US Army Corps of Engineers
Hydrologic Engineering Center

Survey of Programs for Water Surface Profiles

August 1968

TP-11

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
August 1968	Technical Paper	

4. TITLE AND SUBTITLE Survey of Programs for Water Surface Profiles	**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Bill S. Eichert	**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5F. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687	**8. PERFORMING ORGANIZATION REPORT NUMBER** TP-11
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/ MONITOR'S ACRONYM(S)** **11. SPONSOR/ MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Presented at ASCE Hydraulics Division Conference at MIT, 21 August 1968.

14. ABSTRACT
A comparison of available generalized computer programs for determining water surface profiles in rivers and streams is presented. Comparisons are made on languages, bridge routines, critical depth, plotting programs, etc.

15. SUBJECT TERMS
survey, water surface profiles, backwater, HEC-2, mathematical modeling, steady flow, bridge losses, generalized computer models

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			
U	U	U	UU	42	**19b. TELEPHONE NUMBER**

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Papers in this series have resulted from technical activities of the Hydrologic Engineering Center. Versions of some of these have been published in technical journals or in conference proceedings. The purpose of this series is to make the information available for use in the Center's training program and for distribution with the Corps of Engineers.

SURVEY OF PROGRAMS FOR WATER SURFACE PROFILES [1]

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Member ASCE

INTRODUCTION

This paper is intended to promote some stimulating discussions pertaining to the problems of better utilizing computer programs in the field of civil engineering. In addition, it is hoped that the paper will serve to provide engineers interested in water-surface profiles with a few sources where flexible computer programs can be obtained in order to minimize the duplication of effort and to increase the capabilities for determining water-surface profiles by electronic computers. Perhaps the paper will provide a medium for exchanging ideas on current and desired capabilities of computer programs for determining water surface profiles and on techniques or procedures for eliminating computer program limitations.

DESIRABILITY OF COMPUTER SOLUTION

The repetitious nature of the iterative process and the large amount of engineering labor required for computing both subcritical and supercritical flow make the subject of determining water-surface profiles

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highly susceptible to computer techniques. The need for fast accurate profiles with a minimum of cost has never been more apparent than at present, because of the increased interest in flood plain information reports, flood plain zoning, local protection projects and the effects of urbanization. The above needs are coupled with a need for more sophisticated techniques for evaluating such items as subdivision of flows within a cross section, effect of non-uniform velocity distribution (Coriolis effect) and losses through and over bridges.

COMPUTER PROGRAM SHARING

A great deal of time and money has been spent during the last few years in developing and using computer programs for the determination of water surface profiles. Most of these programs were developed for a specific application and are therefore limited in their overall capabilities. A large number of these programs are limited to subcritical flow in a trapezoidal channel.

While most of those computer programs saved more money during this period than they cost, one or two generalized programs could have replaced all of the programs that were developed, and a substantial savings of time and money would have resulted if many of the programs had not been developed. Several comprehensive programs were developed during this period and have been used by many offices for computing the necessary profiles. For instance, more than 50 public and private offices have used the program that was developed by The Hydrologic Engineering Center of the Corps of Engineers (HEC).

There are numerous reasons why most offices are reluctant to use computer programs developed by others. Some of these reasons and a few comments are as follows:

1. It is easier to use a computer program developed in one's own organization because of the relative ease of verifying the program logic and because desired changes can be more readily made. However, if the idea of developing your own program or experimenting to determine the theory for every need is carried to the ultimate, relatively little productive work would be accomplished.

2. Most programs are developed for special purposes and are not capable of handling most of the backwater problems that can be expected in areas throughout the United States. These programs are difficult to modify by the user, and the original programmer usually doesn't have time for the modifications or is not notified of the required changes.

3. Most computer programs have little, if any, documentation. Those that are documented usually do not contain sufficient information for efficient use.

4. The complicated input requirements for most generalized computer programs is a great drawback in attempting to promote the sharing of computer programs.

5. The users are generally reluctant to devote sufficient time to learn how to use the computer programs. Many simple programs can be learned in a few hours, but a highly sophisticated program requires weeks of continuous use and a good understanding of procedures used in the program to acquire proficiency for complicated applications. Few avenues are available for providing detailed training in the use of these programs. Assistance from the originating office in applying these programs to unusual applications is generally not available.

A few generalized computer programs which are highly flexible, thoroughly tested and which will satisfy most of the requirements of the potential users are definitely needed for computing water surface profiles. While some duplication of effort is good for comparison of techniques and procedures, and for exchanging ideas, large amounts of duplication should be avoided in the interest of economy and in order to concentrate these efforts on developing better computer programs covering more areas of interest. Considerable coordination is desirable among the developers of programs and the potential users in order to ascertain new requirements and to assure proper testing of new routines.

Some professional organization such as ASCE (or possibly an inter-agency committee or task force) might well take the lead in setting up and maintaining a system to more efficiently utilize, through the avenue of program exchange, the computer programs that are being or will be developed in the field of civil engineering.

PROGRAM SHARING BY HEC

The Hydrologic Engineering Center, U. S. Army Corps of Engineers, has as a part of its overall mission, the task of developing and distributing generalized computer programs in hydrologic engineering to Corps of Engineers offices throughout the United States. This mission also includes the teaching of methods and techniques used in hydrologic engineering including those required for computer programs and the detailed instructions on the use of the programs. Special assistance is given to users of the programs, and efforts are made to accommodate requested modifications within the capabilities of the small staff of the Center.

It appears desirable that some professional organization should serve the entire profession in coordination with certain governmental agencies, in order to provide these services to both private and governmental organizations. This professional organization should have a large enough staff to devote the required time to the development, teaching and special assistance required by all engineering offices.

REVIEW OF CAPABILITIES OF CURRENT COMPUTER PROGRAMS

SCOPE OF REVIEW

Computer programs for water-surface profiles or knowlege of such programs was solicited from 20 leading water resource agencies including Federal and State governments and several universities. Negative responses were received from eight of these requests and eleven agencies mailed program documentation. The result of this review is based on this documentation (which may not reflect the agencies' latest developments) and personal contacts with the six authors of the programs selected for inclusion in Table 1. The results of this review in terms of computer program capabilities are discussed in the following paragraphs and the six most comprehensive are shown in tabular form in Table 1. The numbers in parentheses in the following paragraphs refer to the line number of Table 1. The Hydrologic Engineering Center program is used as an example to demonstrate many features being discussed because of the writer's familiarity with this program.

LANGUAGE

All of the computer programs received were written in the Fortran language (4), which is acceptable with minor modification on a large number of computers. Some of these programs were originally written in other languages, but were converted to Fortran as new computers were made available to their users.

