MEMORANDUM REPORT

SEPTEMBER, 1975

FCD BACKWATER PROFILE COMPUTATION

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BY
SUN-FU SHIH

FLOOD CONTROL DISTRICT
CENTRAL AND SOUTHERN FLORIDA
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RESOURCE PLANNING DEPARTMENT
CENTRAL AND SOUTHERN FLORIDA
FLOOD CONTROL DISTRICT
WEST PALM BEACH . . . . FLORIDA

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Central and Southern Florida Flood Control District
West Palm Beach, Florida 33402

FCD BACKWATER PROFILES COMPUTATION

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INTRODUCTION

The results of backwater profile computation have been extensively used in the fields of design, planning, management and quality control of water resources problems. Methods of integration of the equation of gradually varied open channel flow have been presented by several investigators. However, a rigid technique used to determine the hydraulic radius is not reliable because at the present time the vertical partition of the subchannel associated with a given wetted perimeter is not a proper procedure in some areas. An improper procedure used to partition the subchannel cross section can cause a significant difference of backwater computation. A proper technique used to compute the backwater profile should be studied further because an area such as the District is flat in slope and very sensitive in stage difference. Over 1,550 miles of canals and levees have been constructed for flood protection and water supply. The average slope of those canals are between 0.3 and 0.4 foot per mile and the mean velocity is about one to two feet per second. It is obvious that a few inches of the flow stage difference can cause a serious impact of canal structures on an operating system. A technique to determine the flow stage of the canal systems in South Florida becomes a very important feature. Therefore, the technique used to compute the backwater profile should be applied carefully in the South Florida area.

OBJECTIVES

The objectives of this report are:

(1) to introduce a basic theory used to perform the backwater profile computation;

(2) to mathematically prove that the conveyance of the channel section calculated by multiple section representations is never less than that by a single section representation;

(3) to introduce the flow equation and numerical technique used to integrate the gradually varied flow;

(4) to develop the computer programs for cross section computation and backwater profile calculation;

(5) to exemplify numerically that different techniques used to perform the subcross sectional area associated with the wetted perimeter gives different conveyances of the channel section;

(6) to present a water surface calculation which is affected significantly by the different techniques used to partition the channel cross section; and

(7) to demonstrate the applications of computer programs.

DESCRIPTION OF THE METHODS

1. BASIC THEORY.

The calculative procedure is based on the Bernoullis theorem for total energy at each cross section and Manning's formula for the friction head loss between cross sections. In the program, average friction slope for a reach between two cross sections is determined in terms of the average of the conveyances at the two ends of the reach.

2. HYDRAULIC ELEMENTS OF FLOW CROSS SECTION

In an open channel, the flow which is transferred across a section equals the product of the cross sectional area and mean velocity component at right angles to the section. The equations commonly used for uniform flow in open channel are the Chezy formula and the Manning formula. Both equations show that the mean velocity of flow is directly proportional to the hydraulic radius and slope of channel. In general, the slope of channel is assumed to be a predeterministic value because the elevation between two reaches is near constant. However, the determination of the hydraulic radius is a varying procedure because the technique used to partition the subcross section associated with a given wetted perimeter is not unique because the hydraulic radius is not a constant value and the result of conveyance is also varied. As mentioned in the introduction, most canals in South Florida are assumed to be a one dimensional flow system because of the flat slopes of the canal, low velocities and the long narrowness of the canal, etc. Based on the existing canal systems in the District, the canals can be classified into two categories: First, a canal with mean constant roughness coefficients; second, a canal with varied roughness coefficient. The concept and summary of the hydraulic representation of flow cross sections have been studied by Shih and Hamrick (1975). The detailed analysis of the two categories are introduced in the following sections.

Category A. Mean Constant Roughness Coefficient

A channel with irregular cross sections such as occurs in a natural channel may be markedly different from a simple geometric channel such as a design channel. However, it is usually possible to divide such irregular shapes into some geometric shapes for easy calculation. For instance, Figure 1 shows that this irregular channel can be divided into three elementary forms, that is, two triangles and one trapezoid shape. According to the equation of continuity, total discharge in the entire channel is equal to the sum of discharges of subchannels, I, II and III, i.e.,

$$Q = Q_1 + Q_2 + Q_3 \tag{1}$$

in which Q, Q_1, Q_2, and Q_3 are the discharges in the entire channel, subchannels I, II, and III, respectively. Equation 1 can be rewritten as:

$$AV = A_1V_1 + A_2V_2 + A_3V_3 \qquad (2)$$

in which A is the cross sectional area and also equals $A_1+A_2+A_3$; where A_1, A_2, A_3 and V_1, V_2, V_3 are cross section areas and mean velocity of subsection channels I, II, and III, respectively. After applying Manning's formula into equation 2 and eliminating the common factors such as 1.486 roughness coefficient n, and slope of channel in both sides of the equation gives

$$A_1(A/P)^{2/3} + A_2(A/P)^{2/3} + A_3(A/P)^{2/3} = A_1(A_1/P_1)^{2/3} + A_2(A_2/P_2)^{2/3} + A_3(A_3/P_3)^{2/3} \qquad (3)$$

where $P = P_1 + P_2 + P_3$; in which P_1, P_2, and P_3 are wetted perimeters of subchannels I, II, and III, respectively. The equal condition in both sides of equation 3 exists only if the following equivalent term of both sides are equal, i.e.,

$$A/P = A_1/P_1 = A_2/P_2 = A_3/P_3 \qquad (4)$$

However, in practical application, P_1, P_2, P_3 are assumed predetermined values, and A_1, A_2 and A_3 are performed by dividing the channel along vertical coordinates which are associated with the given wetted perimeters P_1, P_2 and P_3. The total area, $A_1 + A_2 + A_3$ obtained by any partitioning technique, is a constant value; but the result of using the vertical partitioning technique may not satisfy the condition as given in equation 4. If equation 4 is not considered, the results of the right hand side of equation 3 is never less than the left hand side.

Proof:

Based on the convex function theorem (Rockafeller, 1970), if function f is a postively homogeneous proper convex function, then

$$f(\lambda_1 x_1 + \ldots + \lambda_m x_m) \leq \lambda_1 f(x_1) + \ldots + \lambda_m f(x_m) \qquad (5)$$

whenever $\lambda_1 > 0, \ldots, \lambda_m > 0$.

The equation 3 can be rewritten as

$$\left(\frac{A^{5/2}}{P}\right)^{2/3} \leq \left(\frac{A_1^{5/2}}{P_1}\right)^{2/3} + \left(\frac{A_2^{5/2}}{P_2}\right)^{2/3} + \left(\frac{A_3^{5/2}}{P_3}\right)^{2/3} \qquad (6)$$

The elements of equation 6 such as A, A_1, A_2, A_3, P, P_1, P_2, and P_3 are all positive values, so each term of equation 6 is a positive function. The wetted perimeters P, P_1, P_2 and P_3 are some predetermined values, but A, A_1, A_2, and A_3 are functions of flow depth D, D_1, D_2, and D_3 and multiple channel width B, B_1, B_2, and B_3, respectively. For example, cross section A can be expressed as

$$A = CDB, \qquad (7)$$

where C is some constant. Let $D=\rho D$ and $B=\rho B$, in which ρ is any positive number. Substituting equation 7 and new parameters ρD and ρB into the left-hand side of equation 6 gives

$$\left(\frac{(C\rho D\rho B)^{5/2}}{P}\right)^{2/3} = \rho^{10/3} \left(\frac{(CDB)^{5/2}}{P}\right)^{2/3} = \rho^{10/3} \left(\frac{A^{5/2}}{P}\right)^{2/3} \qquad (8)$$

Based on Euler's Theorem on Homogeneous functions (Spiegel, 1963), a function $f(X_1, X_2, \ldots, X_m)$ is called homogeneous of degree n if, for all values of the parameter ρ and some constant n, we have the identity

$$f(\rho X_1, \rho X_2, \ldots, \rho X_m) = \rho^n f(X_1, X_2, \ldots, X_m). \qquad (9)$$

So the function of $(A^{5/2}/P)^{2/3}$ is a homogeneous function, similarily, the functions of $(A_1^{5/2}/P_1)^{2/3}$, $(A_2^{5/2}/P_2)^{2/3}$, and $(A_3^{5/2}/P_3)^{2/3}$ can be proved as homogeneous functions.

The results of first and second derivativeswith respect to D and B in the left hand side of equation 6 can be expressed as

$$\frac{\partial\left(\frac{A^{5/2}}{P}\right)^{2/3}}{\partial D} = \frac{5}{3} \left(\frac{C^{5/2}}{P}\right)^{2/3} D^{2/3} B^{5/3} \qquad (10)$$

$$\frac{\partial\left(\frac{A^{5/2}}{P}\right)^{2/3}}{\partial B} = \frac{5}{3}\left(\frac{C^{5/2}}{P}\right)^{2/3} D^{5/3} B^{2/3} \tag{11}$$

$$\frac{\partial^2\left(\frac{A^{5/2}}{P}\right)^{2/3}}{\partial D^2} = \frac{10}{9}\left(\frac{C^{5/2}}{P}\right)^{2/3} (B^5/D)^{1/3} \tag{12}$$

$$\frac{\partial^2\left(\frac{A^{5/2}}{P}\right)^{2/3}}{\partial B^2} = \frac{10}{9}\left(\frac{C^{5/2}}{P}\right)^{2/3} (D^5/B)^{1/3} \tag{13}$$

The right-hand side of equations 10, 11, 12 and 13 are all greater than zero, so the function $(A^{5/2}/P)^{2/3}$ is a proper convex function. The functions of $(A_1^{5/2}/P_1)^{2/3}$, $(A_2^{5/2}/P_2)^{2/3}$ and $(A_3^{5/2}/P_3)^{2/3}$ can be proved in a similar way as proper convex functions. Therefore, each term of equation 6 is a positively homogeneous proper convex function.

According to the convex function theorem described,

then

$$\left(\lambda_1\frac{A_1^{5/2}}{P_1} + \lambda_2\frac{A_2^{5/2}}{P_2} + \lambda_3\frac{A_3^{5/2}}{P_3}\right)^{2/3} \leq \lambda_1\left(\frac{A_1^{5/2}}{P_1}\right)^{2/3} + \lambda_2\left(\frac{A_2^{5/2}}{P_2}\right)^{2/3} + \lambda_3\left(\frac{A_3^{5/2}}{P_3}\right)^{2/3} \tag{14}$$

Let the left-hand side equal to

$$\left(\lambda_1\frac{A_1^{5/2}}{P_1} + \lambda_2\frac{A_2^{5/2}}{P_2} + \lambda_3\frac{A_3^{5/2}}{P_3}\right)^{2/3} = \left(\frac{\lambda_1 A_1^{5/2} + \lambda_2 A_2^{5/2} + \lambda_3 A_3^{5/2}}{\lambda_4 P}\right)^{2/3} \tag{15}$$

This equal condition will exist under the condition of equivalent terms if both sides are equal, i.e.

$$\lambda_1\frac{A_1^{5/2}}{P_1} = \frac{\lambda_1 A_1^{5/2}}{\lambda_4 P} \tag{16}$$

$$\lambda_2\frac{A_2^{5/2}}{P_2} = \frac{\lambda_2 A_2^{5/2}}{\lambda_4 P} \tag{17}$$

$$\lambda_3 \frac{A_3^{5/2}}{P_3} = \frac{\lambda_3 A_3^{5/2}}{\lambda_4 P} \tag{18}$$

Eliminating the common parameters of equations, 16, 17 and 18 and summing these three equations together gives

$$\lambda_4 = 1/3 \tag{19}$$

Based on the convex function theorem, the numerator of the right-hand side of equation 15 yields

$$\lambda_1 A_1^{5/2} + \lambda_2 A_2^{5/2} + \lambda_3 A_3^{5/2} \geq (\lambda_1 A_1 + \lambda_2 A_2 + \lambda_3 A_3)^{5/2} \tag{20}$$

combining equations 14, 15, 19 and 20 together gives

$$\left(\frac{(\lambda_1 A_1 + \lambda_2 A_2 + \lambda_3 A_3)^{5/2}}{1/3\ P}\right)^{2/3} \leq \lambda_1 \left(\frac{A_1^{5/2}}{P_1}\right)^{2/3} + \lambda_2 \left(\frac{A_2^{5/2}}{P_2}\right)^{2/3} + \lambda_3 \left(\frac{A_3^{5/2}}{P_3}\right)^{2/3} \tag{21}$$

As the convex function theorem indicated, $\lambda_1, \lambda_2, \lambda_3 > 0$, so let $\lambda_1 = \lambda_2 = \lambda_3 = 1/3$, equation 21 yields

$$\frac{A^{5/3}}{P^{2/3}} \leq \frac{A_1^{5/3}}{P_1^{2/3}} + \frac{A_2^{5/3}}{P_2^{2/3}} + \frac{A_3^{5/3}}{P_3^{2/3}} \tag{22}$$

Multiplying a common factor of 1.486/n which was eliminated in equation 3, back into equation 22 gives

$$\frac{1.486}{n} \left(\frac{A^{5/3}}{P^{2/3}}\right) \leq \frac{1.486}{n} \left(\frac{A_1^{5/3}}{P_1^{2/3}} + \frac{A_2^{5/3}}{P_2^{2/3}} + \frac{A_3^{5/3}}{P_3^{2/3}}\right) \tag{23}$$

The terms of equation 23 are known as the conveyance of the channel section. For convenience, the left-hand side of equation 15 is called a single section representation (SR) and the right-hand side is termed a multiple section representation (MR). As equation 23 shows, the following two conclusions can be drawn:

Conclusion 1. If an equal mean velocity is assumed and the subchannels are not partitioned based on the conditions given by equation 4, then the conveyance of the channel section obtained by the MR method is never less than that by the SR method.

