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Abstract

A new program based on the U.S. Geological Survey slope-area program for indirectly computing peak discharges allows users to employ input data formats used by the water surface profile program WSPRO. The program source is written in Fortran 77 and can be ported easily to any computer that has standard Fortran 77 compilers. The program has been run on mini-computers and personal computers and does not use or require graphics capability, a color monitor, or a mouse.

Introduction

A new slope-area program allows users to employ input data formats used by the WSPRO water surface profile program (Shearman 1990) to compute peak discharges indirectly. It is written in standard Fortran 77 (American National Standards Institute 1978) and is loosely based on the slope-area program written by O.G. Lara and modified by W.H. Kirby (written commun., 1990) of the U.S. Geological Survey.

Use of WSPRO data formats by the slope-area program provides users with a simple and well documented format in which to enter data. Because many one-dimensional (1-D) flow computations require the same types of data, 1-D flow programs can be written to use common data files. Input files using WSPRO data formats can be easily modified for

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use with either the WSPRO program or the slope-area
program. Users have found WSPRO data formats easier to use
than the existing slope-area data format. Interactive
entry and editing of the measured data is not supported by
the program. The user makes the input file with an ASCII
text editor before running the program.

The slope-area program compiles, links, and runs
successfully on IBM[2] personal computers and compatibles,
Macintosh, and mini-computers. It does not use or require
graphics capability, color monitor, or a mouse. Source
code for the program is approximately 87 Kilobytes. A
typical executable file on a PC is 80 Kilobytes.
Additional disk space is needed for input, output, and
temporary files.

Slope-area method

The slope-area method is a technique commonly used to
determine peak discharges indirectly from surveyed cross-
sections and highwater marks. The method is based on one-
dimensional, gradually-varied, steady flow equations. In
reality, natural flows rarely achieve true steady flow.
Flood flows especially are spatially and temporally varied.
However, these variations are usually considered to be
small enough, and can be controlled by appropiate cross-
section spacing, so that flows can be approximated by the
gradually-varied steady flow equations with sufficient
accuracy for most purposes.

The slope-area equation for multiple subreaches is as
follows:

$$Q = K_n \sqrt{\frac{\Delta h}{A+B}}$$

where,

$$A = K_n^2 \frac{L_{1\text{-}2}}{K_1 K_2} + K_n^2 \frac{L_{2\text{-}3}}{K_2 K_3} + \ldots \frac{K_n^2 L_{(n-2)-(n-1)}}{K_{(n-2)} K_{(n-1)}} + \frac{K_n^2 L_{(n-1)-n}}{K_{(n-1)} K_n}$$

and,

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[2]Use of trade names is for identification purposes only
and does not constitues endorsement by the U.S.
Geological Survey.

$$B = \frac{K_n^2}{A_n^2 2g} \left[-\alpha_1 \left(\frac{A_n}{A_1} \right)^2 (1 - k_{1\text{-}2}) + \alpha_2 \left(\frac{A_n}{A_2} \right)^2 (k_{2\text{-}3} - k_{1\text{-}2}) + \alpha_3 \left(\frac{A_n}{A_3} \right)^2 (k_{3\text{-}4} - k_{2\text{-}3}) \right.$$
$$\left. + \ldots \alpha_{(n-1)} \left(\frac{A_n}{A_{(n-1)}} \right)^2 (k_{(n-1)-n} - k_{(n-2)-(n-1)} + \alpha_n (1 - k_{(n-1)-n}) \right]$$

Δh - difference in water-surface elevation at two end
      sections.
A_n - cross-section area of cross-section n.
g - acceleration of gravity
L - length of reach between two cross-sections indicated
      by the subscripts.
K_n - conveyance of cross-section n. K=1.49*A*(R**2/3)/n,
      where n is Manning's coefficient for roughness.
$k_{1\text{-}2}$ - expansion-contraction coefficient for reach between
      cross-sections 1 and 2.
α - the velocity head coefficient.

The method uses the conservation of energy (Bernoulli
equation) and mass (continuity equation) and the normal
flow equation (Manning's equation) to determine discharge.
For a presentation of the method's hydraulic principles and
computations, see Dalrymple and Benson (1967). An error
analysis of the method is presented by Kirby (1985).
Further discussion of the principles on which the slope-
area technique is based can be found in texts by French
(1985), Henderson (1966), and Peterson (1986).

Program operation

An input file containing the data necessary for slope-
area computations must be prepared before program
execution. The necessary data are the surveyed cross-
section dimensions in an appropiate reach that adequately
describe the flow geometry. Dalrymple and Benson (1976)
discuss the selection of an appropriate reach and the
measurement procedures.

Required input data include the distance between
cross-sections and, for each cross-section, estimates of
roughness and measurements of cross-sectional geometry.
Measurements of cross-section geometry include x, y station
elevation coordinate pairs that define the shape of the
cross-section and the boundary locations of areas with
similar roughness. Any text editor that produces ASCII
files may be used to create the input file.

Only a few WSPRO records are actually used by the
slope-area program. These records are XS, GR, N, ND, AS,
XT, GT, and HP. Other WSPRO records are ignored by the
program. One additional non-WSPRO record, a *TT, is

required in the input data file by the slope-area program. This allows the use of existing WSPRO files with limited editing.

Geometry and roughness data for each cross-section in the reach area are entered in the appropriate WSPRO record format (XS, GR, N, ND, and SA). Water surface elevation at each cross-section is entered on the HP record. Water surface fall between sections is computed from the information on the HP record by the program. In the input file the cross-section information is placed in downstream order. As in WSPRO, data can be propagated from previous records to successive cross sections automatically and template formats (GT, and XT) can be used for repetitive geometric data. Shearman(1990) presents a complete description of all WSPRO records and instructions on using those records to describe cross-section geometry.