TYPE OF FLOW

All of the programs described in this review are for steady flow or gradually varying flow (5) although a few agencies are developing computer programs for unsteady, non-uniform flow. Documentation on the unsteady flow programs is meager at best and apparently work on these programs is still developmental. The Tennessee Valley Authority (reference 23) is one of the few agencies developing this type of computer program at present.

All of the programs reviewed used the standard step method of computation (6) and most were developed for subcritical flow only.

TYPE AND SUBDIVISION OF CROSS SECTIONS

While many computer programs for water-surface profiles are written for rectangular or trapezoidal channels, all of the six programs shown in Table 1 (in fact all eleven submitted for review) were written for cross sections of any shape (8). This type of cross section must be subdivided into at least two subareas to separately analyze the hydraulic properties, and hence to accurately determine the discharge capacity of the channel and overbanks. Failure to do this would result in computing a hydraulic radius and a discharge which is not representative of the cross section as shown by Figure 1. The number of possible subdivisions of a cross section in the programs reviewed ranges from 3 to 100 with a median of 8 (9).

DESCRIPTION OF CROSS SECTION

Most of the programs describe the cross sections by using points defined by elevations and distances from one side of the cross section. Four of the programs allow the use of negative distances (10a), but negative elevations may cause trouble in most of the programs. Some of the programs have the ability to repeat cross sections (some without any modification) at other locations without re-entering the cross section points (10c). This is accomplished by multiplying previously given widths by a fixed amount and by raising or lowering the cross section. Skew corrections are also available to modify cross sections which were not taken perpendicular to the direction of flow (10d). One program allows the computer to insert interpolated cross sections where needed during the actual computation (10e).

MODIFICATION OF EFFECTIVE AREA

Several techniques are available for changing the area that is effective in passing the discharge by modifying the given cross sections (according to input data) during the actual computer computations (10f). Figure 2 shows several of these modifications that are available in The Hydrolgic Engineering Center program (reference 19).

EXTENSION OF CROSS SECTION

Several programs will automatically extend cross section ends vertically (10g) to allow the computation of the hydraulic components for an assumed elevation higher than the highest input elevation in the cross section. One program will print out a note stating how much of this extended height is used.

CRITICAL DEPTH COMPUTATION

Critical depth should normally be computed for all cross sections to provide a water surface that is always on the correct side of critical. Many computer programs don't compute critical depth at all (11), and some use the formula:

$$\frac{Q^2}{g} = \frac{A^3}{T}$$

where:

Q = Discharge in cubic feet per second (c.f.s.)

A = Area in square feet

T = Top width in feet

g = Gravitational constant

This formula is appropriate only for prismatic cross sections and may produce errors of several feet when used for irregular cross sections under certain conditions because of the improper averaging of the hydraulic properties of the cross section instead of the subdividing which is done in the usual "step method" of backwater (see figure 1). Three offices used the more accurate method of computing, by an iterative process, the critical water surface elevation corresponding to the minimum specific energy (11).

Critical depth is assumed by four of the programs (12) when the computer finds that the depth changes from subcritical to supercritical; one stops and many (only one in Table 1) accept a water surface elevation that is on the wrong side of critical depth without being aware of this condition.

NON-UNIFORM VELOCITY DISTRIBUTION

It is difficult to determine the method used to account for the non-uniform velocity distribution in calculating the velocity head (Coriolis effect) in the various computer programs. The process of subdividing a cross section into subareas and then computing a weighted velocity head based on the discharge through each subarea is used by all of the programs (13). The above process partially accounts for the non-uniform velocity distribution and is certainly better than the head determined from considering the velocity as the total discharge divided by the total area, but even this approach may allow a large error according to the U. S. Geological Survey Water Supply Paper 1869-C (reference 8) on Velocity-Head Coefficients in Open Channels. This water supply paper discusses this effect and shows a substantial difference between the velocity head based on measured data and the head computed using three subdivisions of the cross section. The larger the number of subdivisions the more accurate the weighted velocity head becomes. Studies are being conducted by the Corps of Engineers Hydrologic Engineering Center to determine the effect of the number of subdivisions upon the accuracy of the velocity head. The Center's program can handle up to 100 subdivisions of the cross section in order to more nearly define this non-uniform velocity distribution. Subdivision, by the HEC program, is made for each point in the overbank area used in describing the cross section.

ROUGHNESS DESCRIPTION

Mannings roughness coefficients are used by all of the programs to compute friction losses (14a). Most of the programs allow different roughness coefficients for channel and overbanks and most also allow for varying the roughness coefficients horizontally across the cross section (14b) using from 3 to 25 different subdivisions. The Little Rock program (reference 20) will allow up to seven different reach lengths between cross sections corresponding to the roughness subdivisions although most programs allow only three reach lengths. Roughness coefficients can be varied with elevation in four of the programs reviewed (14c). Two of the programs will allow all roughness values for a complete profile to be varied by a fixed ratio (one number on one input card) in order to allow the effects of inaccuracies of roughness to be easily evaluated for entire profiles (14d).

DISCHARGE DESCRIPTION

Discharges can be changed to any magnitude at any cross section (15a) for a given profile in five of the programs, and in four programs several profiles can be computed using the same cross sections, while changing the discharge at any cross section to values which are different for each profile (15b). In two programs, all of the discharges for a given profile can be changed by a fixed ratio (one number on one input card) thus allowing the second profile, for example, to be computed using twice the discharge values specified on the first profile (15d). One program will use an interpolated discharge where additional cross sections are inserted (15c).

INITIAL CONDITIONS

The starting water surface elevation for the first cross section can be determined in three basic ways by the various computer programs reviewed. All programs allow the user to specify the starting water surface elevation by input (16a), two will also allow starting using a specified energy slope (16b) and three will also allow starting at critical depth (16c).

BASIN CAPABILITY

The Soil Conservation Service (SCS) program (reference 21) has a feature which allows the water surface elevation to be computed for an entire basin (up to 50 tributaries) in a single computer run (17). This option requires running profiles up to a confluence and then running profiles up both branches until another junction is reached. The SCS program is the only one having this capability.

DATA EDITING

Separate data editing programs (18) are available from three of the offices having computer programs for water surface profiles. These programs are extremely valuable in finding routine data errors before attempting to compute the profile. It is not uncommon, where a data editing program is not used, to make four or five attempts at computing the profile without obtaining results because of input errors.