Conclusion 2. If the stages and discharges of a one-dimensional flow canal are recorded, then the elevation of the backwater profile calculated by the SR method is lower than that of the MR method, because the SR method develops less conveyance for the given channel section.

Category B. Varied Roughness Coefficient

Chow (1959) mentioned that the cross section of a channel may be composed of several distinct subsection with each subsection different in roughness from the others. For example, an alluvial channel subject to seasonal floods generally consists of a main channel and two side channels as shown in Figure 3. Henderson (1969) indicated that the distinct regions of flow shown in Figure 3 have different velocities. Kinori (1970) described that experience, both in the field and in the laboratory, and indicated that it is meaningless to calculate such a cross section in the usual way; that is, to treat it as a whole. The mean velocity in the main channel is greater than the mean velocities in the side channels because the side channels are usually found to be rougher than the main channel. After applying the Manning formula to equation 2 and eliminating the common factors such as 1.486 and slope of channel,

$$\frac{A_1}{n}\left(\frac{A}{P}\right)^{2/3} + \frac{A_2}{n}\left(\frac{A}{P}\right)^{2/3} + \frac{A_3}{n}\left(\frac{A}{P}\right)^{2/3} = \frac{A_1}{n_1}\left(\frac{A_1}{P_1}\right)^{2/3} + \frac{A_2}{n_2}\left(\frac{A_2}{P_2}\right)^{2/3} + \frac{A_3}{n_3}\left(\frac{A_3}{P_3}\right)^{2/3} \qquad (24)$$

in which n is an equivalent roughness coefficient, n_1, n_2, and n_3 are roughness coefficients of subsection channels I, II, III, $A=A_1+A_2+A_3$ and $P=P_1+P_2+P_3$. The equal condition in both sides of equation 24 exists only if the following equivalent terms of both sides are equal, i.e.

$$\frac{A}{nP} = \frac{A_1}{n_1P_1} = \frac{A_2}{n_2P_2} = \frac{A_3}{n_3P_3} \qquad (25)$$

If the conditions of equation 25 are not considered, then equation 24 can be rewritten as

$$\frac{1}{n}\left(\frac{A^{5/2}}{P}\right)^{2/3} \leq \frac{1}{n_1}\left(\frac{A_1^{5/2}}{P_1}\right)^{2/3} + \frac{1}{n_2}\left(\frac{A_2^{5/2}}{P_2}\right)^{2/3} + \frac{1}{n_3}\left(\frac{A_3^{5/2}}{P_3}\right)^{2/3} \tag{26}$$

A similar technique as introduced in the section of constant roughness coefficient is used to prove each term of equation 26 as a postively homogeneous proper convex function. Based on the convex function theorem as mentioned in equation 5, the right-hand side of equation 24 can be expressed as

$$\left(\lambda_1\frac{A_1^{5/2}}{P_1n_1^{3/2}} + \lambda_2\frac{A_2^{5/2}}{P_2n_2^{3/2}} + \lambda_3\frac{A_3^{5/2}}{P_3n_3^{3/2}}\right)^{2/3} \leq \lambda_1\left(\frac{A_1^{5/2}}{P_1n_1^{3/2}}\right)^{2/3} + \lambda_2\left(\frac{A_2^{5/2}}{P_2n_2^{3/2}}\right)^{2/3} + \lambda_3\left(\frac{A_3^{5/2}}{P_3n_3^{3/2}}\right)^{2/3} \tag{27}$$

Let the left-hand side of equation 27 equal

$$\left(\lambda_1\frac{A_1^{5/2}}{P_1n_1^{3/2}} + \lambda_2\frac{A_2^{5/2}}{P_2n_2^{3/2}} + \lambda_3\frac{A_3^{5/2}}{P_3n_3^{3/2}}\right)^{2/3} = \left(\frac{\lambda_1A_1^{5/2} + \lambda_2A_2^{5/2} + \lambda_3A_3^{5/2}}{\lambda_4\ P\ n^{3/2}}\right)^{2/3} \tag{28}$$

The equal condition in equation 28 will exist under the conditions of equivalent terms of both sides are equal, i.e.,

$$\frac{1}{P_1n_1^{3/2}} = \frac{1}{\lambda_4Pn^{3/2}} \tag{29}$$

$$\frac{1}{P_2n_2^{3/2}} = \frac{1}{\lambda_4\ Pn^{3/2}} \tag{30}$$

$$\frac{1}{P_3n_3^{3/2}} = \frac{1}{\lambda_4\ Pn^{3/2}} \tag{31}$$

After summing equations 29, 30, 31 together

$$\lambda_4 = \frac{1}{3}\left(\frac{P_1 n_1^{3/2} + P_2 n_2^{3/2} + P_3 n_3^{3/2}}{P n^{3/2}}\right) \tag{32}$$

Reling on the convex function theorem, the numerator of the right-hand side of equation 19 can be related as

$$\lambda_1 A_1^{5/2} + \lambda_2 A_2^{5/2} + \lambda_3 A_3^{5/2} \geq (\lambda_1 A_1 + \lambda_2 A_2 + \lambda_3 A_3)^{5/2} \tag{33}$$

Combining equations 27, 28, 32, and 33 together;

$$\left(\frac{(\lambda_1 A_1 + \lambda_2 A_2 + \lambda_3 A_3)^{5/2}}{\frac{1}{3}(P_1 n_1^{3/2} + P_2 n_2^{3/2} + P_3 n_3^{3/2})}\right)^{2/3} \leq \lambda_1\left(\frac{A_1^{5/2}}{P_1 n_1^{3/2}}\right)^{2/3} + \lambda_2\left(\frac{A_2}{P_2 n_2^{3/2}}\right)^{2/3} + \lambda_3\left(\frac{A_3}{P_3 n_3^{3/2}}\right)^{2/3} \tag{34}$$

As the convex function theorem indicated, parameters λ_1, λ_2 and λ_3 can be equal to 1/3, so equation 34 is rewritten as

$$\frac{A^{5/3}}{(P_1 n_1^{3/2} + P_2 n_2^{3/2} + P_3 n_3^{3/2})^{2/3}} \leq \frac{A_1^{5/3}}{n_1 P_1^{2/3}} + \frac{A_2^{5/3}}{n_2 P_2^{2/3}} + \frac{A_3^{5/3}}{n_3 P_3^{2/3}} \tag{35}$$

The left and right side of equation 35 are termed as homogeneous techniques with roughness coefficient (HTR) and composite technique with roughness coefficient (CTR), respectively.

The following two cases can be used to discuss the physical concept of equation 35:

<u>Case 1</u>. Each subsection of channel with different coefficients of roughness has the same mean velocity which was assumed by Horton (1933). This assumption may be existing in some design channel with different construction material for side walls and channel bottom. According to this assumption, Chow (1959) indicated the following relationship

$$(Pn^{3/2})^{2/3} = (P_1 n_1^{3/2} + P_2 n_2^{3/2} + P_3 n_3^{3/2})^{2/3} \qquad (36)$$

where n is an equivalent coefficient of roughness. Substituting equation 36 into equation 35 gives

$$\frac{A^{5/3}}{nP^{2/3}} \leq \frac{A_1^{5/3}}{n_1 P_1^{2/3}} + \frac{A_2^{5/3}}{n_2 P_2^{2/3}} + \frac{A_3^{5/3}}{n_3 P_3^{2/3}} \qquad (26)$$

As equation 25 indicated, both sides of equation 26 will be equal under the conditions introduced in equation 25. From equations 25 and 36, the following functions can be drawn:

$$A_1 = \frac{P_1 A n_1^{3/2}}{P_1 n_1^{3/2} + P_2 n_2^{3/2} + P_3 n_3^{3/2}} \qquad (37)$$

$$A_2 = \frac{P_2 A n_2^{3/2}}{P_1 n_1^{3/2} + P_2 n_2^{3/2} + P_3 n_3^{3/2}} \qquad (38)$$

$$A_3 = \frac{P_3 A n_3^{3/2}}{P_1 n_1^{3/2} + P_2 n_2^{3/2} + P_3 n_3^{3/2}} \qquad (39)$$

If a channel is assumed such that each part of a subchannel has the same mean velocity and the A_1, A_2, and A_3 are not chosen by the conditions introduced in equations 37, 38, and 39, then a higher mean velocity will be obtained by the CTR method according to equation 26. A later example will show the numerical difference between HTR and CTR methods.

Case 2. An alluvial channel with different roughness coefficients in the main channel and side channels has a distinct different mean velocity in each subchannel. In this type of channel, a CTR method is more reliable because the assumption of the same mean velocity in the entire channel is not practical. However, it should be realized that the technique of selecting boundaries between side channels and main channel will affect the results of computation. But, in practical application, a vertical boundary between the main channel and side channel is assumed because of the following two reasons: First, the number of main channel and side channel boundaries are limited to a few numbers of subsections such as shown in Figure 3 as only two boundary lines; second, the possible deviation of area due to the vertical boundary assumption is also very small as compared with each subchannel area. So the deviation caused by a different technique to partition the boundary between the main channel and side channel is assumed a negligible value in alluvial channel.

3. GRADUALLY VARIED FLOW EQUATION.

Chow (1959) indicated that the differential equation of gradually varied flow is

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - \frac{\alpha Q^2 T}{g A^3}} \tag{40}$$

in which y is the depth of flow; x is the distance along the channel bed; S_0 is the slope of the stream bed; S_f is the energy gradient; α is the energy coefficient; and Q is the discharge; T is the top width of the channel section; g is the acceleration due to gravity; and A is the cross-sectional area of the channel. When the Manning formula is used the energy slope is

$$S_f = \frac{n^2 V^2}{2.22 \, R^{4/3}} \tag{41}$$

Substituting V = Q/A and R = A/P into equations 41 and 40 yields

$$\frac{dy}{dx} = \frac{S_0 - \frac{n^2 Q^2 P^{4/3}}{2.22 \, A^{10/3}}}{1 - \frac{\alpha Q^2 T}{g A^3}} \tag{42}$$

in which V is the velocity of flow; n is Manning's roughness coefficient; R is the hydraulic radius; and P is the wetted perimeter. The parameters A, P, n and T are functions of the depth of flow y and channel geometry. So equation 42 is nonlinear. This nonlinear equation can be solved by numerical procedure which is based on the iteration technique (Hildebrand, 1956; Prasad, 1970). However, as indicated in the previous section of hydraulic elements of open channel flow, the technique used to partition the channel cross section was neglected. Therefore, some modifications were made in this study. The value of α was introduced in detail value by Chow (1959) as follows:

CHANNELS	Value of α		
	Minimum	Average	Maximum
Regular channels, flumes, spillways	1.10	1.15	1.20
Natural streams and torrents	1.15	1.30	1.50
Rivers under ice cover	1.20	1.50	2.00
River valleys, overflooded	1.50	1.75	2.00

As can be seen from the above table, the values of α ranged from 1 to 2. Based on the author's previous study in the Kissimmee River area, the value of α equaling 1 is quite satisfactory in most cases.

COMPUTER PROGRAM DESCRIPTIONS

Three computer programs are involved in the backwater profile computation. First, the parameters of wetted perimeter and the top width in each reach is computed based on different stages. Second, the backwater profile is computed by using an equal size of ΔX assignment. Third, the backwater profile is integrated by using an unequal size of ΔX.

1. E070 - CHANNEL CROSS SECTION PERFORMANCE

The channel cross section performance was developed in a computer program called E070.

Input of Program:

(a) Canal Name (CN card): Each run of the program should be identified with a name such as the name of the canal, structure or location, dates, etc.

(b) Elevation Limit and End of Slope (EL card): The maximum elevation limit to which the end slopes of the canal are extended. It should be noted that the elevation limit needs to be higher than the possible stage of computation. Two options are involved in this card. Option 1 is the slopes of both sides of the canal which are extended to the end point of the section. The main purpose of this option is to keep discharge in both floodplain and main channel. Option 2 is the slopes of both sides of the canal which are extended to the high points in each side of the canal. The purpose of option 2 is to keep the flow in the main design channel. The assignment of horizontal extension of slope for each foot of elevation to the elevation limit is also required.

(c) Manning's "n" classification (CL card): Since Manning's "n" coefficient depends on such factors as type and amount of vegetation, seasonal variation of vegetation growing, channel configuration and stage, several options are available to vary "n". Five different coefficients are classified in this program:

(d) Channel Station (ST card): The input of station is based on feet because the distance between two stations is subtracted from two stations' input. Where it is desired to change the flow beginning at a certain cross section, such as confluence with another tributary or a significant variation of the cross section configuration portion, a new station should be indicated.

