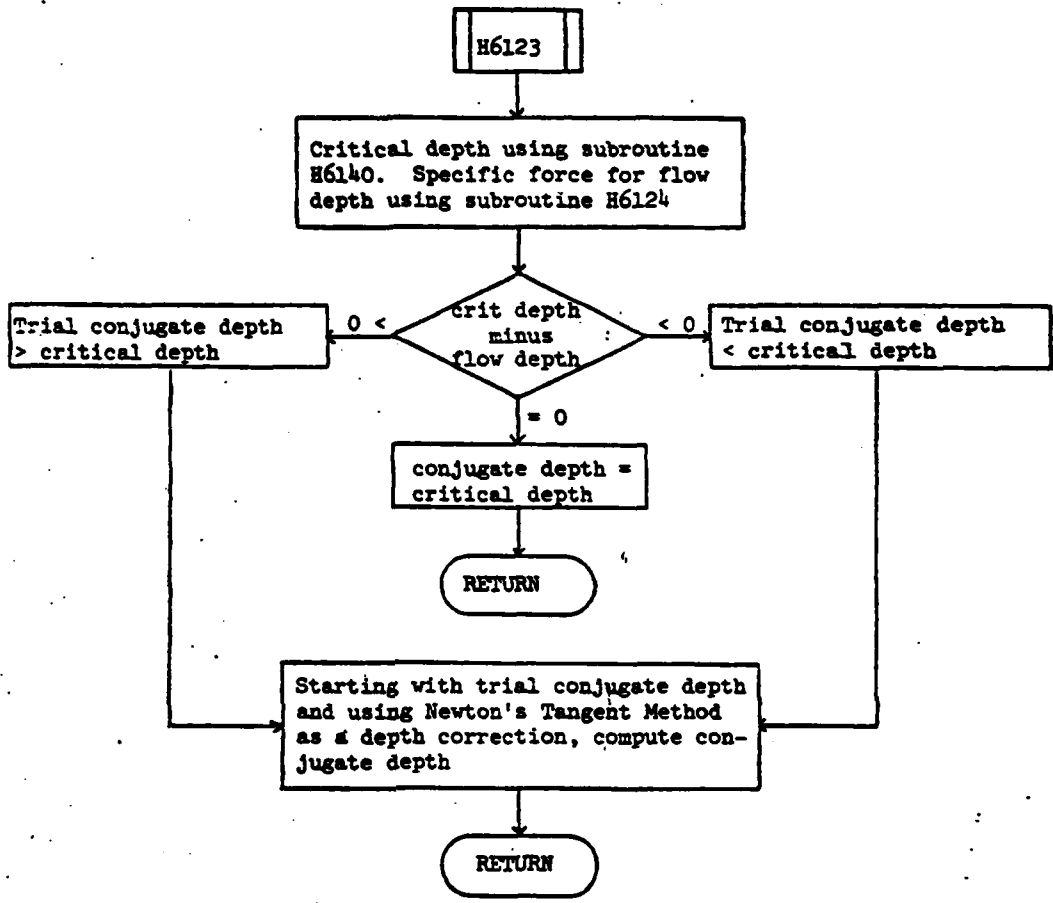
c. The given data, plus the conjugate depth, are printed.

6. ACCURACY: Governed by accuracy of input data; conjugate depth is computed to $\pm .001$ ft.
7. REMARKS: Velocity distribution is uniform across flow section and the invert slope is small (i.e., < 10 degrees).

PART II: COMPUTER FUNCTIONAL DESCRIPTION

1. REVISION LOG: N/A
2. FUNCTIONAL FLOW CHART:





3. EQUIPMENT AND OPERATING SYSTEM: The program was developed on a G635 time-share system in which input/output equipment consisted of a Model 33 remote teletype. It is now operational on the WES G635, Vicksburg, MS; HIS 66/80, Macon, GA; and Boeing CDC, Seattle, WA.
4. INPUT REQUIREMENTS: The required inputs are entered via the user's time-share terminal device in free field format. All input cues and reads are performed in the main program. The subroutines handle the computations. Since computations are done in the subroutines, and subroutines H6140 and H6124 are subordinate to H6123, the necessary inputs to subroutine H6123 are passed via the CALL statement. The calling sequence is:

```
CALL H6123 (arg1,...,arg5)
```

where:

- arg₁ - discharge, cfs
- arg₂ - bottom width, ft
- arg₃ - side slope (cotangent)
- arg₄ - flow depth, ft
- arg₅ - conjugate depth, ft

All arguments are floating point. Arguments 1-4 are the inputs and argument 5 is the output.