PLOTTING ROUTINES

Another good way of checking data to assure accuracy and to verify assumption made on input data is to use plotting routines which are available in some computer programs for plotting cross sections (19a) and profiles (19b). Samples of the plotted output of the HEC program are shown on Figures 3 and 4. This program uses a Fortran plotting routine with a high speed printer instead of a plotter since most plotter programs are not interchangeable on various types of computers.

USE OF METRIC UNITS

The Bureau of Reclamation program (reference 22) allows the use of either the English or the Metric units for input and output values (20). This idea has been recently incorporated in another program as a direct result of reviewing the Bureau program.

CALCULATION OF MANNINGS ROUGHNESS

The Bureau of Reclamation and the HEC program both have the ability to directly calculate the roughness coefficient necessary to produce the observed high water marks (21). The Bureau program in addition, has the ability to automatically adjust the high water marks by an allowable error when needed to compute reasonable roughness coefficients.

BRIDGE LOSSES

Five of the nine programs reviewed make special computations to account for bridge losses through piers and one office is adding this feature. All of the programs are limited to one bridge per cross section (22a). Of the five that consider pier losses only three also consider separate losses for pressure flow and a combination of pressure flow and weir flow. All of these programs use a form of the orifice equation $Q = CA \quad 2gH$ (22d) for pressure flow where:

Q = Discharge is c.f.s.

C = Coefficient of discharge

A = Area of orifice in square feet

H = Head producing discharge in feet

Two of the three use the weir equation, $Q = CLH^{3/2}$, for flow over the roadway where:

Q = Discharge in c.f.s.

C = Coefficient of Discharge

L = Length of weir in feet

H = Head over crest in feet

BRIDGE LOSSES - LOW FLOW

The methods of determining changes in water surface elevation for subcritical flow where the water surface is below the low chord are (22b):

(1) Bernoullis equation as in normal backwater;

(2) Yarnell Energy Principles (references 5 and 12) and Koch and Carstanjen Momentum Studies (reference 4);

(3) U. S. Bureau of Public Roads Criteria (reference 17); and

(4) Kindsvater's computation of peak discharges at contractions (reference 3).

Pier losses for supercritical flow, available only in the HEC program (22c), is determined by criteria developed by the Los Angeles District Corps of Engineers (reference 11) who have considerable experience with this type of flow. The Bureau of Reclamation program can perform normal backwater (standard step method) through a bridge for supercritical flow. The HEC method uses the momentum formula by Koch and Carstanjen as applied to trapezoidal channels. Verification of the use of this method is contained in reference 10.

BRIDGE LOSSES - PRESSURE OR LOW FLOW

The existence of pressure flow instead of low flow is determined in the HEC program (reference 19) by comparing the respective energy gradient elevations required to pass the given discharge. The higher energy gradient elevation corresponds to the controlling flow as shown on Figure 5. The existence of pressure flow and weir flow instead of pressure flow only is established in the HEC program when the energy gradient elevation for pressure flow exceeds the minimum top of roadway elevation. In the HEC program, if low flow controls and the corresponding energy gradient elevation is above the minimum top of roadway elevation, then a combination of low flow under the bridge and weir flow over the roadway approaches exists.

BRIDGE LOSSES - COMBINATION FLOW

The combination flow (pressure and weir (22e) or low flow and weir (22f)) is determined in the HEC program by an iterative process of assuming energy gradients elevations and computing corresponding discharges through the bridge (pressure or low flow) and overbanks (weir flow) until the total discharge corresponds to the given discharge.

For the above conditions, the Bureau of Reclamation program computes bridge flow by normal backwater instead of orifice flow when the water surface elevation is below the low chord of the bridge. The overbanks are computed by weir equation unless the tailwater is above the roadway in which case normal backwater is assumed.

The Iowa Natural Resources Council's program (reference 18) uses normal backwater (for bridge) and weir flow (for overbanks) for the combination of pressure and weir flow and for the combination of low flow and weir flow. The head for the weir equation used in this method is based on the upstream water surface elevation instead of the energy gradient elevation used by the HEC and USBR programs.

BRIDGE LOSSES - WEIR FLOW

The effect of submergence on the weir equation (22g) is taken into account by each program in a different manner. The HEC program uses the Hydraulic Design Criteria developed by the U. S. Army Waterways Experiment Station (reference 12). The USBR program switches to the normal backwater procedures before submergence occurs. The other methods for submergence are shown on Table 1.

The computation of weir flow normally requires subdividing the overflow area (22h) since the roadway elevation is not always horizontal. Data from each pair of points describing the roadway is used to compute a rectangular area which allows the use of the conventional weir formula discussed previously.

BRIDGE LOSSES - NORMAL BACKWATER

The HEC program also has a second routine for computing losses through bridges. This routine uses normal backwater computations for all types of flow and corrects the area and wetted perimeter for the bridge deck obstruction. This method is similar to that used by the Bureau of Reclamation and the Iowa Natural Resources Council for certain types of flow.

PROGRAM FEATURES NOT EVALUATED

The following important features of these computer programs were not evaluated in this review, but are nevertheless important to users when selecting the most appropriate computer program to use:

1. Ease in adapting computer program for use on another computer
2. Simplicity of input preparation
3. Clearness and usefulness of output
4. Adequacy of documentation particularly input instructions
5. Availability of assistance from originating office
6. Thoroughness of testing
7. Accuracy of program logic and technical procedures

These features should be evaluated and reported on by a group of qualified engineers rather than by this writer, because of the subjectiveness of these features. Perhaps one or more of the sub-committees of ASCE could undertake such a task for the major computer application fields in civil engineering.

LIMITATIONS OF CURRENT COMPUTER PROGRAMS

One of the greatest drawbacks of existing computer programs is the necessity of having to thoroughly review intermediate answers to assure a reasonable computed profile. Extreme care in preparation of input data is not sufficient, at the present time, to assure reasonable accuracy for some of the more complicated problems. Large changes in water surface elevations must be substantiated by logical changes in the river regime; however, velocities should make only gradual changes between cross sections in order to accurately define the change in the energy gradient.

The need for manual review is often caused by the inability to properly locate and to properly define the effective cross section before a profile is computed. By inserting additional cross sections in the proper locations, abrupt changes in the water-surface profile can often be reduced, thereby giving a more accurate profile. Computer programs which can insert intermediate, interpolated cross sections, where needed, during the computation can help in overcoming the problem of properly locating cross sections, but it is extremely difficult to program a computer to always interpolate reasonably between two cross sections which are different in shape. The portion of the cross section which is effective in passing the discharge can often change with stage or discharge. In this case the effective cross section downstream of a bridge is restricted to the channel for flows which can be passed under the bridge and includes both the channel and overbanks when the discharge also passes over the bridge. This problem of determining the effective area for a given discharge is equally difficult when natural or manmade levees are involved.