(e) Range and Elevation: The cross sections may be oriented looking either upstream or downstream since the program considers the left side to be the lowest range number and the right side the highest. The inputs of range and elevation are in feet.

Output of Program:

The inputs of canal name, elevation limit, channel station, range of each coefficient classification, and range associated elevation are all printed out. Rearrangement of range and elevations with the end of slope adjustment, top width and wetted perimeter of five coefficient classifications are also printed out.

2. E081 - BACKWATER COMPUTATION WITH EQUAL MESH SIZE ASSIGNMENT.

The backwater functions have been integrated by several investigations. Chow (1955) presented a method of integration in which a set of tables of the varied flow function is required. Keifer and Chu (1955) showed a method of numerical integration for circular conduits. Pickward (1963) demonstrated a numerical integration based on a finite series of polylogarithms and polynomials. [illegible], Prasad (1970) introduced a numerical solution based on a simple rapidly converging iterative [illegible]. However, no single method has been found to be suitable in South [illegible] because of the flat slopes of the canals and low velocity of the flow. Therefore, a modification of iterative method as indicated in the hydraulic elements of cross sections is used in this computer program. Due to several errors involved in the numerical solution, Shin (1974) [illegible] a detailed description of six possible errors which can make the numerical solution meaningless. Therefore, the technique used in this integration of backwater function should be applied carefully. For example, although a better approximation of the backwater function is desirable in using a small mesh size, the cumulative effect of error in rounding off is increased. Therefore, decreasing the mesh size will not always increase the accuracy of the finite difference calculations. Roundoff error has a random character, which makes it difficult to deal with. In this program, the ranges of mesh size between 25' to 100' are suggested. The user should note that if a smaller mesh size is used a longer computer time is required. Therefore, the decision of mesh size not only depends upon the accuracy and computer time but also the size should be smaller than half the distance between two stations. For example, if the distance between two stations is only 50' then the mesh size should be smaller than 25'.

<u>Input of Program:</u>

Alfa = energy coefficient, dimensionless constant.

UPDWN = Either upstream run or downstream run; dimensionless constant.

SIT = Mesh size for iterating method, in units of feet.

NS = Number of stages. The maximum value is 20.

NFC = Number of friction coefficients to change in run including [illegible] friction coefficients. The maximum number is 20

NST1 = Position or location of station in run to start profile calculation.

NST2 = Position or location of station in run to end profile calculation.

SI(IS) = Initial stages to be used in runs. IS is ranged from 1 to NS.

SQ(IQ) = Station value (in feet) at which discharge is to be changed. IQ is ranged from 1 to NQ.

Q(IQ) = New discharge at the corresponding SQ(IQ) station.

SF(IC) = Station value (feet) at which roughness coefficients for each classification are to be changed. IC is ranged from 1 to NFC.

XFC(IC,J) = New roughness coefficients at the SF(IC) station. J is ranged from 1 to 5.

The output of the E070 program has also become an input of this E081 program.

Output of Program:

The input data such as canal name, discharge, initial stage, roughness coefficient and station are all printed out. The computed results are listed as follows:

Water Stage: the stage of water in unit of feet.

Depth: The water depth in unit of feet.

Top Width: The width of water surface in unit of feet.

Area: Cross section area of water flowing in unit of square feet.

Conveyance: Conveyance of the canal section is defined in equation 23 of the SR method.

Accumulated Surface Area: Accumulated average top width multiplied by distance in unit of acres.

Accumulated Volume: Accumulated the average area multiplied by distance in acre-ft.

Section Intercept at Left: Where the range is starting to flow, the water in units of feet.

Section Intercept at Right: Where the range is ending to flow the water in units of feet. The difference between section intercept at right and left equals the top width.

3. E071 - BACKWATER COMPUTATION WITHOUT CONSIDERING THE MESH SIZE.

As mentioned in E081, a smaller mesh size is used and a longer time is required. Especially, if a short distance between two stations is used and the mesh size is smaller than 25 feet, then a much longer computing time is required. Therefore, an unequal mesh size with only ten meshes between two stations are used is applied to the program development. Due to the uneven error propagation, the accuracy of the result is slightly decreased, but a smaller computing time is expected.

EXAMPLES OF APPLICATION

Example 1: Simple Geometric Channel

As Figure 1 shows, a set of numerical values such as b=2', d=1', x=1' and Manning coefficients n = 0.03 are used in this design channel section. Two techniques are used to partition the entire channel section into three subchannels. First, a vertical partition without considering the conditions given by equation 4 is used to divide the entire channel section into two right triangular and one rectangular subchannels. The results are shown as dotted lines in Figure 1. The conveyance calculated by SR and MR methods are equal to 108.18 and 123.83, respectively. The results obtained by the MR method is 14.5 percent higher than by the SR method. This result is also consistent with the theoretical description as stated in conclusion 1. Second, the conditions given by equation 4 are used to partition the entire channel section into two triangular and one trapezoidal subchannels. As mentioned in a previous section, the values of A, P, P_1, P_2 and P_3 can be directly calculated from the record data. The values of A_1, A_2 and A_3 which can be obtained based on the condition given by equation 4 are equal to AP_1/P, AP_2/P, and AP_3/P, respectively. The results are shown as inclined dash-lines in Figure 1, and the value of x' is 1.757'. The conveyances calculated by both methods are all equal to 108.18. This implies that the SR method is independent of the technique used to partition the subchannels. If a channel with a wide and shallow cross section is considered where the hydraulic radius approximates the mean depth, then the conveyance calculated by both methods is not significantly different. For instance, let b equal 100' in the above example, and without considering the condition given by equation 4, the conveyance calculated by the SR method is 4943, and by the MR method, it is 4978. The difference between the two methods is less than 1 percent.

Example 2: Water Surface Profile Computation in C-123:

A canal such as C-123 (Corps of Engineers, 1966) located in Broward County, Florida, is used to illustrate the statement given by conclusion 2. Manning's n value used to design the canal is 0.03, which was reported by the Corps of Engineers (1953). This canal was opened by the FCD in September 1972. The roughness coefficients of this canal were also re-evaluated by Taylor and Tai (1974). The results of the roughness coefficients studied in April, May, and July are shown in Table 1. The field data of stages and discharges in those three studies are also used to illustrate the water surface profile calculation. The roughness coefficient varies until the elevation of the computed water surface at the upstream end approaches the historical record. As illustrated in Conclusion 1, if the condition given by equation 4 is used to partition the subchannels, then both the SR and MR methods give the same results. Therefore, only a vertical partition technique without considering the condition given by equation 4 is used in the MR method. The results of the elevation of computed water surface are listed in Table 1. Two conclusions can be drawn from Table 1: First, if the elevation of computed water surface is expected to approach the historical data, then the roughness coefficient computed based on the MR method is higher than the measured data. It is higher by about 7 to 14%, and based on the SR method is within 4.4% difference as compared with the measured data. This 4.4% difference is still within the 95% statistical confidence limits. Hence, the roughness coefficient computed based on the SR method does not distort the actual roughness coefficient significantly. Second, if the approximate roughness coefficients are known, then the upstream elevation computed, based on the MR method, is lower than the historical elevation difference by about 15%. However, based on the SR method, it is only a 2% difference, which is also within the 95% statistical confidence limits. Hence, the SR method is more reliable than the MR method in this example of backwater profile calculation. The results of conveyance computed by both methods are listed on Table 2. As can be seen from Table 2, if the same approximate roughness coefficients are used in both methods, then the conveyance computed by the MR method is never less than that by the SR method. Therefore, the elevation of the computed water surface based on the MR method is never lower than that by the SR method.

EXAMPLE 3: WATER SURFACE PROFILE IN C-24 CANAL

A canal such as C-24 located in St. Lucie County, Florida, is another example used to exemplify the statement given by Conclusion 2. The total discharge is obtained by field observations. Manning's n value, which is equal to 0.03, was used by the Corps of Engineers. The vertical coordinates partitions, without considering equation 4 conditions, are used to perform the subchannel cross sections. The results of the water profile calculation based on both the MR and SR methods are shown in Figure 4. As can be seen from Figure 4, the water surface profile calculated by the MR method is one foot lower than that by the SR method. This result is consistent with the statement given by conclusion 2 that the stage of backwater profile computed by the MR method is lower than that of the SR method. Although the difference of stage is only one foot in this 20 miles of C-24, the error is as large as 15 percent because the total elevation difference is only 6.6 feet. This shows that the water surface profile computation is significantly affected by the technique used to partition the channel cross section.

EXAMPLE 4: DESIGN CHANNEL WITH DIFFERENT ROUGHNESS COEFFICIENT MATERIALS

A design channel as shown in Figure 2 with b=20', d=3', and x=3' is constructed with a concrete bottom float finished, and the side walls are built with dry rubble. Chow (1959) indicated that the roughness coefficients are 0.015 for float finished concrete, 0.025 for cement rubble masonry. If the conditions of equations 37, 38, and 39 are used to estimate the subsection area as the dash line indicated, x'=10.98'; the values of CTR and HTR are all equal to 6816. If an equivalent n=0.02 is used in equation 35, the HTR value is 6223. The difference between 6816 and 6223 is about 9 percent. This result indicates that if an equivalent n value is not available in a compound channel, but an assumption of the same mean velocity is used in the entire channel, then the HTR method can be used to estimate the discharge based on individual parts of construction materials. However, if the subsection channel is divided as a dotted line with x=3', the result of the CTR method is 8695, which will be higher than 6816 by about 28 percent and higher than 6223 by about 40 percent. This result implies that if an equivalent roughness coefficient is not available, the HTR method is more reliable than the CTR method.

DISCUSSION AND SUMMARY

Based on these studies of computation for hydraulic elements in open channel cross section, four different techniques were demonstrated, i.e., homogeneous technique (SR) and composite technique (MR) for constant roughness coefficient, homogeneous technique for varied roughness coefficient (HTR) and composite technique for varied roughness coefficient (CTR). The results of the theoretical proof and numerical exemplification showed that the conveyance computed by composite technique is not less than by the homogeneous technique. If a mean velocity is assumed equal in the entire cross section, then the SR or HTR method is more reliable because this method is relatively easy to use and the calculating result is also independent of the technique used in partitioning the boundary between subchannels. A design channel with different constructing materials for the channel bottom and side walls, especially when an equivalent roughness coefficient is not available during the time of designing, the HTR method is suggested to estimate the primary discharge because the results obtained from the MR or CTR methods are not unique. In other words, the MR or CTR methods are strongly dependent upon the technique for partitioning the subchannel section. If a mean velocity is obviously unequal in the whole cross section, for example, a designed channel with one depth central channel and two shallow channels, or an alluvial channel, the composite technique is more reliable because the mean velocities in the central and side channels are distinctly different.

This study also concluded that the different techniques used to partition the channel cross section will affect the water surface profile calculation.

For instance, the C-24 canal at St. Lucie County, Florida, will have about a one foot elevation difference between the SR method and MR method. This one foot is about 16 percent of the total elevation difference.

Based on the study of C-123 canal backwater profile computation, the SR method is more reliable. Therefore, the FCD backwater profile computation program is based on the SR technique. Three computer programs are developed in this backwater computation. The first is called E070 which is used to develop the channel cross section, elevation control, roughness coefficient classification, wetted perimeter, and top width of each stage. The second is called E081 which is used to compute the backwater profile computation with an equal mesh size assignment. The third is called E071 which is also used to calculate the backwater profile calculation without considering the mesh size assignment.

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Table 1. Comparison of the results of the elevation of water surface computed based on the single section representation (SR) and multiple section representations (MR).

Stations (from downstream ft.)	Water Surface Elevation, M.S.L. - Ft. May 22, 1974 SR 0.037*	MR 0.037	MR 0.041	April 24, 1974 SR 0.035	MR 0.035	MR 0.039	July 25, 1974 SR 0.025	MR 0.025	MR 0.028
		Q=590 cfs			Q=690 cfs			Q=1190 cfs	
811+50	6.75	6.75	6.75	7.03	7.03	7.03	9.96	9.96	9.96
736+00	6.94	6.90	6.93	7.25	7.20	7.24	10.14	10.09	10.12
735+00	6.94	6.90	6.93	7.25	7.20	7.24	10.14	10.09	10.12
308+00	8.39	8.06	8.31	8.85	8.49	8.78	11.40	11.09	11.34
		Q=530 cfs			Q=600 cfs			Q=1170 cfs	
307+00	8.39	8.07	8.31	8.85	8.49	8.78	11.41	11.09	11.34
214+50	8.76	8.37	8.66	9.23	8.81	9.16	11.80	11.40	11.72
214+00	8.76	8.37	8.66	9.23	8.81	9.16	11.80	11.40	11.72
		Q=510 cfs			Q=580 cfs			Q=1165 cfs	
162+00	9.17	8.74	9.07	9.62	9.17	9.53	12.11	11.69	12.05
161+00	9.18	8.76	9.08	9.64	9.18	9.55	12.13	11.72	12.07
109+00	9.33	8.90	9.24	9.78	9.32	9.70	12.28	11.86	12.23
108+00	9.33	8.90	9.24	9.78	9.33	9.71	12.28	11.86	12.23
57+00	9.40	8.97	9.32	9.86	9.40	9.79	12.36	11.94	12.32
55+50	9.40	8.97	9.32	9.86	9.40	9.79	12.36	11.94	12.32
2+87	9.45	9.02	9.37	9.91	9.45	9.84	12.41	11.99	12.37
0+62	9.45	9.02	9.37	9.91	9.45	9.84	12.41	11.99	12.37
0+00	9.45	9.02	9.37	9.91	9.45	9.84	12.41	11.99	12.37
Record Data – Downstream		6.75			7.03			9.96	
Record Data – Upstream		9.43			9.86			12.39	
Measured n value		0.0377			0.0341			0.0261	

*Roughness coefficient used to compute the backwater profile.