5. SECONDARY STORAGE INPUT: None
6. INPUT DATA DESCRIPTION: The following names are used for the input variables in program H6123.

DISCH - discharge, cfs (arg₁)
 BWID - bottom width, ft (arg₂)
 SSLOPE - side slope (cotangent) (arg₃)
 N - number of flow depths, integer
 Y - flow depth, ft (arg₄)

7. OUTPUT DATA DESCRIPTION: The following name is used for the output variable in program H6123

DEPTH2 - conjugate depth, ft (arg₅)

8. PROGRAM ERROR MESSAGES: None

9. VARIABLE DEFINITIONS:

AREA - area at trial conjugate depth, ft²
 BWID - bottom width, ft (0 if tria sect)
 CRIT - critical depth, ft; returned from subroutine H6140
 N - number of flow depths, $0 < N \leq 25$
 Y - flow depth, ft; dimensioned max 25
 DEPTH1 - flow depth, ft; equal to Y(I) for I = 1, ..., N
 DEPTH2 - conjugate depth, ft
 DEPTHT - trial conjugate depth, ft
 DISCH - discharge, cfs
 F - function of trial conjugate depth used for Newton's Tangent Method, ft³; the value of the function is a specific force difference between that at trial conjugate depth and flow depth
 FP - first derivative of function (F) with respect to trial conjugate depth, ft²

- FORCE - specific force, ft^3 ; returned from subroutine H6124
- F1 - working storage to hold FORCE at a constant when FORCE is returned from H6124 as the specific force at flow depth, ft^3
- G - acceleration of gravity, 32.2 ft/sec^2
- HFILE - five character name of program; passed to WESLIB count routine HACCT
- LQZ - equal 1, execute all input cues and reads; equal 2, call WESLIB routine RERUN and enter only desired inputs
- LQX - equal 1, print instructions from RERUN; equal 3, no print
- JKL - direct return from RERUN to desired input read
- KKK - total number of inputs; passed to RERUN
- M - power of 2 to converge Newton's Tangent Method if conjugate depth ≤ 0
- TYPE - character; type of flow cross section; trap, tria, or rect
- ZZZZ - character; equal RE, rerun; equal ST, stop

10. EXAMPLE CASE: Compute the conjugate depth for 6 given flow depths in a rectangular channel.

a. Input data:

Discharge (DISCH) = 100.00 cfs

Bottom width (BWID); (0 if tria sect) = 3.51 ft

Side slope, cotangent (SSLOPE); (0 if rect sect) = 0.0

Number of flow depths (N) = 6

Flow depths (Y(I), for I = 1, N) = 1.00, 1.43, 2.50, 4.00, 5.27, and 6.00 ft

b. Output:

INPUT H6123-CONJUGATE DEPTH-TRAP,RECT,TRIA-OPEN CHANNEL

AA-ENTER DISCHARGE,CFS.

=100

AB-ENTER CHAN BOTTOM WIDTH,FT (0 IF TRIA SECT).

=3.51

AC-ENTER CHAN SIDE SLOPE, (0 IF RECT SECT).

=0

AD-ENTER THE NUMBER OF DEPTH(S) FOR WHICH THE CONJUGATE DEPTH IS TO BE CALCULATED. MUST NOT EXCEED 25 DEPTHS.

=6

AE-ENTER THE 6 DEPTH(S) SEPARATED BY COMMAS.

=1,1.43,2.5,4,5.27,6.5

OUTPUT H6123-CONJUGATE DEPTH(S) FOR A RECT OPEN CHANNEL

DISCHARGE = 100.00 CFS

BOTTOM WIDTH = 3.51 FT

SIDE SLOPE = 0. H:1V

FLOW DEPTH (FT)	CONJUGATE DEPTH (FT)
1.00	6.62
1.43	5.27
2.50	3.41
4.00	2.07
5.27	1.43
6.50	1.03

ENTER RERUN OR STOP

=STOP

REF: ER 1110-1-10 - ENGINEERING AND DESIGN - Engineering and Computer Program Library Standards and Documentation, Appendix C