None of the computer programs reviewed has the capability of directly computing "island type flow", which occurs when the discharge is carried in two or more separate channels as it flows around one or more islands. Since the discharge remains constant in each channel for several consecutive cross sections and since the hydraulic properties of these channels can be different, the water surface elevations are not necessarily equal for a cross section passing through all of the channels. The present computer programs can be used in conjunction with a graphical process to determine the proper division of flow (between the channels) around the island, and the resulting water surface elevations by computing several separate profiles up each channel for various discharges. Unfortunately this condition frequently occurs in nature and, unless ignored, greatly increases the efforts required in determining the profile.

While all programs reviewed are able to compute a profile for subcritical flow, none of the programs are able to directly determine the water surface profile where subcritical and supercritical flows are present in adjacent segments of the river. The HEC program can be used, in conjunction with judgment, to determine the profile by computing two separate profiles assuming alternately subcritical and supercritical flow for the entire length of the profile. The second profile can presently be computed by reversing the order of the cross sections cards and by specifying the other type of flow. The HEC computer program assumes critical depth whenever the flow switches from subcritical to supercritical or vice versa. When subcritical flow is assumed for the entire profile by input data, the resulting profile is either at or above critical depth throughout the length; when supercritical flow is assumed, the profile is either at or below critical depth throughout the length. By superimposing one profile on the other and by eliminating those reaches having assumptions of critical depth on consecutive cross sections, the proper type of flow and the correct profile can be determined.

The effects of sedimentation and scour in the river are not considered by any of the programs reviewed except for two which have simple routines that ignore the area below the elevation of the sediment profile for backwater studies in reservoirs. Perhaps the inclusion of more sophisticated techniques for sedimentation or scour should be incorporated when and if the programs are modified for non-steady flow.

The routines for supercritical flow in all of the programs ignore any effects of air entrainment. This effect is probably very small for natural rivers, but may be quite important for very steep slopes such as experienced in computation of profiles down steep spillway chutes.

The last and one of the most important limitations to be discussed concerns the need for more generalized and sophisticated bridge routines.

Since all of the programs reviewed provided different methods of determining profiles through and over bridges, and since little measured data is available to check the relative accuracy of each method, additional research is needed to improve and verify these routines. The Bureau of Public Roads is actively studying methods of determining profiles for the design of new bridges where the water passes below the bridge. However, supercritical flow or conditions involving flow over the bridge are not included in these studies. Nevertheless, results from the studies are promising and should add materially to part of this problem.

COMPUTER PROGRAM CAPABILITY IN THE FUTURE

While it is difficult to envision the technical advances that might be made in the near future, it is rather certain that some developments will occur which will greatly improve the capabilities of computer programs for determining water surface profiles. There are many limitations in current programs that will be overcome in the next few years with present techniques and some rather elaborate programming. The problems of manually describing the effective cross section will be mastered along with the problem of handling island type flow. These problems can be eliminated, but will require a large programming effort. The ability to compute subcritical and supercritical flow in one continuous operation for different reaches of the same stream will be obtained, hopefully, by utilizing new techniques which are being developed. The problem of sediment and scour will take quite a few years to incorporate in existing programs. The writer is confident that, after several more years of research and development, new and more accurate techniques for determining profiles through bridges will be developed.

One of the most difficult problems to overcome is the need to manually review intermediate output to insure reasonable results. Programs can be written to overcome the mass of complicated conditions (although this may take years) but man's inability to prepare the input data correctly will still be with us.

Our only hope in eliminating this problem is to automate the input data preparations. This is currently being done in a modest way for preparation of points which describe the cross section. One procedure currently used by a few offices is to take aerial photographs of the area in question, trace over the contours with a stereo plotter and automatically digitize the information on computer cards. As new advances are made in aerial photography, this process will be improved and in a short time input data describing cross sections for a complete river will be determined by simply flying the area and turning the film over to the computer.

The effective cross section can be modified and obvious errors in resulting profiles can be tested and corrected in the near future by the use of graphic displays such as the cathode ray tube.

CONCLUSIONS

Several highly developed computer programs are currently available for determining water-surface profiles. However, there are many capabilities that are not available in these programs and no single program reviewed had all of the capabilities of the others. A large amount of work remains in developing the computer program of the future for determining water-surface profiles.

There is a need to concentrate the future development in this subject on a few generalized programs capable of handling almost all problems encountered in order to reduce duplication of effort and to develop programs that can be used dependably by many offices.

The writer feels that ASCE or some other professional organization should take the lead in setting up and maintaining a committee or a group of committees to more effectively utilize computer programs in the field of civil engineering. This committee should initially collect, review, and report their findings on computer programs to the Civil Engineering profession through technical journals. Ultimately the committee should direct or coordinate the development, testing, applications, instruction, and documentation of certain highly capable computer programs in the field of civil engineering.

The approaches taken in developing the problem oriented languages such as ICES and HYDRO are commendable indeed, and will be valuable in constructing new programs since they have larger building blocks than FORTRAN. However, it is doubtful if these approaches will replace the need for or use of large generalized computer programs which are highly capable of solving a large engineering problem such as the determination of water-surface profiles.

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TABLE 1

SUMMARY OF COMPUTER PROGRAM CAPABILITIES

FOR

DETERMINATION OF WATER SURFACE PROFILES

(all numbers in parentheses refer to reference numbers at end of text)