Table 2. Comparison of the results of the conveyance computed by single section representation (SR) and multiple section representations (MR).

Stations ft.	Conveyance, $\times 10^5$ May 22, 1974 SR 0.037*	MR 0.037	MR 0.041	April 24, 1974 SR 0.035	MR 0.035	MR 0.039	July 25, 1974 SR 0.025	MR 0.025	MR 0.028
811+50									
736+00	1.178	1.344	1.215	1.291	1.473	1.325	2.473	2.884	2.579
735+00	1.055	1.197	1.085	1.160	1.316	1.187	2.260	2.610	2.340
308+00	1.015	1.128	1.038	1.129	1.253	1.150	2.184	2.457	2.230
307+00	0.959	1.054	0.983	1.075	1.179	1.098	2.031	2.261	2.075
214+50	0.826	0.910	0.851	0.927	1.019	0.952	1.765	1.961	1.807
214+00	0.699	0.752	0.711	0.795	0.851	0.805	1.625	1.737	1.616
162+00	0.574	0.597	0.574	0.662	0.688	0.660	1.482	1.514	1.425
161+00	0.779	0.799	0.763	0.889	0.910	0.869	1.856	1.902	1.786
109+00	0.972	0.988	0.941	1.103	1.119	1.064	2.214	2.273	2.130
108+00	1.141	1.171	1.114	1.299	1.322	1.257	2.570	2.652	2.484
57+00	1.318	1.350	1.283	1.490	1.522	1.445	2.919	3.024	2.831
55+50	1.510	1.544	1.467	1.704	1.739	1.650	3.309	3.429	3.209
2+87	1.700	1.737	1.650	1.482	1.954	1.854	3.696	3.831	3.583
0+62	1.985	2.002	1.919	2.257	2.277	2.181	4.651	4.685	4.408
0+00	2.261	2.262	2.183	2.592	2.594	2.501	5.515	5.527	5.212
Average	1.045	1.137	1.056	1.140	1.269	1.175	2.276	2.496	2.291

* Roughness coefficient used to calculate the conveyance.

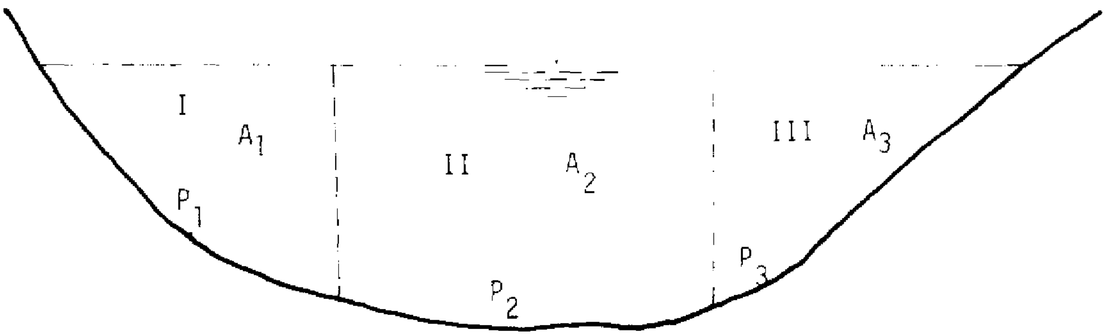

Figure 1. Natural channel section with constant Manning's n.

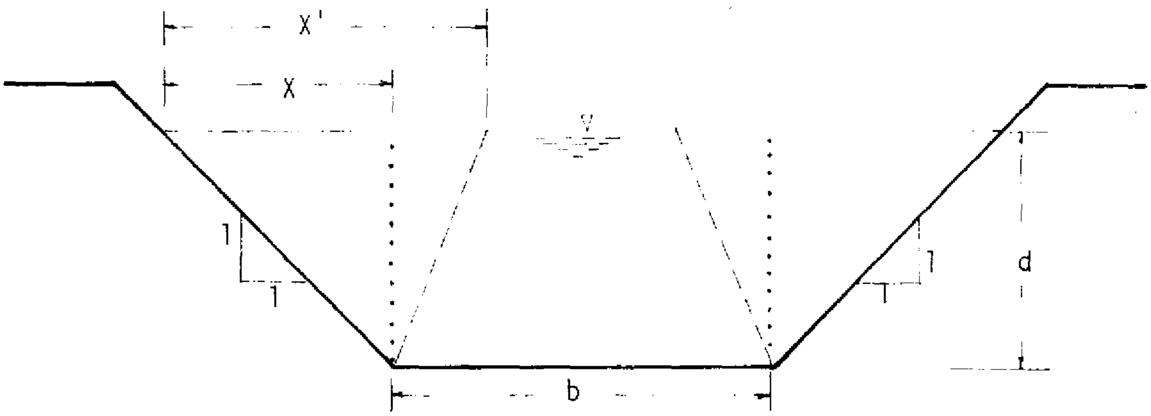

Figure 2. Design channel cross section.

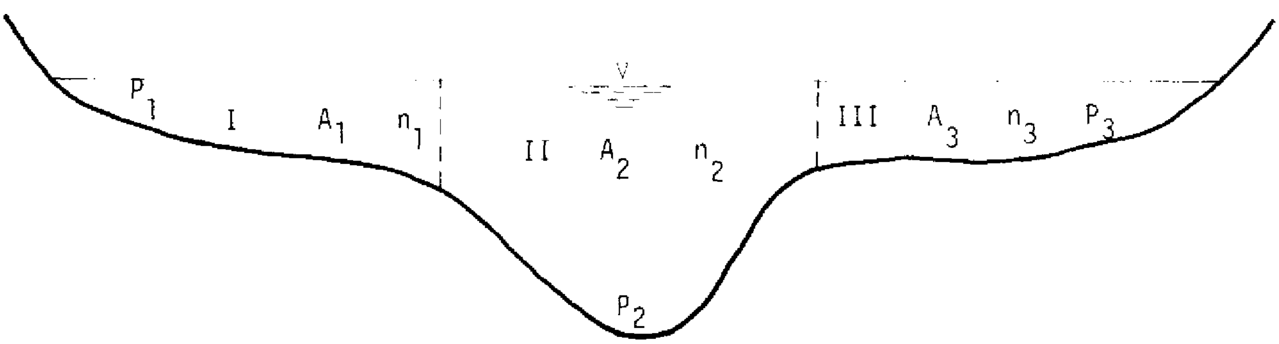

Figure 3 Example of overbank flow.

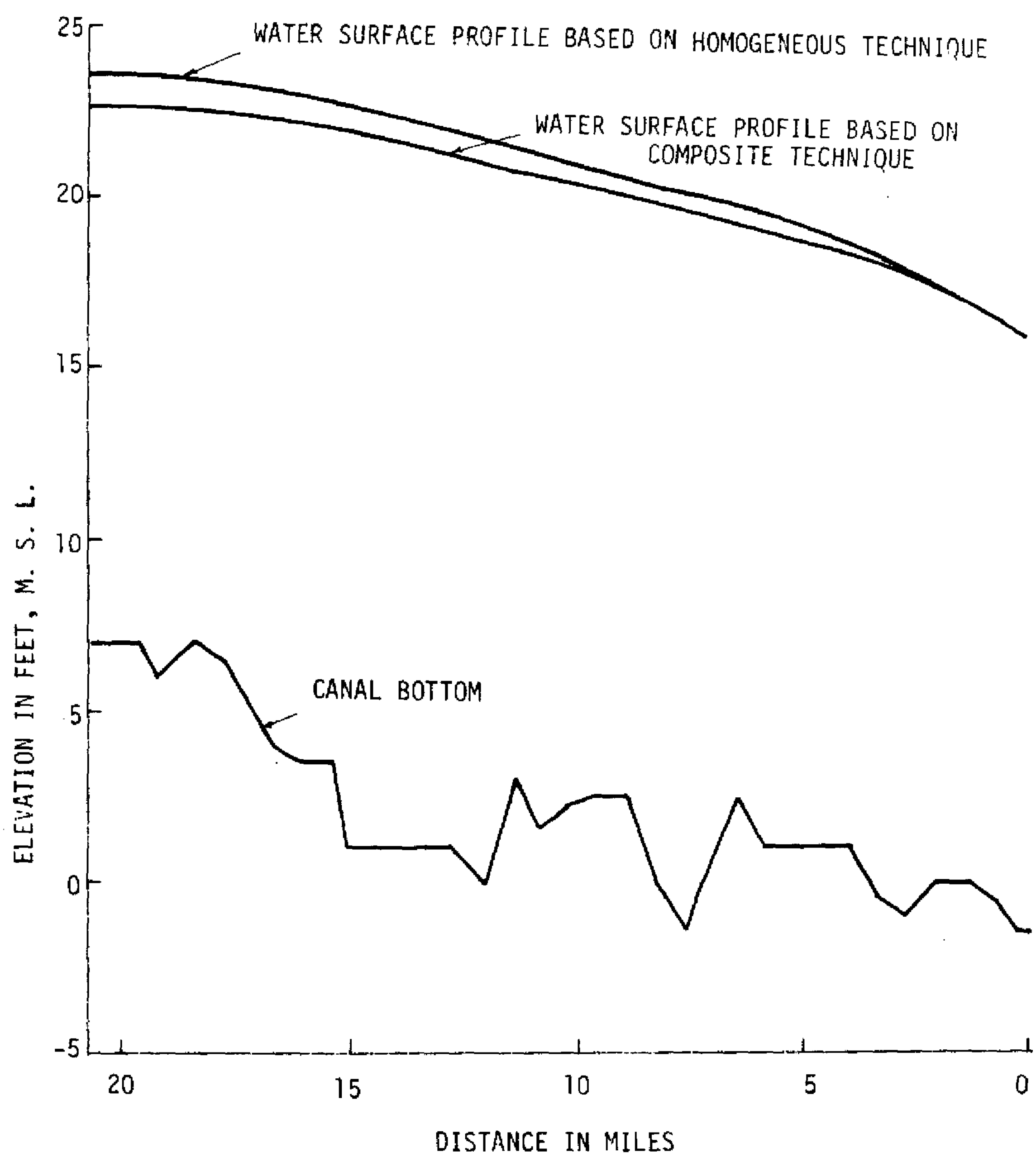

Figure 4. Comparing water surface profiles of C - 24, St. Luice County, Florida.

APPENDIX I: USERS MANUAL FOR E070

FOR PROGRAM TO BUILD TAPE FILE
OF SECTION GEOMETRY AND CHARACTERISTICS
FROM CROSS-SECTION DATA

E070

(BLDWS)

CENTRAL AND SOUTHERN FLORIDA
FLOOD CONTROL DISTRICT

PROGRAM LIMITATIONS

1. Limit of 500 stations with section data in any one run.

2. Limit of 68 range and elevation points per section.

3. Limit of 5 coefficient classification codes in the range of 1 to 5 inclusive.

4. Limit of 5 pairs of ranges for any of the 5 classification codes (must all be on the same card).

5. Limit of 50 distinct elevations.

NOTES: Error messages are printed and processing is discontinued if any of the above limitations are exceeded.

A warning message is printed if the coefficient classification ranges do not extend over the width of the section; however, processing will continue.

REQUISITION FOR COMPUTER WORK

Est. Time - - One minute is needed, approximately, for one cross section in natural channel or for five cross sections in designed channel.

Category - - Production Run

Job Run No. - E-070

Output Tapes - 11 = Tape No. is assigned by user

Disks - - 6100

USER'S INPUT DESCRIPTION

MISCELLANEOUS NOTES

CARD ORDER

The first input cards must be a "CN" card followed by an "EL" card. The "CL" card must be present before "RE" cards are encountered.

The "CL" card(s) may be present at intervals throughout the run; however, for a "CL" card(s) to apply to a given station, the "CL" card must be placed between the "ST" card and the "RE" card(s) for that station. All "RE" card(s) processed will use the last "CL" card(s) encountered for coefficient classification ranges.

The "EL" card(s) may be present at intervals throughout the run; however, for an"EL" card(s) to apply to a given station, the "EL" card must be placed after the "ST" card for that station. All "ST" card(s) processed will use the last "EL" card(s) encountered for the elevation limit and end slopes.

The very last card of the run must be an "EN" card.

The section data must be entered in an upstream order, also the ranges on the "CL" card(s) must be in the same order as the ranges on the "RE" cards (increasing in magnitude from left to right or right to left.)