PART III: FILE DOCUMENTATION

1. REVISION LOG: N/A
2. TITLE: H6123 - Conjugate Depth in Either a Trapezoidal, Triangular, or Rectangular Open Channel.
3. PROGRAM SOURCE LISTINGS: See pages 12-14
4. NUMERICAL AND LOGICAL ANALYSIS: Solves the momentum equation for the conjugate depth by application of Newton's Tangent Method.
5. SUBROUTINES NOT DOCUMENTED IN ABSTRACT: The following subroutines are used in program H6123.
 - a. SUBROUTINE H6124(DISCH, BWID, SSLOPE, DEPTH, AREA, FORCE)
The subroutine statement for H6124 as documented in program H6124 is:

SUBROUTINE H6124(DISCH, BWID, SSLOPE, DEPTH, ENERGY, FORCE)

The argument list was changed to (a) to facilitate the solution of program H6123. This change has no effect on H6124 as documented.
 - b. SUBROUTINE H6140(DISCH, WIDTH, SSLOPE, DEPTH, CRIVEL)

Complete documentation of these subroutines is available from the Engineer Computer Program Library, Technical Information Center, WES.
6. MISCELLANEOUS: The program is part of the CORPS computer system. CORPS is an acronym standing for Conversationally Oriented Real-Time Program-Generating System. The program is now operational on the WES G635, Vicksburg, MS; HIS 66/80, Macon, GA; and Boeing CDC, Seattle, WA.

H6123

The source listing on page 12 contains the first line run command and brief for H6123. This first line run command runs the binary H6123B of the source listing on pages 13-14 (Fortran source of H6123) and attaches the WESLIB routines HACCT and RERUN.

H6123

0001*#RUN WESLIB/CORPS/H6123B,R;WESLIB/RERUN,R;WESLIB/HACCT,R
0800 63THIS PROGRAM COMPUTES CONJUGATE DEPTHS IN EITHER A TRAPEZOIDAL,
0810 62TRIANGULAR, OR RECTANGULAR CHANNEL. INPUTS REQUIRED ARE CHAN-
0820 59NEL BOTTOM WIDTH IN FT(ZERO IF TRIANGULAR SECTION), CHANNEL
0830 61SIDE SLOPE EXPRESSED AS THE COTANGENT OF THE ACUTE ANGLE WITH
0840 63RESPECT TO THE HORIZONTAL(ZERO IF RECTANGULAR SECTION), AND THE
0850 61FLOW DEPTH(S) IN FT. OUTPUT INCLUDES THE GIVEN DATA, TYPE OF
0860 42CROSS-SECTION, AND THE CONJUGATE DEPTH(S).
0999*06FINISH

```

00001*#RUN *:=;/CORPS/H6123B(NOGO)
10000 CHARACTER TYPE*4,HFILE*5
10010 DIMENSION DEPTH(25)
10020 HFILE=5HH6123
10030 LQZ=1;LQX=1
10040 15000 CALL HACCT(HFILE)
10050 PRINT 15111
10060 15111 FORMAT(/"INPUT H6123-CONJUGATE DEPTH-TRAP,RECT,TRIA-OPEN
10065& CHANNEL"/)
10070 GO TO(15003,15023),LQZ
10080 15003 PRINT 15004
10090 15004 FORMAT("AA-ENTER DISCHARGE,CFS.")
10100 15005 READ,DISCH
10110 GO TO(15007,15023),LQZ
10120 15007 PRINT 15008
10130 15008 FORMAT("AB-ENTER CHAN BOTTOM WIDTH,FT (0 IF TRIA SECT).")
10140 15009 READ,BWID
10150 GO TO(15011,15023),LQZ
10160 15011 PRINT 15012
10170 15012 FORMAT("AC-ENTER CHAN SIDE SLOPE,(0 IF RECT SECT).")
10180 15013 READ,SSLOPE
10190 GO TO(15015,15023),LQZ
10200 15015 PRINT 15016
10210 15016 FORMAT("AD-ENTER THE NUMBER OF DEPTH(S) FOR WHICH THE CONJUG
10215&ATE DEPTH IS TO BE"/"CALCULATED. MUST NOT EXCEED 25 DEPTHS.")
10220 15017 READ,N
10230 GO TO(15019,15023),LQZ
10240 15019 PRINT 15020,N
10250 15020 FORMAT("AE-ENTER THE ",I2," DEPTH(S) SEPARATED BY COMMAS.")
10260 15021 READ,(DEPTH(I),I=1,N)
10270 GO TO(15026,15023),LQZ
10280 15023 KKK=5
10290 CALL RERUN(KKK,LQX,JKL)
10300 GO TO(15005,15009,15013,15017,15021,15026),JKL
10310 15026 TYPE=4HTRAP
10320 IF(BWID) 15029,15028,15029
10330 15028 TYPE=4HTRIA
10340 15029 IF(SSLOPE) 15031,15030,15031
10350 15030 TYPE=4HRECT
10360 15031 PRINT 15032,TYPE,DISCH,BWID,SSLOPE
10370 15032 FORMAT(/"OUTPUT H6123-CONJUGATE DEPTH(S) FOR A ",A4," OPEN
10380& CHANNEL"/"DISCHARGE = ",F12.2," CFS"/"BOTTOM WIDTH = ",F9.2," FT
10390&"/"SIDE SLOPE = ",F11.2,"H:1V"/"4X,"FLOW",5X,"CONJUGATE"/4X,"DEPTH
10400&","6X,"DEPTH"/4X,"(FT)",7X,"(FT)")
10410 DO 15039 I=1,N
10420 DEPTH1=DEPTH(I)
10430 CALL H6123(DISCH,BWID,SSLOPE,DEPTH1,DEPTH2)
10440 15039 PRINT 15040,DEPTH1,DEPTH2
10450 15040 FORMAT(F8.2,F11.2)
10460 PRINT," "