Line		1	2	3	4	5	6
1	Developing Office	The Hydrologic Engineering Center US Army Corps of Engineers Sacramento, California	Bureau of Reclamation Chiefs Office, Denver	Little Rock District US Army Corps of Engineers	Iowa Natural Resources Co. and C.I.R.A.S.	Soil Conservation Service Hyattsville, Maryland	U.S. Geological Survey Washington, D. C.
1a	Reference Number	(19)	(22)	(20)	(18)	(21)	(14)
2	Authors and Telephone Numbers	Bill S. Eichert 961-449-2105	Eugene Cristofano 303-233-8037	W. A. Thomas 501-372-5394	James O. Shearman 608-622-2488 and Merwin D. Dougal 515-294-4244	Robert E. Maclay and others 202-388-7555, ext. 8655	Water Resources Division for information call: Harry Barnes 202-343-5018
3	Computer Used	CDC 6600 and others	CDC 6400 and others	GE 225	IBM 360 MOD 40	IBM 7090 or 360	IBM 360
4	Program Language	FORTRAN II or IV	FORTRAN IV	GE CARD FORTRAN	FORTRAN IV	FORTRAN IV	FORTRAN IV
5	Type of Flow	Gradually Varied Subcritical and Supercritical	Gradually Varied Subcritical and Supercritical	Gradually Varied Separate Programs for Subcritical and Supercritical	Gradually Varied Subcritical Only	Gradually Varied Subcritical Only	Gradually Varied Subcritical Only
6	Basic Method of Backwater	Standard Step (?)	Standard Step	Standard Step	Standard Step	Standard Step	Standard Step
7	Are Tables of Hydraulic Elements Computed?	No	No	No	Separate Program	No	No
8	Type of Cross Section	Any	Any	Any	Any	Any	Any
9	Max. Number of Subdivisions of Cross Sections	100	9	7	25	3	6
10	Cross Section Description						
10a	Can Negative Stations Be Used?	Yes	Yes	No	No	Yes	Yes
10b	Max. Number Points	100	100	100	50	48	100
10c	Can Cross Section Be Repeated?	Yes	Yes	No	Yes	No	No
10d	Can Cross Section Be Skewed?	Yes	Yes	No	No	No	No
10e	Can Cross Sections be Interpolated Automatically?	Yes	No	No	No	No	No
10f	Can Effective Area Be Modified During Computation?	Yes	Yes	Yes	Yes	Not This Version	No
10g	Is Cross Section Extended Vertically?	Yes	Yes	Yes	Yes	Yes	Yes
11	Method of Computing Critical Depth	Min. Specific Energy	Min. Specific Energy	Min. Specific Energy	Modified Prismatic	Prismatic Channels	None
12	Assumption When Depth Crosses Critical	Critical Depth	Critical Depth	Critical Depth	Critical Depth Bridge Only	Critical Depth	Stops
13	Method for Cross Section Velocity Head	Weighted by Q	Weighted by Q	Weighted by Q	Weighted by Q	Weighted by Q	Weighted by Q
14	Friction Loss Computation						
14a	Formula	Manning					Manning
14b	Max. No. Subdivisions of Roughness	20	9	7	25	3	6
14c	Can Roughness Vary by Elevation?	Yes	Yes	Yes	No	No	Yes
14d	Can All Roughness Vary by Fixed Ratio?	Yes	Yes	No	No	No	No
15	Ability to Change Discharge						
15a	At Any Cross Section?	Yes	Yes	Yes	Yes	Not Directly	Yes
15b	At Any Cross Section, Diff. Each Prof.?	Yes	No	Yes	Yes	Not Directly	Yes
15c	Interpolate Q for Inserted Cross Section?	Yes	No	--	No	No	No
15d	Vary All Discharges by Fixed Ratio?	Yes	Yes	No	No	No	No

TABLE I (Continued)

SUMMARY OF COMPUTER PROGRAM CAPABILITIES
FOR
DETERMINATION OF WATER SURFACE PROFILES
(all numbers in parentheses refer to reference numbers at end of text)

Line		1	2	3	4	5	6
1	Developing Office	The Hydrologic Engineering Center	Bureau of Reclamation	Little Rock District	Iowa Natural Resources Co.	Soil Conservation Service	U.S. Geological Survey
16	Starting Water Surface By:						
16a	Known Elevation	Yes	Yes	Yes	Yes	Yes	Yes
16b	Slope - Area	Yes	Yes	No	No	Not in this Version	No
16c	Critical Depth	Yes	Yes	Yes	No	No	No
17	Ability for Basin Backwater	No	No	No	No	Yes	No
18	Is Data Editing Program Available?	Yes	Yes - Symbolic Language	Yes	Under Development	Yes	No
19	Availability of Plotting Programs						
19a	For Cross Sections?	Yes	Separate Program	Yes	No	Separate Program	No
19b	For Profiles?	Yes	Separate Program	No	No	No	No
20	Can Metric Units Be Used?	Yes	Yes	No	No	No	No
21	Can Roughness Be Calculated Directly From Known High Water Marks?	Yes	Yes	Separate Program	No	No	Separate Program
22	Method of Loss Through Bridge	*				(Under Development)	
22a	Number of Bridges Per Cross Section	1	1	1	1		
22b	Method Low Flow - Subcritical Flow	Yarnell (12) and Carstanjen Trapazoidal Cross Section	Normal Backwater Bernoulli Formula	Kindsvater, Geological Survey Circular 284(3)	Normal Backwater Bernoulli Formula (1)		Bureau of Public Roads Criteria (17)
22c	Method Low Flow - Supercritical Flow	Carstanjen - Momentum (6)	Normal Backwater				
22d	Method of Pressure Flow	Orifice Formula (12)	Orifice Formula	Kindsvater, Geological Survey Circular 284(3)	Orifice Formula		None
22e	Method of Combination Pressure and Weir Flow	Trial and Error for Energy Gradient by Orifice and Weir Formulas (19)	Orifice (Bridge) and weir Flow (When Tailwater Below Road. Otherwise - Normal Backwater)	Considers either one but not both	Weir (2 and 15) and Normal Backwater or Weir and Orifice		None
22f	Method of Combination Low Flow and Weir Flow	Trial and Error for Energy Gradient by Yarnell and Weir Formulas	Normal Backwater	Considers either one but not both	Weir and Normal Backwater		None
22g	Method of Submergence on Weir	HDC 111-4 Based on Ratio Tailwater to Headwater (12)	Normal Backwater	By Master's Thesis of W. A. Thomas (7)	By Yarnell and Negler (16) and Master's Thesis of Sigundsson 1955 (6)		None
22h	Max. No. Subdivisions of Weir Flow	50	20	1	20		None
23	Reference Number	19	22	20	18	21	14

* A second bridge routine is available which uses the normal backwater with corrections for area and wetted perimeter for the bridge deck.