FORMAT INFORMATION

Symbols used to indicate the proper method for numbers or letters entered in card columns shown are -

RJ - Indicates that a whole number must be right justified in card columns shown.

DI(XX-XX) - Indicates that the decimal point is implied between the card columns shown

A - Any alpha-numeric character

Do not indicate any decimal points on data sheets.

NOTES: "CL" card(s)

If at any time during the course of a run, a previously defined coefficient classification code is no longer used - insert a "CL" card with that code present and the range fields blank at the point where it has been discontinued.

USER'S INPUT DESCRIPTION
Card Format Information

"CN" Card (Canal name card)

C.C.	Symbol	Description
1-2	A	"CN"
6-11	A	Contains canal name

"EL" Card (Elevation limit and end slope card)

C.C.	Symbol	Description
1-2	A	"EL"
5-13	DI(10-11)	Elevation limit to which the end slopes are extended.
17	RJ	1-Slopes are extended from end points of section. 0-Slopes are extended from high points on ends of section.
18-25	RJ	Horizontal extension of slope for each foot of elevation to the elevation limit.

"CL" Card (coefficient classification card)

C.C.	Symbol	Description
1-2	A	"CL"
4	RJ	Coefficient classification code
5-12	DI(11-12)]	
20-27	DI(26-27)]	Starting range for the area of the
35-42	DI(41-42)]	........section for which this coefficient
50-57	DI(56-57)]	classification applies.
65-72	DI(71-72)]	
13-19	DI(18-19)]	
28-34	DI(33-34)]	Ending range for the area of the
43-49	DI(48-49)]	........section for which this coefficient
58-64	DI(63-63)]	applies.
73-79	DI(78-79)]	

"ST" Card (Station Card)

C.C.	Symbol	Description
1-2	A	"ST"
5-13	DI(12-13)	Station of section in feet.

"RE" Card (Range and elevation card)

C.C.	Symbol	Description
1-2	A	"RE"
5-13	DI(10-11)]	
20-28	DI(25-26)]	
35-43	DI(40-41)]........	Range of point at which elevation is given.
50-58	DI(55-66)]	
65-73	DI(70-71)]	
14-19	DI(17-18)]	
29-34	DI(32-33)]	
44-49	DI(47-48)]........	Elevation of point for corresponding above range.
59-64	DI(62-63)]	
74-79	DI(77-79)]	

"EN" Card (End of data card)

C.C.	Symbol	Description
1-2	A	"EN"

Note - Blank code in C.C. 1-2 indicates to use previous code encountered for this card.

APPENDIX 2: USERS MANUAL FOR E081

PROGRAM TO CALCULATE WATER
SURFACE PROFILE FROM SECTION
CHARACTERISTICS ON TAPE FILE

E081
(WSPRF)

PROGRAM LIMITATIONS

1. Limit of 20 initial stages.
2. Limit of 20 discharge changes with corresponding station values
3. Limit of 20 roughness coefficient changes with corresponding station values.

REQUISITION FOR COMPUTER WORK

Category - - Production Run

Job Run No. - - E081

Input Tape - - 11=Assigned No. of tape from Job Run No. E070

Disks - - 6100

USER'S INPUT DESCRIPTION

Miscellaneous Notes

For each of the number of initial stages selected, the program will calculate the water surface profile using the given discharge and roughness coefficient information.

Symbols used to indicate the proper method for numbers entered in card columns shown are:

RJ - Indicates that a whole number must be right justified in card columns shown.

DP - Indicates that the number must have a decimal point indicated in one of the card columns shown.

USER'S INPUT DESCRIPTION

Card Format Information

PARAMETER CARD

C.C.	Symbol	Description
1-10	DP	Alpha value, a positive value is required. If a negative value, e. g.(-1.0), is used, the alpha value will be changed with corresponding section characteristics.
11-20	DP	+1.0 - upstream run ; -1.0 - downstream run.
21-30	DP	Δx, between 25.0 and 100.0 are recommended.

CONTROL CARD

C.C.	Symbol	Description
4-5	RJ	Number of stages
9-10	RJ	Number of discharges to change in run including initial discharge
14-15	RJ	Number of friction coefficients to change in run including initial friction coefficients
18-20	RJ	Position or location of station in run to start profile calculation
23-25	RJ	Position or location of station in run to end profile calculation

Note: For the last two entrys use the position number or location of station (not station value) in an upstream order.

INITIAL STAGES CARD(S)

C.C.	Symbol	Description
1-10	DP	
11-20	DP	
21-30	DP	Initial stages to be used in runs.
31-40	DP	
41-50	DP	

C.C.	Symbol	Description
51-60	DP	
61-70	DP	Initial stages to be used in runs.
71-80	DP	

Use as many stage cards as necessary. No imbedded blank fields allowed.

DISCHARGE CARD(S)

C.C.	Symbol	Description
1-10	DP	Station value (feet) at which discharge is to be changed.
11-20	DP	New discharge at the above station.

ROUGHNESS COEFFICIENT CARD(S)

C.C.	Symbol	Description
1-10	DP	Station value (feet) at which roughness coefficients for each classification are to be changed.
11-20	DP	New roughness coefficients at the above station. A positive value is required; if a negative value, e. g. (-1.0), is used, the roughness coefficients will be changed with corresponding depth of flow. (This program at present time was developed only for marsh area, if user wants to use this variable roughness coefficients in other area, please contact personnel in Water Planning Division)
21-30	DP	
31-40	DP	
41-50	DP	
51-60	DP	

Note: At least one discharge and roughness coefficient card containing starting station value must be present in run.

Station values on these cards must be in order of run, either upstream or downstream.

PLOT CARD

C.C.	Symbol	Description
5	RJ	Plot code Blank or 0 - Do not plot water surface profile 1 - Plot water surface profile
11-20	DP	Horizontal scale of plot
21-30	DP	Vertical scale of plot

Note: One plot card must be present after roughness coefficient card(s). Use as many new parameter cards with succeeding cards as necessary. The last card must be present as a blank form.

APPENDIX 3: USERS FOR E071

PROGRAM TO CALCULATE WATER
SURFACE PROFILE FROM SECTION
CHARACTERISTICS ON TAPE FILE

E071

(WSPRF)

The input used in this program is the same as E081 except the columns from 21 to 30 in the first card is not considered. In other words, the same set of E081 cards can be run in E071 because the data between columns 21 and 30 is automatically not used in E071.

APPENDIX 4: E070 COMPUTER PROGRAM

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COSY V3.3      - MSOS V5.0     09/08/75
 E070      DECK/      I=01.L
       PROGRAM BLOWS
       DIMENSION E(70),R(70),KODE(7),KARD(79),CL(5,5,2),IC(5)
       DIMENSION ICODE(7),ISTA(15),NCAAL(6),ISTB(15),IPCK(1)
       DATA ((KODE(I),I=1,7)=2HST,2HRF,2HCN,2HEN,2HEL,2H  ,2HCL)
       DATA ((ICODE(I),I=1,7)=7(0)),(NT=11),((IC(I),I=1,5)=5(0))
       DATA ((((CL(I,J,K),I=1,5),J=1,5),K=1,2)=50(0.0)),(IBLNK=1H )
 300   FORMAT(1H1,17HILLEGAL CARD CODE)
 301   FORMAT(1H1,57HSTATION CARD ENCOUNTERED WITH NO PREVIOUS CANAL NAME
      1 CARD)
 303   FORMAT(1H1,62HSTATION CARD ENCOUNTERED WITH NO PREVIOUS ELEVATION
      1LIMIT CARD)
 500   FORMAT(1H0,10(1H*),18H CHANNEL STATION =,15A1,26H  =  FLOOD PLAIN
      1STATION =,15A1,2X,10(1H*))
 510   FORMAT(1H0,33HCRITICAL ELEVATION DOES NOT APPLY)
 511   FORMAT(1H0,20HCRITICAL ELEVATION =,F6.2)
 304   FORMAT(1H1,66HRANGE AND ELEVATION CARD ENCOUNTERED WITH NO PREVIOU
      1S STATION CARD)
 305   FORMAT(1H1,85HRANGE AND ELEVATION CARD ENCOUNTERED WITH NO PREVIOU
      1S COEFFICIENT CLASSIFICATION CARD)
 13    FORMAT(1H0,55HALLOWABLE NUMBER OF RANGE AND ELEVATION POINTS EXCEE
      1DED)
 501   FORMAT(1H1,6HCANAL ,6A1)
 502   FORMAT(1H0,17HELEVATION LIMIT =,F10.2)
 503   FORMAT(1H0,41HRANGES FOR COEFFICIENT CLASSIFICATION NO.,I2,2H =/
      1 1H ,4X,5(F9.2,1H-,F9.2,1H,,2X))
 C
 C     READ DATA CARD
 C
 10    READ(60,200)KARD
 200   FORMAT(80A1)
       CALL PACK(KARD,1,2,IPCK,1)
       ISAVE=K
       DO 20 K=1,7
       IF(IPCK(1)-KODE(K))20,21,20
 20    CONTINUE
       WRITE(61,300)
       GO TO 999
 C
 C     DETERMINE TYPE OF CARD
 C
 21    IF(K-6)41,42,41
 42    K=ISAVE
 41    GO TO(1,2,3,4,5,1,7),K
 C
 C     STATION CARD
 C
 1     IF(ICODE(3))22,22,23
 22    WRITE(61,301)
       GO TO 999
 23    IF(ICODE(5))28,28,62
 28    WRITE(61,303)
       GO TO 999
 62    IGO=1
       IF(ICODE(1))24,24,25
 24    STATN=SGET(KARD,5,13,0,1)
       DO 240 L=14,22
       IF(KARD(L)-IBLNK)241,240,241
 240   CONTINUE
       STATM=STATN
       GO TO 242
```

```
 241    STATM=SGET(KARD,14,22,0.1)
 242    DO 250 L=23,30
        IF(KARD(L)-IBLNK)251,250,251
 250    CONTINUE
        CRELV=-9999.0E30
        GO TO 252
 251    CRELV=SGET(KARD,23,30,0.01)
 252    CALL STAT(STATN,ISTA)
        CALL STAT(STATM,ISTB)
        WRITE(61,500)ISTA,ISTB
        IF(CRELV+9998.0E30)253,253,254
 253    WRITE(61,510)
        GO TO 255
 254    WRITE(61,511)CRELV
 255    ICODE(1)=1
        N=0
        GO TO 10
C
C       PROCESS PREVIOUS STATION
C
C       CALCULATE GEOMETRY
C
 25     CALL DESCT(N,E,R,ELIMT,KODEL,SL)
C
C       ROUTINE TO CHECK FOR SECTION COVERAGE WITH COEFFICIENT RANGES
C
        CALL COFCH(R(1),R(N),CL,IC)
C
C       CALCULATE SECTION CHARACTERISTICS
C
        CALL SCHAR(N,E,R,CL,IC,STATN,STATM,CRELV)
        GO TO(24,30),IGO
C
C       RANGE AND ELEVATION CARD
C
 2      IF(ICODE(1))31,31,29
 31     WRITE(61,304)
        GO TO 999
 29     IF(ICODE(7))61,61,32
 61     WRITE(61,305)
        GO TO 999
 32     N=N+1
        M=N+4
        MK=-9
        DO 33 L=N,M
        MK=MK+15
        IF(L-70)11,11,12
 12     WRITE(61,13)
        GO TO 9999
 11     R(L)=SGET(KARD,MK-1,MK+7,0.001)
        E(L)=SGET(KARD,MK+8,MK+13,0.01)
        IF(R(L))33,34,33
 34     IF(E(L))33,35,33
 33     CONTINUE
        N=M
        GO TO 36
 35     N=L-1
 36     ICODE(2)=1
        GO TO 10
C
C       CANAL NAME CARD
C
```

```
3     CALL MOVE(KARD,6,11,NCAAL,1)
      WRITE(61,501)NCAAL
      REWIND NT
      WRITE(NT)NCAAL
      ICODE(3)=1
      GO TO 10
C
C     END OF DATA CARD
C
4     IGO=2
      GO TO 25
30    END FILE NT
999   REWIND NT
      GO TO 9999
C
C     ELEVATION LIMIT CARD
C
5     ELIMT=SGET(KARD,5,13,0.001)
      KODEL=SGET(KARD,17,17,1.0)
      SL=SGET(KARD,18,25,1.0)
      WRITE(61,502)ELIMT
      ICODE(5)=1
      GO TO 10
C
C     COEFFICIENT CLASSIFICATION CARD
C
7     II=SGET(KARD,4,4,1.0)
      IC(II)=0
      MK=-9
      DO 50 J=1,5
      MK=MK+15
      RR1=SGET(KARD,MK-1,MK+6,0.1)
      RR2=SGET(KARD,MK+7,MK+13,0.1)
      IF(RR1)51,52,51
52    IF(RR2)51,53,51
51    MM=IC(II)+1
      CL(II,MM,1)=RR1
      CL(II,MM,2)=RR2
      IC(II)=IC(II)+1
50    CONTINUE
53    ICODE(7)=1
      J=IC(II)
      IF(J)10,10,71
71    WRITE(61,503)II,((CL(II,MM,ID),ID=1,2),MM=1,J)
      GO TO 10
9999  CALL EXIT
      END