```

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10470 LQZ=2
10480 CHARACTER ZZZZZZ*2
10490 16000 PRINT, "ENTER RERUN OR STOP"
10500 READ 16001, ZZZZZZ
10510 16001 FORMAT(A2)
10520 IF(ZZZZZZ.EQ.2HRE) GO TO 15000
10530 IF(ZZZZZZ.EQ.2HST) GO TO 20000
10540 PRINT,"ERROR *** RETYPE"
10550 GO TO 16000
10560 20000 STOP;END
20000 SUBROUTINE H6123(DISCH,BWID,SSLOPE,DEPTH1,DEPTH2)
20010 G=32.2;N=2
20020 CALL H6140(DISCH,BWID,SSLOPE,CRIT,CV)
20030 CALL H6124(DISCH,BWID,SSLOPE,DEPTH1,AREA,FORCE)
20040 F1=FORCE
20050 IF(CRIT-DEPTH1) 20060,20070,20080
20060 20060 DEPTHT=CRIT/N;N=2*N;GO TO 20090
20070 20070 DEPTH2=CRIT;RETURN
20080 20080 DEPTHT=CRIT**2/DEPTH1
20090 20090 CALL H6124(DISCH,BWID,SSLOPE,DEPTHT,AREA,FORCE)
20100 F=FORCE-F1
20110 FP=AREA-DISCH**2*(BWID+2.*SSLOPE*DEPTHT)/(G*AREA**2)
20120 DEPTH2=DEPTHT-F/FP
20130 IF(DEPTH2.LE.0.0) GO TO 20060
20140 IF(ABS(DEPTH2-DEPTHT).LE..001) RETURN
20150 DEPTHT=DEPTH2;GO TO 20090
20160 END
30000 SUBROUTINE H6124(DISCH,BWID,SSLOPE,DEPTH,AREA,FORCE)
30010 G=32.2
30020 AREA=DEPTH*(BWID+SSLOPE*DEPTH)
30030 ENERGY=DEPTH+DISCH**2/(2.*G*AREA**2)
30040 FORCE=BWID*DEPTH**2/2.+SSLOPE*DEPTH**3/3.+DISCH**2/(G*AREA)
30050 RETURN
30060 END
40000 SUBROUTINE H6140(DISCH,WIDTH,SSLOPE,DEPTH,CRIVEL)
40010 G=32.2
40020 IF(WIDTH) 30,10,30
40030 30 DEPTH=((DISCH**2)/(G*(WIDTH**2)))*.1/.3.)
40040 GO TO 20
40050 10 DEPTH=((2.*DISCH**2)/(G*SSLOPE**2))*.1/.5.)
40060 GO TO 100
40070 20 IF(SSLOPE) 25,100,25
40080 25 A=DISCH**2*(WIDTH+2.*SSLOPE*DEPTH)
40090 B=G*DEPTH**3*(WIDTH+SSLOPE*DEPTH)**3
40100 DIFF=B-A
40110 IF(DIFF.LT.0.0001) GO TO 100
40120 DEPTH = DEPTH-0.01
40130 GO TO 25
40140 100 CONTINUE
40150 AREA=(WIDTH+SSLOPE*DEPTH)*DEPTH
40160 CRIVEL = DISCH/AREA
40170 RETURN
40180 END

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END

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