ILLUSTRATION OF EFFECT OF SUBDIVISION OF CROSS SECTION

COMPUTATION OF DISCHARGE															
	SUBDIVISIONS OF CROSS SECTION											NO SUBDIVISION			
	CHANNEL ELEMENTS				OVERBANK ELEMENTS				DISCHARGES - CFS			TOTAL			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ELEVATION IN FEET	DEPTH D	AREA A (ft^2)	WETTED PERIMETER WP (ft)	HYDRAULIC RADIUS R (ft)	DEPTH D	A	WP	R	CHANNEL	OVERBANK	TOTAL	A	WP	R	Q
100	0	0	10	0	0	0	0	0	0	0	0	0	10	0	0
103	3	30	16	1.87	0	0	0	0	13.5	0	13.5	30	16	1.87	13.5
106	6	60	22	2.73	0	0	0	0	34.7	0	34.7	60	22	2.73	34.7
110	10	100	30	3.33	0	0	0	0	66.2	0	66.2	100	30	3.33	66.2
110+	10	100	30	3.33	0	0	100	0	66.2	0	66.2	100	130	.77	25.0
111	11	110	30	3.67	1	100	102	.980	77.8	29	107	210	132	1.59	84.8
113	13	130	30	4.33	3	300	106	2.83	103	178	281	430	136	3.16	275
115	15	150	30	5.00	5	500	110	4.54	130	407	537	650	140	4.64	537
120	20	200	30	6.67	10	1000	120	8.33	210	1220	1430	1200	150	8.00	1425

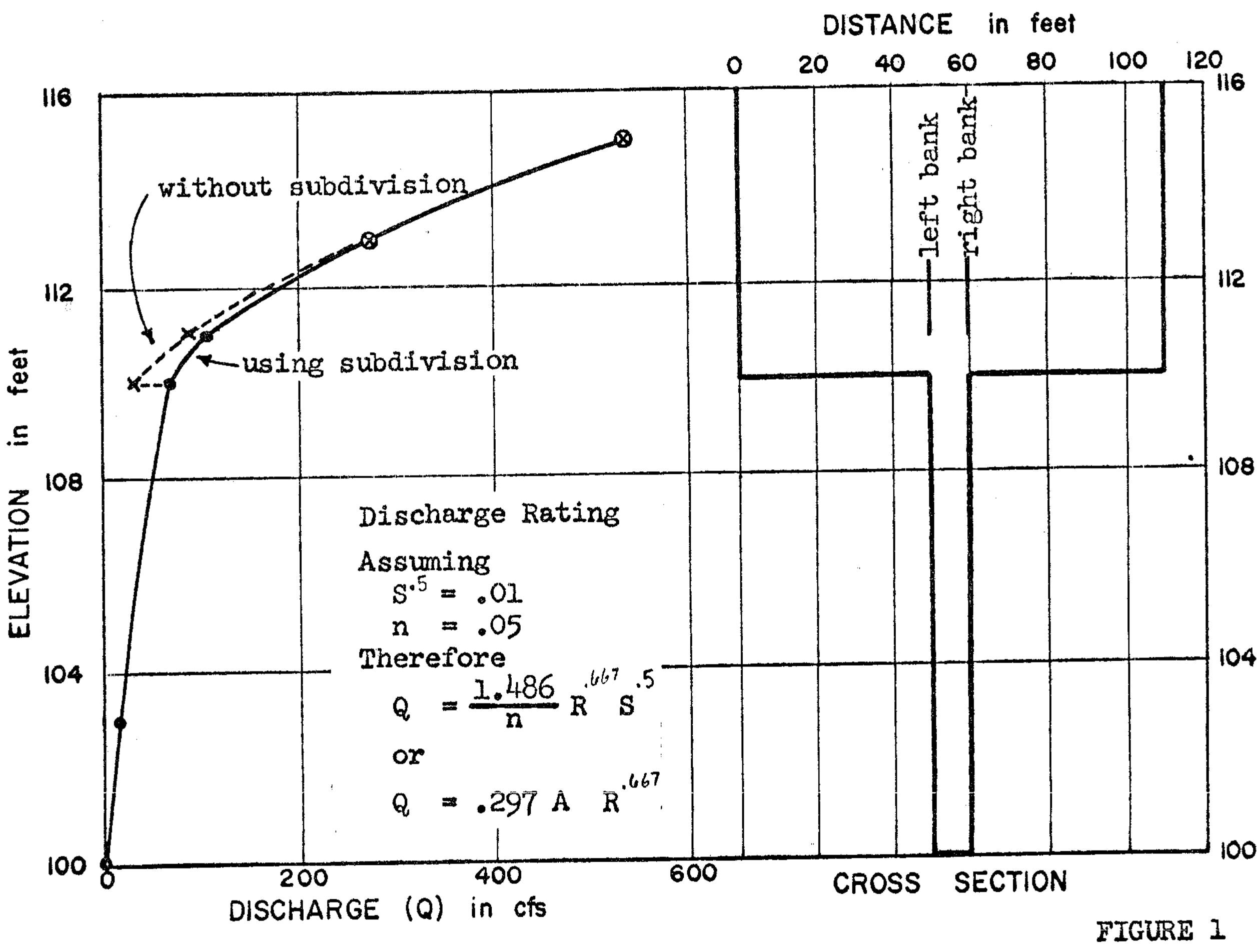
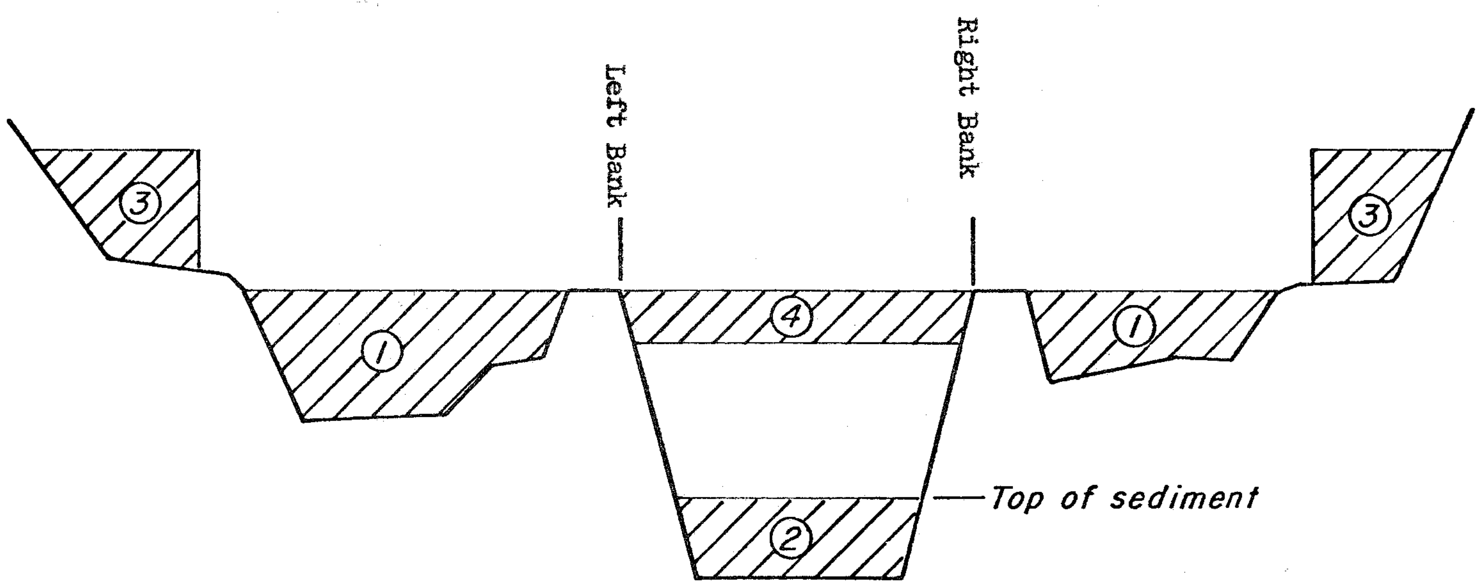