      SUBROUTINE COFCH(RL,RR,CL,IC)
300   FORMAT(1H0,120(1H*)/)
302   FORMAT(1H ,96HRANGES FOR COEFFICIENT CLASSIFICATIONS ARE NOT CONTI
     1GUOUS OR DO NOT EXTEND BEYOND SECTION LIMITS)
      DIMENSION CL(5,5,2),IC(5),XR(50)
      N=0
      DO 10 J=1,5
      NC=IC(J)
      IF(NC)10,10,11
11    DO 10 I=1,NC
      XR(N+1)=CL(J,I,1)
      XR(N+2)=CL(J,I,2)
      N=N+2
10    CONTINUE
```

```
      CALL SORT1(N,XR,1)
      IF(RL-XR(1))50,60,60
60    IF(RR-XR(N))70,70,50
70    IF(N-2)99,99,20
20    K=N-1
      DO 80 I=2,K,2
      IF(ABS(XR(I)-XR(I+1))-0.01)80,80,50
80    CONTINUE
      GO TO 99
50    WRITE(61,300)
      WRITE(61,302)
      WRITE(61,301)(XR(I),I=1,N)
301   FORMAT(1H ,12F10.1)
      WRITE(61,300)
99    RETURN
      END

      SUBROUTINE DESCT(N,E,R,ELIMT,KODEL,SL)
      DIMENSION E(1),R(1),XL(70),YL(70),XR(70),YR(70)
300   FORMAT(1H0,27HINPUT RANGES AND ELEVATIONS)
302   FORMAT(1H0,36HSECTION UN-DEFINED ON LEFT HAND SIDE)
303   FORMAT(1H0,37HSECTION UN-DEFINED ON RIGHT HAND SIDE)
304   FORMAT(1H0,I3,29H POINTS ABOVE ELEVATION LIMIT)
59    FORMAT(1H0,90HALLOWABLE NUMBER OF RANGE AND ELEVATION POINTS EXCEE
     1DED WITH ADDITION OF CALCULATED POINTS)
305   FORMAT(1H0,40HRE-DEFINED SECTION RANGES AND ELEVATIONS)
C
C     SORT POINTS IN ASCENDING ORDER BY RANGE
C
      CALL SORT2(N,R,E,1)
C
C     PRINT INPUT RANGE AND ELEVATION DATA
C
      WRITE(61,300)
      DO 56 I=1,N
      WRITE(61,301)R(I),E(I)
56    CONTINUE
301   FORMAT(1H ,2F10.2)
C
C     SORT POINTS IN ASCENDING ORDER BY ELEVATION
C
      CALL SORT2(N,E,R,1)
C
C     USING RANGE OF LOWEST ELEVATION - PLACE POINTS ON LEFT OR RIGHT
C
      L=0
      M=0
      DO 10 I=1,N
      IF(R(I)-R(1))11,11,12
11    L=L+1
      XL(L)=R(I)
      YL(L)=E(I)
      GO TO 10
12    M=M+1
      XR(M)=R(I)
      YR(M)=E(I)
10    CONTINUE
C
C     DETERMINE IF SECTION UN-DEFINED
C
      IF(L-1)13,13,14
14    IF(M)15,15,16
```

```
13    WRITE(61,302)
      L=L+1
      XL(L)=XL(L-1)-(ELIMT-YL(L-1))*SL
      YL(L)=ELIMT
      GO TO 16
15    WRITE(61,303)
      M=1
      XR(M)=XL(1)+(ELIMT-YL(1))*SL
      YR(M)=ELIMT
C
C     TEST FOR EXTENSION OF SLOPES ON FAR LEFT OR RIGHT
C
16    IF(KODEL)29,29,30
C
C     EXTEND SLOPES FROM FAR LEFT AND RIGHT
C
30    CALL SORT2(L,XL,YL,2)
      IF(YL(L)-ELIMT)31,32,32
31    L=L+1
      YL(L)=ELIMT
      XL(L)=XL(L-1)-(ELIMT-YL(L-1))*SL-0.001
32    CALL SORT2(M,XR,YR,1)
      IF(YR(M)-ELIMT)33,99,99
33    M=M+1
      XR(M)=XR(M-1)+(ELIMT-YR(M-1))*SL+0.001
      YR(M)=ELIMT
99    K=L
      J=M
      GO TO 34
C
C     ELIMINATE POINTS TO LEFT OF HIGHEST ELEVATION ON LHS
C
29    K=0
      DO 35 I=1,L
      IF(XL(I)-XL(L))35,36,36
36    K=K+1
      XL(K)=XL(I)
      YL(K)=YL(I)
35    CONTINUE
C
C     ELIMINATE POINTS WITH EQUAL ELEVATIONS ON FAR LHS
C
      CALL SORT2(K,XL,YL,2)
37    IF(YL(K)-YL(K-1))38,39,38
39    K=K-1
      GO TO 37
C
C     ELIMINATE POINTS TO RIGHT OF HIGHEST ELEVATION ON FAR RHS
C
38    J=0
      DO 41 I=1,M
      IF(XR(I)-XR(M))42,42,41
42    J=J+1
      XR(J)=XR(I)
      YR(J)=YR(I)
41    CONTINUE
C
C     ELIMINATE POINTS WITH EQUAL ELEVATIONS ON FAR RHS
C
      CALL SORT2(J,XR,YR,1)
40    IF(YR(J)-YR(J-1))98,44,98
44    J=J-1
```

```
      GO TO 40
98    L=K
      M=J
      GO TO 30
C
C     TRUNCATE ANY AREA ABOVE ELEVATION LIMIT ON BOTH SIDES
C
C     SORT POINTS ON LHS IN DESCENDING ORDER BY RANGE AND RE-CALCULATE
C     POINTS ABOVE ELEVATION LIMIT ON FAR LHS
C
34    L=K
      IF(YL(L)-ELIMT)17,17,18
18    L=L-1
      IF(YL(L)-ELIMT)19,17,18
19    XL(L+1)=XL(L+1)+(XL(L)-XL(L+1))*(YL(L+1)-ELIMT)/(YL(L+1)-YL(L))
      YL(L+1)=ELIMT
      L=L+1
C
C     SORT POINTS ON RHS IN ASCENDING ORDER BY RANGE AND
C     POINTS ABOVE ELEVATION LIMIT ON FAR RHS
C
17    M=J
      IF(YR(M)-ELIMT)21,21,22
22    M=M-1
      IF(YR(M)-ELIMT)23,21,22
23    XR(M+1)=XR(M+1)-(XR(M+1)-XR(M))*(YR(M+1)-ELIMT)/(YR(M+1)-YR(M))
      YR(M+1)=ELIMT
      M=M+1
C
C     RE-SET ELEVATIONS ABOVE ELEVATION LIMIT ON LHS
C
21    K=0
      DO 20 I=1,L
      IF(YL(I)-ELIMT)20,20,24
24    YL(I)=ELIMT
      K=K+1
20    CONTINUE
C
C     RE-SET ELEVATIONS ABOVE ELEVATION LIMIT ON RHS
C
      DO 25 I=1,M
      IF(YR(I)-ELIMT)25,25,26
26    YR(I)=ELIMT
      K=K+1
25    CONTINUE
      IF(K)27,27,28
28    WRITE(61,304)K
C
C     PLACE REMAINING POINTS IN RANGE AND ELEVATION ARRAYS
C
27    DO 50 I=1,L
      IM=L+1-I
      R(I)=XL(IM)
50    E(I)=YL(IM)
      DO 60 I=1,M
      J=L+I
      R(J)=XR(I)
60    E(J)=YR(I)
      N=L+M
      CALL AMXMN(E,N,EMAX,EMIN)
      L=0
      K=N-1
```

```
      DO 70 I=2,K
      IF(E(I)-E(I+1))70,71,70
71    IF(E(I)-EMIN)70,70,72
72    L=L+1
      LL=N+L
      E(LL)=E(I)-0.0001
      R(LL)=R(I)
70    CONTINUE
      N=N+L
      IF(N-70)57,57,58
58    WRITE(61,59)
      STOP
57    CALL SORT2(N,R,E,1)
      WRITE(61,305)
      DO 55 I=1,N
      WRITE(61,301)R(I),E(I)
55    CONTINUE
      RETURN
      END

      SUBROUTINE SCHAR(N,ELEV,RANGE,CL,IC,STATN,STATM,CRELV)
      DIMENSION ELEV(1),RANGE(1),CL(5,5,2),IC(5),Y3(70)
      DIMENSION TW(50,5),WP(50,5)
      DATA (NT=11)
300   FORMAT(1H0,59HTOP WIDTHS BY  N  CLASSIFICATION AT EACH DISTINCT EL
     1EVATION)
302   FORMAT(1H0,66HWETTED PERIMETERS BY  N  CLASSIFICATION AT EACH DIST
     1INCT ELEVATION)
C
C     DETERMINE DISTINCT ELEVATIONS
C
      DO 10 I=1,N
      Y3(I)=ELEV(I)
10    CONTINUE
      CALL SORT1(N,Y3,2)
      L=0
      DO 20 I=1,N
      IF(I-N)12,11,11
12    M=I+1
      DO 13 J=M,N
      IF(Y3(I)-Y3(J))13,20,13
13    CONTINUE
11    L=L+1
      Y3(L)=Y3(I)
20    CONTINUE
      LLL=L
C
C     INITIALIZE TOP WIDTH AND WETTED PERIMETER ARRAYS
C
      DO 30 K=1,LLL
      DO 30 J=1,5
      TW(K,J)=0.0
      WP(K,J)=0.0
30    CONTINUE
      M=N-1
C
C     ENTER LOOP FOR DETERMINATION OF TOP WIDTH AND WETTED PERIMETER
C     FOR EACH DISTINCT ELEVATION
C
      DO 40 K=1,LLL
C
C     CALCULATE TOP WIDTH AND WETTED PERIMETERS FOR EACH CLASSIFICATION
```

```
C     AT THIS DISTINCT ELEVATION
C
      DO 50 J=1,5
      IF(IC(J))50,50,51
51    NC=IC(J)
C
C     CALCULATE TOP WIDTH AND WETTED PERIMETER FOR EACH PAIR OF RANGES
C     WITHIN THIS CLASSIFICATION AT THIS DISTINCT ELEVATION
C
      L=1
      DO 60 I=1,NC
      IGO=1
C
C     RUN ALONG SECTION TO CALCULATE TOP WIDTH AND WETTED PERIMETER
C     FOR EACH PAIR OF RANGES WITHIN THIS CLASSIFICATION AT THIS
C     DISTINCT ELEVATION
C
      DO 70 LJ=L,M
      GO TO(73,74),IGO
C
C     FIND STARTING INTERSECTION
C
73    IF(CL(J,I,1)-RANGE(LJ))85,71,71
85    IF(CL(J,I,2)-RANGE(LJ))60,60,91
91    IGO=2
      RG1=RANGE(LJ)
      EL1=ELEV(LJ)
      GO TO 92
71    IF(CL(J,I,1)-RANGE(LJ+1))81,70,70
81    IGO=2
      RG1=CL(J,I,1)
      EL1=ELEV(LJ)+(ELEV(LJ+1)-ELEV(LJ))/(RANGE(LJ+1)-RANGE(LJ))*
     1(RG1-RANGE(LJ))
92    RG2=RANGE(LJ+1)
      EL2=ELEV(LJ+1)
C
C     DETERMINE IF THIS LINE SEGMENT IS ON OR BELOW THIS DISTINCT
C     ELEVATION
C
83    IF(EL1-Y3(K))72,72,75
72    IF(EL2-Y3(K))76,76,78
C
C     DETERMINE IF SECOND CLASSIFICATION FALLS WITHIN THIS LINE SEGMENT
C
76    IF(CL(J,I,2)-RG2)61,61,62
C
C     SECOND CLASSIFICATION FALLS WITHIN THIS LINE SEGMENT
C
61    IF(CL(J,I,2)-RG1)14,14,15
15    RG2=CL(J,I,2)
      EL2=ELEV(LJ)+(ELEV(LJ+1)-ELEV(LJ))/(RANGE(LJ+1)-RANGE(LJ))*
     1(RG2-RANGE(LJ))
      TW(K,J)=TW(K,J)+RG2-RG1
      WP(K,J)=WP(K,J)+SQRT((EL1-EL2)**2+(RG2-RG1)**2)
14    L=L-1
      IF(L)16,16,60
16    L=1
      GO TO 60
C
C     ACCUMULATE TOP WIDTH AND WETTED PERIMETER FOR THIS LINE SEGMENT
C
62    TW(K,J)=TW(K,J)+RG2-RG1
```

