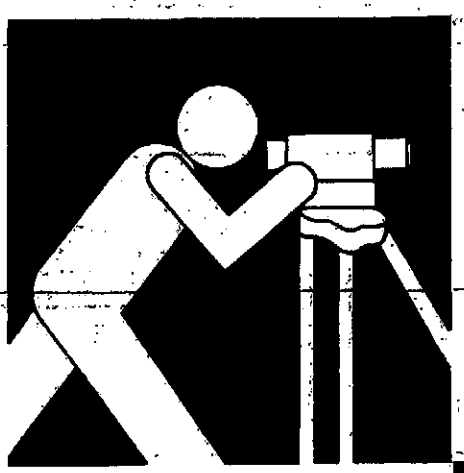

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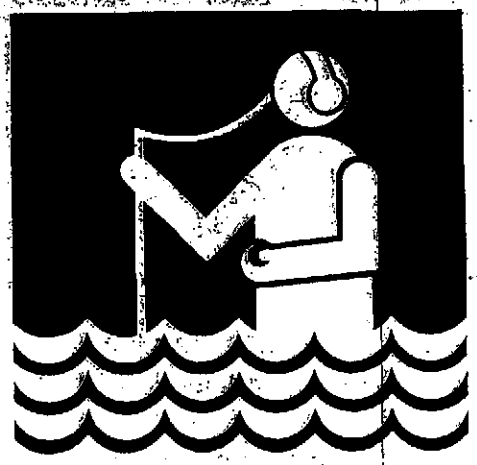

Cooperating Agencies:

Fish and Wildlife Service
Environmental Protection Agency
Heritage Conservation and Recreation Service
Bureau of Reclamation

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HYDRAULIC SIMULATION IN INSTREAM FLOW STUDIES: THEORY AND TECHNIQUES

Instream Flow Information Paper No. 5

by

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APPENDIX E

COMPUTER SOFTWARE FOR HYDRAULIC SIMULATIONS IN INSTREAM FLOW ASSESSMENTS

At the outset, it must be emphasized that a methodology for assessing instream flow requirements is not the same as a hydraulic simulation model. All references to the R-2 Cross program, WSP program, stage-discharge approach, etc., refer to methods of predicting hydraulic variables at different discharges. An instream flow assessment method interfaces these measured or predicted hydraulic variables with some type of implied or expressed biological criteria to measure the habitat available for a given species at each discharge investigated. Therefore, the type of model used to predict hydraulic conditions in a stream is interchangeable in many methodologies.

However, if the IFG incremental method is to be used, only a select few computer programs are currently compatible for use with the IFG-3 (HABTAT) program. These hydraulic simulation programs will be pointed out during the discussion.

Three basic types of hydraulic simulation software are currently available from various sources. Input requirements are functions of the assumptions according to by the approach. Output varies by program.

TYPE 1 - MANNING EQUATION ASSUMING UNIFORM FLOW

R-2 Cross (U.S.Forest Service)

IFG-1 (IFG, USFWS) (IFG, U.S. Fish and Wildlife Service)

The IFG-1 program is a modified version of the U.S. Forest Service R-2 Cross program. The depth and velocity distributions may be predicted using the Manning equation, with input data either from sagtape or level measurements. Program outputs are:

1. Distance to channel edge (ft)
2. Channel width (ft)
3. Cross sectional area (ft^2)
4. Wetted perimeter (ft)

5. Surface width (ft)

6. Hydraulic radius (ft)

7. Average Depth (ft)

8. Discharge (cfs)

9. Average velocity (fps)

The primary difference between IFG-1 and R-2 Cross is that IFG-1 outputs widths of stream having specified depths. Both R-2 Cross and IFG-1 are to be used for single cross section methods only.

TYPE 2 - MANNING/BERNOULLI EQUATIONS ASSUMING GRADUALLY VARIED FLOW

Three "step-backwater" programs are available, and all are somewhat similar. However, at this time only the PSEUDO program of the U.S. Bureau of Reclamation is compatible with the IFG-3 program.

PSEUDO (Bureau of Reclamation)

This program utilizes an energy balance model, using the Manning equation and one set of calibration measurements which require level-surveying precision. The program has been modified to produce outputs compatible as inputs to the IFG-3 (HABTAT) program, which is described below. The PSEUDO program requires data inputs as described under the section concerning data collection. Program outputs include for up to 9 cross section subdivisions:

1. Station index which indicates distance upstream from initial cross section

2. Thalweg elevation at cross section

3. Thalweg slope

4. Centroid length - average distance between a cross section and the next downstream cross section

5. Conveyance (cross sectional) areas (ft^2)

6. Top widths (ft)

7. Hydraulic radii (ft)

8. Roughness coefficients

9. Velocities (mean for subsection) in ft/sec

10. Discharge in cfs

11. Computed water surface elevation in ft

This program is calibrated by adjusting Manning's n until the water surface elevations and velocities approximate those measured in the field at the calibration flow. Documentation for this program is only fair, and it is often difficult to calibrate. However, proficiency increases rapidly with practice.