FIGURE 1



Ineffective areas:

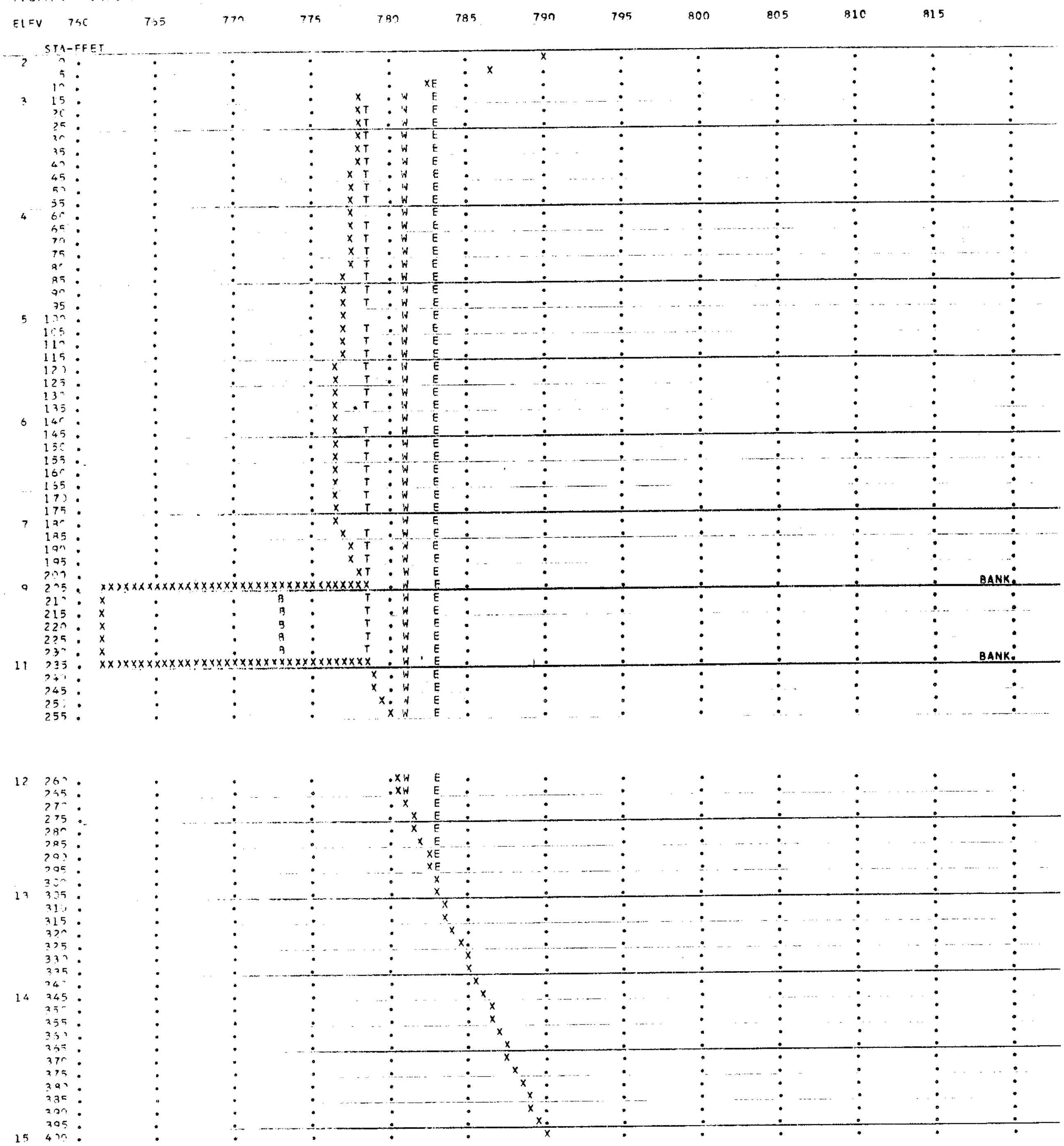
1. *When flows are below bank elevations.*
2. *Caused by sediment deposition.*
3. *Caused by encroachment in flood plains.*
4. *Caused by bridge deck.*