```
      WP(K,J)=WP(K,J)+SQRT((EL1-EL2)**2+(RG2-RG1)**2)
82    RG1=RANGE(LJ+1)
      EL1=ELEV(LJ+1)
      GO TO 70
75    IF(FL2-Y3(K))77,82,82
C
C     LINE SEGMENT INTERSECTS THIS DISTINCT ELEVATION WITH NEGATIVE
C     SLOPE
C
77    RG1=RG1+(RG2-RG1)*(EL1-Y3(K))/(FL1-FL2)
      EL1=Y3(K)
      GO TO 76
78    IF(EL1-Y3(K))64,82,82
C
C     LINE SEGMENT INTERSECTS THIS DISTINCT ELEVATION WITH POSITIVE
C     SLOPE
C
64    RG2=RG1+(RG2-RG1)*(Y3(K)-EL1)/(EL2-FL1)
      EL2=Y3(K)
      GO TO 76
C
C     FIRST CLASS RANGE PREVIOUSLY ENCOUNTERED - CHECK FOR SECOND
C
74    RG2=RANGE(LJ+1)
      EL2=ELEV(LJ+1)
      GO TO 83
70    CONTINUE
60    CONTINUE
50    CONTINUE
40    CONTINUE
      WRITE(61,300)
      WRITE(61,301)(Y3(K),(TW(K,J),J=1,5),K=1,LLL)
      WRITE(61,302)
      WRITE(61,301)(Y3(K),(WP(K,J),J=1,5),K=1,LLL)
301   FORMAT(1H ,F10.2,5F20.5)
      WRITE(NT)STATN,STATM,CRELV,N,(RANGE(I),ELEV(I),I=1,N),LLL,
     1(Y3(K),(TW(K,J),WP(K,J),J=1,5),K=1,LLL)
      RETURN
      END
```

APPENDIX 5: EC81 - COMPUTER PROGRAM

```
      PROGRAM WSPRF
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SQ(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LL(2)
      DIMENSION ISTA(15),STATM(2),CRELV(2),JCC(2,5),ICC(20,5),SNC(20)
      DIMENSION IBUF(125),IA(20)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,    TOPW,CO,AREA,STATN,LL
      COMMON IA
      COMMON R,E,NT,ALFA,UPDWN,NQ,NS,NST1,NST2,NST,NOST,WS,NRE,ZALF,SIT
      COMMON IERR,IQ,IS,DEPTH,IST,SQ,XFC,SFC,NFC,ICC,SNC,NCC
      EQUIVALENCE (ZSTA,IA(1)),(ZWS,IA(3)),(ZDPTH,IA(5)),(ZTOP,IA(7)),
     1           (ZAR,IA(9)),(ZCO,IA(11)),(ACARE,IA(13)),(ACVOL,IA(15))
     2          ,(SLPL,IA(17)),(SLPR,IA(19))
 301  FORMAT(1H0,12HDISCHARGE = ,F10.1)
 302  FORMAT(1H0,24HROUGHNESS COEFFICIENTS =,5F10.3)
 999  CALL LOCATE(40,88,MMM)
      WRITE(40)MMM
      CALL DOPEN(IBUF,40,20,6)
      IREC=0
C
C     READ WATER SURFACE PROFILE CONTROL DATA
C
      CALL WSRED
C
C     LOOP FOR EACH STAGE
C
      DO 30 IS=1,NS
C
C     SET DISCHARGE AND FRICTION COEFFICIENTS AT INITIAL STATION
C
      DO 10 J=1,5
      FC(J)=XFC(1,J)
      JCC(1,J)=ICC(1,J)
      JCC(2,J)=ICC(1,J)
 10   CONTINUE
      IQ=1
C
C     READ INITIAL SECTION DATA AND PRINT HEADINGS
C
      REWIND NT
      READ(NT)NCAAL
C
C     DETERMINE IF TAPE TO BE READ UPSTREAM OR DOWNSTREAM
C
      IF(UPDWN)74,75,75
 74   NTAP=NST2-1
      DO 76 K=1,NTAP
      READ(NT)
 76   CONTINUE
      GO TO 81
 75   IF(NST1-1)81,81,82
 82   NTAP=NST1-1
      DO 83 K=1,NTAP
      READ(NT)
 83   CONTINUE
 81   READ(NT)STATN(1),STATM(1),CRELV(1),NRE,(R(I),E(I),I=1,NRE),LL1,
     1(Y3(1,K),(TW(1,K,M),AP(1,K,M),M=1,5),K=1,LL1)
      WS=SI(IS)
      LL(1)=LL1
      CALL WSTAP
```

```
      JFC=2
      KCC=2
C
C     TRANSFER TO BOTTOM OF LOOP IF ERROR PRESENT
C
      GO TO(14,30),IERR
C
C     DETERMINE SECTION INTERCEPTS FOR INITIAL STATION
C
14    CALL SCINT(WS,NRE,R,F,SLPL    ,SLPR    )
C
C     DETERMINE SECTION CHARACTERISTICS FOR INITIAL STATION
C
      CALL WSCHR(LL(1),DEPTH,Y3,TW,AP,FC,ZTOP,ZCO,ZAP,CRELV(1),JCC,1,
     1ALFA,ZALF)
C
C     PRINT AND STORE INITIAL STATION DATA
C
      CALL STAT(ZSTA,ISTA)
      WRITE(61,388)ISTA,ZWS,ZDPTH,ZTOP,ZAP,ZCO,ACARE,ACVOL,SLPL,SLPR,
     1ZALF
 388  FORMAT(1H0,15A1,2F8.2,5F13.6,2F12.5,F6.2)
      IREC=IREC+1
      CALL DPUT(IBUF,IREC,IA)
C
C     ENTER ITERATION PROCESS FOR THIS CHANNEL
C
C
C     LOOP FOR EACH STATION
C
      DO 40 IST=1,NST
C
C     ENTER INTERPOLATION AND ITERATION PROCESS FOR THIS STATION
C
      IF(UPDWN)77,78,78
77    DO 80 N=1,2
      BACKSPACE NT
80    CONTINUE
78    READ(NT)STATN(2),STATM(2),CRELV(2),NRE,(R(I),F(I),I=1,NRE),LL2,
     1(Y3(2,K),(TW(2,K,M),AP(2,K,M),M=1,5),K=1,LL2)
      LL(2)=LL2
C
C     DETERMINE IF CHANNEL DESIGNATION TO BE CHANGED AT THIS STATION
C
      IF(KCC-NCC)42,42,46
42    IF(ABS(SNC(KCC)-STATN(2))-0.01)43,43,46
43    DO 45 J=1,5
      JCC(2,J)=ICC(KCC,J)
45    CONTINUE
      KCC=KCC+1
46    CALL RCINT(STATM,CRELV,JCC)
      GO TO(949,30),IERR
C
C     CALCULATE SECTION INTERCEPTS AT THIS WATER SURFACE
C
949   CALL SCINT(WS,NRE,R,F,SLPL,SLPR)
      CALL STAT(ZSTA    ,ISTA)
      WRITE(61,388)ISTA,ZWS,ZDPTH,ZTOP,ZAP,ZCO,ACARE,ACVOL,SLPL,SLPR,
     1ZALF
      IREC=IREC+1
      CALL DPUT(IBUF,IREC,IA)
C
```

```
C     DETERMINE IF DISCHARGE IS TO BE CHANGED AT THIS STATION
C
      IF(IQ+1-NQ)21,21,12
21    IF(ABS(SQ(IQ+1)-STATN(1))-0.01)11,11,12
11    IQ=IQ+1
      WRITE(61,301)Q(IQ)
C
C     DETERMINE IF FRICTION COEFFICIENTS TO BE CHANGED AT THIS STATION
C
12    IF(JFC-NFC)22,22,40
22    IF(ABS(SFC(JFC)-STATN(1))-0.01)13,13,40
13    DO 15 J=1,5
      FC(J)=XFC(JFC,J)
15    CONTINUE
      JFC=JFC+1
      WRITE(61,302)FC
40    CONTINUE
30    CONTINUE
      CALL DCLOS(IBUF)
      READ(60,201)IPLOT,HSCAL,VSCAL
201   FORMAT(I5,5X,2F10.3)
      IF(IPLOT)999,999,998
  998 CALL PLOTS(0,0,0)
      CALL WSPLT(NOST,NCAAL,HSCAL,VSCAL,UPDWN)
      CALL PLOT(0.0,0.0,999)
      GO TO 999
      END

      SUBROUTINE SCINT(WS,N,R,E,SLPLT,SLPRT)
      DIMENSION R(1),E(1)
      DO 10 K=1,N
      IF(WS-E(K))10,11,12
10    CONTINUE
      SLPLT=0.0
      GO TO 20
 11   SLPLT=R(K)
      GO TO 20
12    SLPLT=R(K-1)+(E(K-1)-WS)/(E(K-1)-E(K))*(R(K)-R(K-1))
20    DO 30 K=1,N
      L=N-K+1
      IF(WS-E(L))30,31,32
30    CONTINUE
      SLPRT=0.0
      GO TO 99
31    SLPRT=R(L)
      GO TO 99
32    SLPRT=R(L)+(WS-E(L))/(E(L+1)-E(L))*(R(L+1)-R(L))
99    RETURN
      END

      SUBROUTINE WSPLT(NOST,NCAAL,        HSCAL,VSCAL,UPDWN)
      DIMENSION ISTA(15),NCAAL(6)
      DIMENSION IBUF(125),IA(20),MSG(11)
      DIMENSION LCHAR(32),IPL1(15),IPL2(7)
      DATA ((IPL1(I),I=1,5)=4HELEV,4HATIO,4HN IN,4H FEE,4HT    )
      DATA((IPL2(I),I=1,7)=4HWATE,4HR SU,4HRFAC,4HE PR,4HOFIL,4HE FO,
     1  4HR    )
      DATA (MSG=41HSET PEN ON PLAIN PAPER AGAINST RIGHT STOP)
      EQUIVALENCE (STA,IA(1)),(WS,IA(3)),(DEPTH,IA(5))
300   FORMAT(1H1,59HPROFILE WILL NOT FIT IN 27 INCHES WITH GIVEN VERTICA
     1L SCALE)
      CALL FACTOR(0.5)
```

```
      CALL DOPEN(IBUF,40,20,6)
C
C     DETERMINE MAXIMUM AND MINIMUM STATION VALUES
C
      CALL DGET(IBUF,1,IA)
      ST1=STA
      CALL DGET(IBUF,NOST,IA)
      ST2=STA
      IF(ST1-ST2)27,28,28
27    SGN=1.0
      GO TO 29
28    SGN=-1.0
C
C     DETERMINE MAXIMUM AND MINIMUM BOTTOM ELEVATION AND WATER SURFACE
C
29    WSMX=-9999.0E30
      WSMN=+9999.0E30
      DO 17 K=1,NOST
      CALL DGET(IBUF,K,IA)
      IF(WS-WSMX)18,18,19
19    WSMX=WS
18    IF((WS-DEPTH)-WSMN)26,17,17
26    WSMN=WS-DEPTH
17    CONTINUE
C
C     DETERMINE IF PLOT WILL FIT ON PLOTTER WITH GIVEN SCALES
C
      XMIN=IFIX(WSMN)-VSCAL
      XMAX=IFIX(WSMX)+VSCAL
      XINCH=(XMAX-XMIN)/VSCAL
      IF(XINCH-27.0)10,10,11
11    WRITE(61,300)
      GO TO 9999
C
C     POSITION PEN, PLOT AND LABEL ELEVATION AXIS
C
10    CALL SETMSG(11,MSG)
      CALL EPLOT(1,3.0,2.0)
      CALL SCALE(1.0,1.0/VSCAL,0.0,0.0)
      CALL EGRID(1,0.0,0.0,VSCAL/2.0,IFIX(XINCH)*2)
      CALL EPLOT(1,0.0,0.0)
      CALL SCALE(1.0,1.0,0.0,0.0)
      Y=-1.05
      YV=XMIN-VSCAL
      N=XINCH+1
      DO 12 K=1,N
      Y=Y+1.0
      YV=YV+VSCAL
      CALL PUTDC(YV,2,LCHAR,1,6)
      CALL ECHAR(-0.70,Y,0.1,0.1,0.0,LCHAR,6)
12    CONTINUE
      CALL A4A1(IPL1,1,5,LCHAR,1)
      CALL ECHAR(-0.90,1.0,0.2,0.2,1.5707,LCHAR,17)
C
C     PLOT AND LABEL STATION AXIS
C
      CALL EPLOT(1,0.0,0.0)
      CALL SCALE(1.0/HSCAL,1.0,ST1*SGN-0.5*HSCAL,0.0)
      DO 13 K=1,NOST
      CALL DGET(IBUF,K,IA)
      CALL EPLOT(2,STA*SGN,0.0)
      CALL EPLOT(1,STA*SGN,0.04)
```