The general order of input records for the slope area program is a *TT record followed by the WSPRO records; XS, GR, N, ND and (or) XT/GT records and HP records. The *TT record is required by the slope-area program and is treated as a comment card by the WSPRO program. An example input file is listed in figure 1.

```
*TT 4
XS   SEC4 1000
GR   2,13.8 5,13.4 10,13.2 15,13.1 20,12.6 22,10.7
GR   27,9.7 31,9.5 35,9.3 40,9.2 45,9.4 50,9.7
GR   55,9.7 60,9.7 64,10.5 67,10.6 69,12.7 72,13.4
GR   74,13.8
N    0.045 0.045
SA   20.
HP 4 SEC4 13.8
XS   SEC3 1119
GR   1,14.7 5,14.1 10,13.7 14,13.2 16,11.9 20,11.3
GR   25,10.8 30,10.5 35,10.5 40,10.4 45,10.5 50,10.4
GR   55,10.5 60,10.7 63,11.5 66,12.2 68,14.1 72,14.6
GR   73,15.0
N    0.045 0.045
SA   14.
HP 4 SEC3 14.9
XS   SEC2 1209
GR   2,15.3 4,14.9 8,14.4 11,14.0 12,11.6 15,11.6
GR   20,11.8 25,11.8 30,11.5 35,11.3 40,11.1 45,11.1
GR   50,11.1 55,11.5 59,12.2 63,13.1 66,15.1 67,15.5
N    0.045 0.045
SA   11.
HP 4 SEC2 15.5
XS   SEC1 1330
GR   1,16.3 4,15.0 7,13.5 10,13.2 15,13.1 20,12.9 25,13.0
GR   30,12.9 35,12.4 40,12.5 45,12.1 50,12.5 55,12.6 60,13.7
GR   64,15.2 67,16.4
N    0.045
HP 4 SEC1 16.4
EX
ER
```

Figure 1. - Example input file for slope-area program.

Hydraulic properties

The program employs a group of Fortran routines that tabulate hydraulic properties as a function of stage. Among the hydraulic properties tabulated are conveyance, area, width, wetted perimeter, composite roughness, and velocity head coefficient. The properties are tabulated by the routines in a file that is accessed by the slope-area program. This group of routines also reads the WSPRO input file and is implemented through a single call by the slope-area program. The program structure of these routines allow other programs to easily employ them to compute hydraulic properties from WSPRO input files.

Program output

Output of the slope-area program include the definitions of the tabulated variables names used in the output, the results of the slope-area computations, and a summary of hydraulic properties for each cross-section. It is similar to output from the older USGS slope-area program. Figure 2 is a sample of the definitions and discharge computations part of the output.

SLOPE-AREA PROGRAM
Definitions of Terms

Q is the computed discharge
H,DelH is the water-surface fall, entrance to exit
F is the friction factor, the sum of (L/K1*K2) over all sub-
    reaches
L is the length of subreach
K1 is the conveyance of upstream cross section
K2 is the conveyance of downstream cross section
RC is the velocity head change in contracting section divided
    by friction head
RX is the velocity head change in expanding section divided by
    friction head
KC is the contraction loss coefficient (assumed = 0)
KX is the expansion loss coefficient (assumed = 0.5)
HF is the friction head (HF = F*Q*Q)
CX is the computed discharge divided by the discharge
    computed with no expansion loss (KC=0, KX=0)
SPREAD is the percent difference between discharge computed
    with no expansion loss (KC=0, KX=0) and discharge computed
    with full expansion loss (KC=0, KX=1.0) divided by the
    computed discharge

		DISCHARGE	COMPUTATIONS					
Sections	DelH	L	Q	Spread	HF/H	CX	RC	RX
SEC2 - SEC1	.90	121.	1351.	0	1.01	.995	.000	-.019
SEC3 - SEC2	.60	90.	1414.	5	1.06	.971	.000	-.110
SEC4 - SEC3	1.10	119.	1441.	0	.85	1.000	.172	.000
SEC3 - SEC1	1.50	211.	1375.	2	1.03	.986	.000	-.054
SEC4 - SEC2	1.70	209.	1431.	2	.93	.989	.101	-.045
SEC4 - SEC1	2.60	330.	1402.	1	.96	.992	.062	-.035

Figure 2.- Sample of discharge computations portion of slope-area output.

Summary

A new slope-area program based on the U.S. Geological Survey slope-area program uses WSPRO input records to compute indirect peak discharges. This allows users to employ existing WSPRO input files with minor editing for slope-area computations. The WSPRO input records are easier to input and edit that the input files used by the old program.

References

American National Standard Programming Language FORTRAN, (1978), American National Standards Institute, New York, NY.

Dalrymple, Tate, and M. A. Benson, 1967, Measurement of Peak discharge by the slope-area method, Techniques of Water-Resources Investigations, Book 3, Ch. A2, U.S. Geological Survey.

French, Richard H., 1985, Open-channel hydraulics, R.R. Donnelley & Sons Co.

Henderson, F.M.,1966 ,Open channel flow, Macmillan, New York.

Kirby, W. ,July 1985, Linear Error Analysis of Slope-Area Discharge, United States/People's Republic of China Bilateral Symposium on the Analysis of Extraordinary Flood Events.

Petersen, Margaret S.,1986, River Engineering, Prentice-Hall, Englewood Cliffs,NJ, .

Shearman, J.O., 1990, User's Manual for WSPRO--A computer model for water surface profile computations, FHWA-IP-89-027, Federal Highway Administration.