POSSIBLE EFFECTIVE AREA REDUCTIONS IN CROSS SECTION

FIGURE 2

CROSS SECTION 134.00
RIVER SOUTH BUFFALO CK
DISCHARGE= 10600

PLOTTED POINTS (BY PRIORITY)-B=BOTTOM BRIDGE,T=TOP BRIDGE,X=GROUND,W=WATER SUR,E=ENERGY GRADIENT,C=CRITICAL WSEL



NRD= 0 ELLC= 773.20 ELTRD= 778.50

FIGURE 3

PROFILE FOR RIVER LITTLE COTTONWOOD, SACRAMENTO DISTRICT

PLOTTED POINTS (BY PRIORITY)-E-ENERGY GRADIENT,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-MAXIMUM

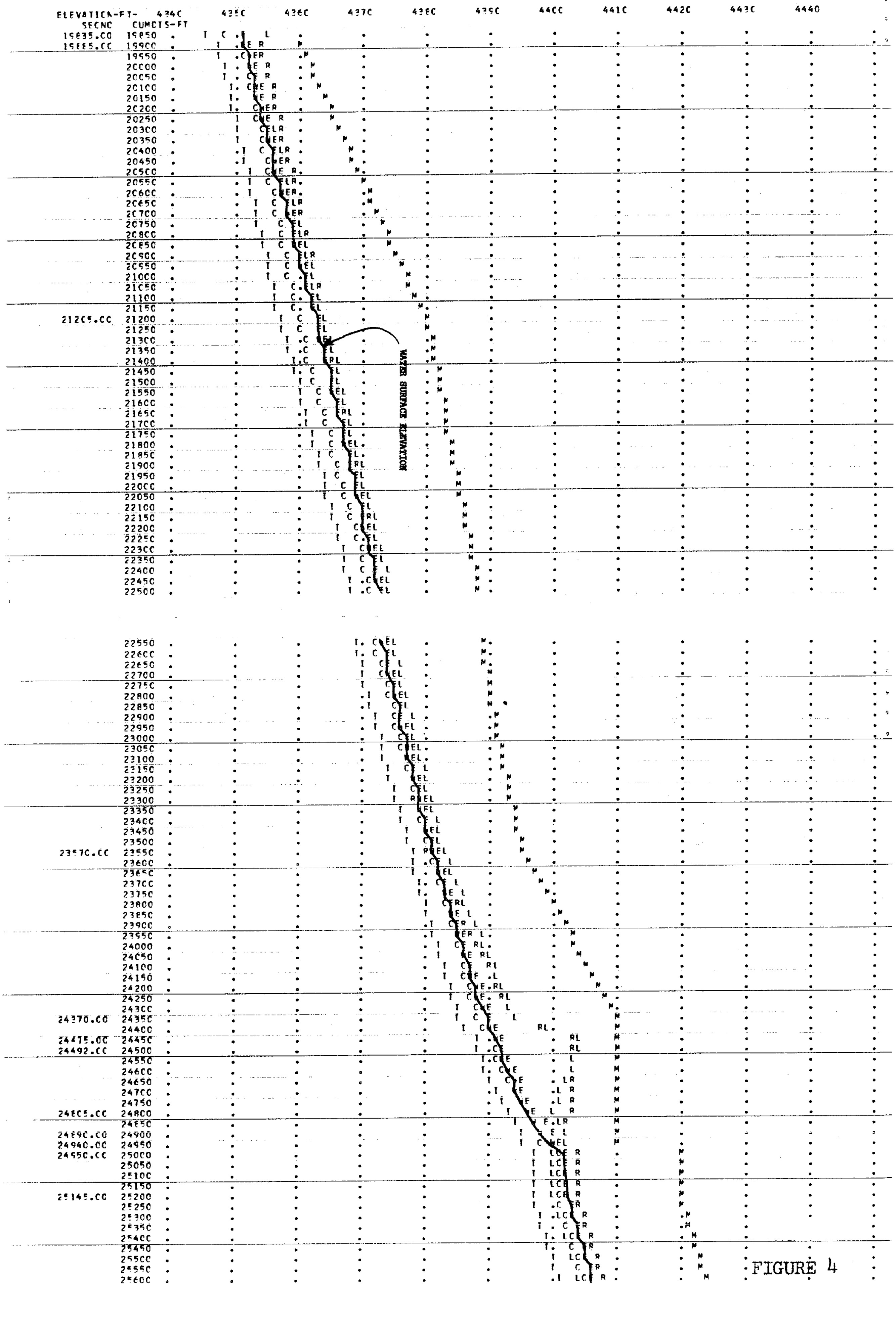
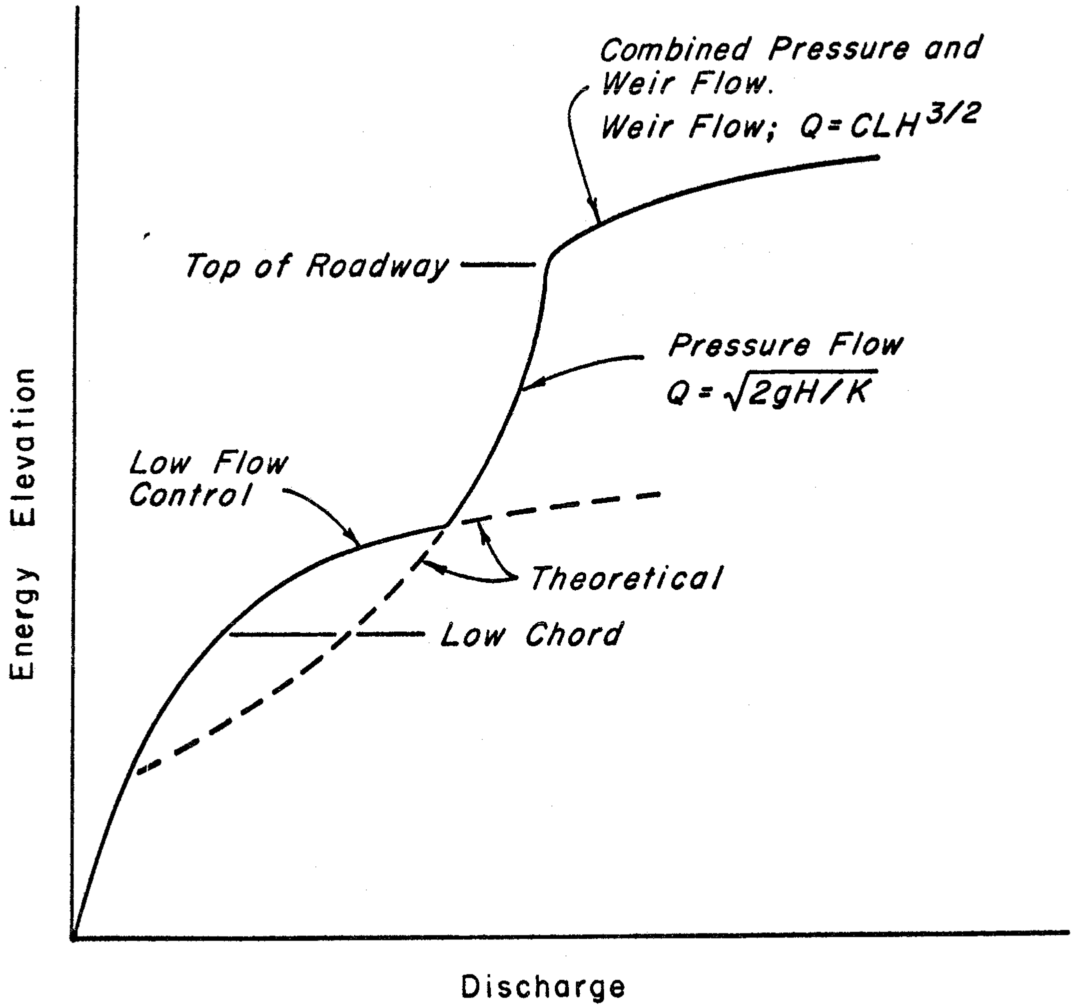


FIGURE 4



TYPICAL DISCHARGE RATING CURVE
FOR BRIDGE

FIGURE 5

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