Documentation is available from:

Office of Chief Engineer, Hydrology Branch
Sedimentation Section
U.S. Bureau of Reclamation
Denver Federal Center
Denver, Colorado

HEC-2 (Corps of Engineers)

The HEC-2 program is very similar to PSEUDO, although up to 20 cross section subdivisions for the velocity distribution may be used with HEC-2. Documentation is quite good, and may be obtained from:

The Hydrologic Engineering Center
U.S. Army Corps of Engineers
609 Second Street
Davis, California

WSP-2 (Soil Conservation Service)

The WSP-2 program is also quite similar to other step-backwater programs. With WSP-2 the user is limited to six cross section subdivisions to describe the velocity distribution, which may limit the WSP-2 program for use with instream flow studies. Documentation for WSP-2 is quite good, and available from:

Engineering Division
Soil Conservation Service
U.S. Department of Agriculture
Washington, D.C.

TYPE 3 - RATING CURVE APPROACH

IFG-4 (IFG, USFWS)

The IFG-4 program utilizes two or more sets of stage and velocity measurements taken at different discharges to establish a least-squares fit of log stage versus log discharge, and log velocity vs log discharge for each measurement point on the cross section. Input to the program may be taken directly from the field notes. Required inputs are:

1. Water surface elevation at each cross section.
2. Velocities at specified intervals across section.
3. Ground elevation (cross sectional profile).
4. Distance between cross sections.
5. Estimate of substrate composition at each velocity measurement point.

Given these inputs, the program computes the discharge for each set of calibration measurements. Outputs from the program include:

1. Station indexing
2. Distance across transect from zero point
3. Average depth of channel subsection
4. Average velocity of channel subsection
5. Substrate of channel subsection

These parameters may be obtained for up to 100 channel cross section subdivisions.

For each discharge simulated at each cross section the program also outputs an "adjustment factor." For a given discharge, the depths and velocities across the section are calculated independently. If the predicted depths and velocities are accurate, a discharge calculated from these variables should equal the discharge originally requested. The "adjustment factor" is a ratio between the discharge calculated from these simulated parameters and the discharge requested. This factor can be used as an indicator of the accuracy of the predictions; the closer to 1.0 the ratio is, the better the predictions. If the adjustment factor deviates significantly from 1.00 ±10% it indicates that some change has occurred on the stage-discharge relationship, and either more

measurements are needed, or some manipulation of the data is needed to calibrate the model. This most frequently occurs at low flow extrapolations, and overbank, high flows.

The IFG-4 program has recently been completed. Documentation for this program should be available in August, 1978, from the Instream Flow Group.

IFG-3 (IFG, USFWS)

The IFG-3, or HABTAT program, is the core to the IFG incremental method. This program uses hydraulic input data from either the PSEUDO or IFG-4 hydraulic simulation programs or direct measurements. These hydraulic data are interfaced with probability criteria for specified life stages of different species. An adjunct to the HABTAT program is a curve maintenance program (CRVMNT) which contains digitized versions of probability-of-use curves for each life stage and species for which criteria have been developed. The appropriate curve sets are accessed by means of a catalog number, which is input to the program in the control deck. Catalog identifiers are six-digit numbers, with the first two digits identifying the family; the middle two, the species; and the last two digits, the life stage. Number 011300 refers to brown trout fry, as shown below:

01	13	00
Family Salmonidae	Species Salmo trutta	Life-stage fry

A listing of catalog numbers, by family and species, are included in Table E-1. Not all of these curves are on file at this time.

Having accessed the appropriate curve sets for the desired life stages and species, the HABTAT program computes the weighted usable area for the stream reach at each discharge simulated with the hydraulic model. For each species, life stage, and discharge, two-way matrix tables may be obtained as output (velocity versus depth, velocity versus substrate, or depth versus substrate). It is recommended that one copy of the complete output be produced for each study site for examination of the detailed distribution of hydraulic parameters within the reach. However, in those cases when all of the matrix tables are not needed or desired, a change of control cards gives a printout of a summary table of weighted usable area for each life stage of a species, by month (if flow duration curve used) and by discharge. Documentation for this program will be available in August, 1978.