```
      CALL EPLOT(2,STA*SGN,-0.04)
      CALL STAT(STA    ,ISTA)
      CALL ECHAR(STA*SGN+0.05*HSCAL,-1.60,0.1,0.1,1.5707,ISTA,15)
      CALL EPLOT(1,STA*SGN,0.0)
13    CONTINUE
      CALL A4A1(IPL2,1,7,LCHAR,1)
      CALL MOVE(NCAAL,1,6,LCHAR,27)
      CALL ECHAR(ST1*SGN+HSCAL,-2.0,0.2,0.2,0.0,LCHAR,32)
C
C     PLOT WATER SURFACE PROFILE
C
      CALL EPLOT(1,ST1*SGN,0.0)
      CALL SCALE(1.0/HSCAL,1.0/VSCAL,ST1*SGN,XMIN)
      DO 20 K=1,NOST
      CALL DGET(IBUF,K,IA)
      IF(K-1)24,24,25
24    CALL EPLOT(1,STA*SGN,WS)
25    CALL EPLOT(2,STA*SGN,WS)
      CALL PUTDC(WS,2,LCHAR,1,6)
      CALL ECHAR(STA*SGN+0.05*HSCAL,WS   +0.05*VSCAL,0.1,0.1,1.5707,
     1LCHAR,6)
      CALL EPLOT(1,STA*SGN,WS)
20    CONTINUE
C
C     PLOT BOTTOM ELEVATION PROFILE
C
      DO 30 K=1,NOST
      L=NOST-K+1
      CALL DGET(IBUF,L,IA)
      IF(K-1)34,34,35
34    CALL EPLOT(1,STA*SGN,WS   -DEPTH    )
      GO TO 36
35    CALL DASLN(XSTA,XWS-XDP,STA*SGN,WS-DEPTH,0.25,HSCAL)
36    CALL PUTDC(WS-DEPTH,2,LCHAR,1,6)
      CALL ECHAR(STA*SGN+0.05*HSCAL,WS   -DEPTH    -0.65*VSCAL,0.1,0.1,
     1   1.5707,LCHAR,6)
      XSTA=STA*SGN
      XWS=WS
      XDP=DEPTH
30    CONTINUE
      CALL EPLOT(1,ST2*SGN+3.0*HSCAL,XMIN)
9999  CALL EPLOT(999,0.0,0.0)
      RETURN
      END

      SUBROUTINE WSTAP
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SO(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LI(2)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,    TOPW,CO,AREA,STATN,LI
      COMMON ZSTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
      COMMON R,E,NT,ALFA,UPDWN,NQ,NS,NST1,NST2,NST,NOST,WS,NRE,ZALF,SIT
      COMMON IERR,IQ,IS,DEPTH,IST,SO,XFC,SFC,NFC
304   FORMAT(1H1,51X,6A1//1H ,33X,11HDISCHARGE =,F9.0,2X,
     1 15HINITIAL STAGE =,F6.2/1H0,43X,22HROUGHNESS COEFFICIENTS)
25    FORMAT(1H ,41X,14HCLASSIFICATION,I2,3H = ,F7.4)
22    FORMAT(1H0,18X,5HWATER,14X,3HTOP,30X,2(13H  ACCUMULATED),3X,
     1 18HSECTION INTERCEPTS/1H ,6X,7HSTATION,5X,13HSTAGE   DEPTH,5X
     2 5HWIDTH,8X,4HAREA,6X,24HCONVEYANCE  SURFACE AREA,5X,6HVOLUME,
     3 8X,4HLEFT,6X,5HRIGHT,4X,5HALPHA)
900   FORMAT(1H0,17HINITIAL STAGE OF ,F7.2,27H BELOW BOTTOM ELEVATION OF
     1 ,F7.2)
```

```
901   FORMAT(1H0,17HINITIAL STAGE OF ,F7.2,23H ABOVE TOP ELEVATION OF ,
     1F7.2)
      LL1=LL(1)
      WRITE(61,304)NCAAL,Q(IQ),WS
      DO 23 JJL=1,5
      IF(FC(JJL))23,23,24
24    WRITE(61,25)JJL,FC(JJL)
23    CONTINUE
      WRITE(61,22)
C
C     DETERMINE IF INITIAL STAGE OUT OF RANGE
C
      IF(WS-Y3(1,LL1))11,11,12
11    WRITE(61,900)WS,Y3(1,LL1)
77    IERR=2
      RETURN
12    IF(WS-Y3(1,1))14,14,15
15    WRITE(61,901)WS,Y3(1,1)
      GO TO 77
14    IERR=1
C
C     FIND DEPTH AT INITIAL STATION
C
      DEPTH=WS-Y3(1,LL1)
C
C     DETERMINE SECTION CHARACTERISTICS AT INITIAL STAGE
C
      ZDPTH   =DEPTH
      ZSTA   =STATN(1)
      ZWS    =WS
      ACARE   =0.0
      ACVOL   =0.0
      RETURN
      END

      SUBROUTINE WSRED
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SQ(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LL(2),ICC(20,5),SNC(20)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,   TOPW,CO,AREA,STATN,LL
      COMMON ZSTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
      COMMON R,E,NT,ALFA,UPDWN,NQ,NS,NST1,NST2,NST,NOST,WS,NRE,ZALF,SIT
      COMMON IERR,IQ,IS,DEPTH,IST,SQ,XFC,SFC,NFC,ICC,SNC,NCC
      NT=11
      READ(60,201)ALFA,UPDWN,SIT
201   FORMAT(8F10.3)
      IF(UPDWN)50,60,50
60    CALL EXIT
50    READ(60,202)NS,NQ,NFC,NST1,NST2,NCC
202   FORMAT(6I5)
      READ(60,201)(SI(IS),IS=1,NS)
      DO 10 IQ=1,NQ
10    READ(60,201) SQ(IQ),Q(IQ)
      DO 20 IC=1,NFC
20    READ(60,201)SFC(IC),(XFC(IC,J),J=1,5)
      IF(NCC)1,1,2
2     DO 30 NC=1,NCC
30    READ(60,203)SNC(NC),(ICC(NC,J),J=1,5)
203   FORMAT(F10.3,10I5)
1     NST=NST2-NST1
      NOST=NST+1
      RETURN
```

```
      END

      SUBROUTINE WSCHR(INDEX,DEPTH,Y3,TW,AP,FC,TOPW,CO,AREA,CRELV,JCC,I,
     1ALFA,ALF)
      DIMENSION Y3(2,50),TW(2,50,5),AP(2,50,5),FC(5),JCC(2,5)
      DIMENSION ARR(5),VEL(5)
      WS=DEPTH+Y3(I,INDEX)
      DO 10 K=2,INDEX
      IF(WS-Y3(I,K))10,11,11
10    CONTINUE
      STOP
11    RATIO=(WS-Y3(I,K))/(Y3(I,K-1)-Y3(I,K))
      TOPW=0.0
      CO=0.0
      AREA=0.0
      DO 20 J=1,5
      IF(CRELV+9998.0E30)42,42,41
41    IF(WS-CRELV)43,43,42
43    IF(JCC(I,J))40,40,42
42    IF(FC(J))21,40,21
21    IF(TW(I,K-1,J))40,40,22
22    TP=(TW(I,K-1,J)-TW(I,K,J))*RATIO+TW(I,K,J)
      AR=(TP+TW(I,K,J))/2.0*(WS-Y3(I,K))
      IF(K-INDEX)23,24,24
23    M=INDEX-1
      DO 30 L=K,M
      AR=AR+(TW(I,L,J)+TW(I,L+1,J))/2.0*(Y3(I,L)-Y3(I,L+1))
30    CONTINUE
24    WP=(AP(I,K-1,J)-AP(I,K,J))*RATIO+AP(I,K,J)
      ARR(J)=AR
      TOPW=TOPW+TP
      AREA=AREA+AR
      IF(FC(J))51,52,52
51    D=AR/TP
      FN=1.5613-1.08471*D+0.490179*D**2-0.124972*D**3+0.0173095*D**4-
     1 0.0012181*D**5+0.0000341199*D**6
      CO=CO+1.486*(AR**(5.0/3.0)/WP**(2.0/3.0))/FN
      GO TO 25
52    CO=CO+1.486*(AR**(5.0/3.0)/WP**(2.0/3.0))/FC(J)
      FN=FC(J)
   25 VEL(J)=((ARR(J)/WP)**(2.0/3.0))/FN
      GO TO 20
   40 ARR(J)=0.0
      VEL(J)=0.0
20    CONTINUE
      IF(ALFA) 26,27,27
   26 AR1=0.0
      AVEL=0.0
      AVR=0.0
      DO 28 J=1,5
      AR1=AR1+ARR(J)
      AVEL=VEL(J)**3.0*ARR(J)+AVEL
   28 AVR=VEL(J)*ARR(J)+AVR
      ALF=AVEL*AR1*AR1/(AVR*AVR*AVR)
      GO TO 29
   27 ALF=ALFA
   29 RETURN
      END

      SUBROUTINE RCINT(STATM,CRELV,JCC)
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SQ(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
```

```
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LL(2),ALFF(2)
      DIMENSION ICC(20,5),SNC(20),STATM(2),CRELV(2),JCC(2,5)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,    TOPW,CO,AREA,STATN,LL
      COMMON ZSTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
      COMMON R,E,NT,ALFA,UPDWN,NO,NS,NST1,NST2,NST,NOST,WS,NOF,ZALF,SIT
      COMMON IERR,IO,IS,DEPTH,IST,SQ,XFC,SFC,NFC,ICC,SNC,NCC
970   FORMAT(1H0,38HUNABLE TO CONVERGE AFTER 20 ITERATIONS)
902   FORMAT(1H0,18HDEPTH OUT OF RANGE)
968   FORMAT(1H0,7HDEPTH =,F6.2/1H ,20HITERATION INTERVAL =,I3/1H ,
     1 25HINTERPOLATION INCREMENT =,F10.2/1H ,20HREACH BOTTOM SLOPE =,
     2 E15.7/1H ,28HDISTANCE FROM LAST STATION =,F10.3/1H ,11HTOP WIDTH
     3=,E15.7/1H ,12HCONVEYANCE =,E15.7/1H ,6HAREA =,E15.7)
964   FORMAT(1H0,37HSUPER-CRITICAL FLOW AT A DISTANCE OF ,F10.3,
     1 18H PAST LAST STATION/1H ,11HTOP WIDTH =,E13.6,7H AREA =,E13.6,
     2 13H CONVEYANCE =,E13.6)
      LL1=LL(1)
      LL2=LL(2)
C
C     DETERMINE REACH CONTROL DATA
C
      REACH=ABS(STATN(1)-STATN(2))
      NIT=REACH/SIT+0.5
      FNIT=NIT
      DX=REACH/FNIT
      IF(UPDWN)532,532,533
533   SLOPE=(Y3(2,LL2)-Y3(1,LL1))/REACH
      GO TO 534
532   SLOPE=(Y3(1,LL1)-Y3(2,LL2))/REACH
C
C     ENTER ITERATION PROCESS FOR THIS REACH
C
  534 DO 55 M=1,NIT
      ICOUT=0
      START=FLOAT(M   )*DX
      IF(UPDWN)11,12,12
11    START=START-DX
12    YSTRT=DEPTH
      IGO=0
C
C     CHECK FOR EXCESS NUMBER OF ITERATIONS
C
43    ICOUT=ICOUT+1
      IF(ICOUT-20)68,68,969
969   MO=1
C
C     ERROR DISCOVERED - PRINT DATA TO THIS POINT WITH PERTINENT DATA
C
61    GO TO(1,2),MO
1     WRITE(61,970)
      GO TO 3
2     WRITE(61,902)
3     WRITE(61,968)DEPTH,M,DX,SLOPE,START,XTOPW,XCO,XAR
      IERR=2
      RETURN
C
C     CALCULATE INITIAL AND ENDING STATION TOP WIDTHS, AREAS AND
C     CONVEYANCES FOR INTERMEDIATE POINT CALCULATIONS
C
68    DO 90 I=1,2
C
C     CHECK FOR ALLOWABLE RANGE OF DEPTH
C
```

```
      INDEX=LL(I)
      IF(DEPTH)44,44,45
45    IF((DEPTH+Y3(I,INDEX))-Y3(I,1))46,46,44
44    MO=2
      GO TO 61
46    CALL WSCHR(LL(I),DEPTH,Y3,TW,    AP,FC,TOPW(I),CO(I),AREA(I),
     1CRELV(I),JCC,I,ALFA,ALFF(I))
90    CONTINUE
C
C     FIND TOP WIDTH, AREA AND CONVEYANCE AT INTERMEDIATE POINT
C
      XTOPW=(TOPW(2)-TOPW(1))/REACH*START+TOPW(1)
      XAR=(AREA(2)-AREA(1))/REACH*START+AREA(1)
      XCO=(CO(2)-CO(1))/REACH*START+CO(1)
      XALF=(ALFF(2)-ALFF(1))/REACH*START+ALFF(1)
C
C     CALCULATE SLOPE AT THIS DEPTH
C
      SE=(Q(IQ)/XCO)**2
      FROD2=(XALF*Q(IQ)**2*XTOPW)/32.2/XAR/XAR/XAR
      IF(FROD2-1.0)224,225,225
224   SLOP2=(-1.0*SIGN(1.0,UPDWN))*(SLOPE-SE)/(1.0-FROD2)
      GO TO 226
225   FROD2=0.01
      WRITE(61,964)START,XTOPW,XAR,XCO
      GO TO 224
226   IF(IGO)19,19,21
C
C     SAVE CALCULATED SLOPE OF FIRST ITERATION
C
19    SLOP1=SLOP2
      IGO=1
C
C     CALCULATE NEW DEPTH
C
      TEMP=SLOP2
      DEPTH=YSTRT+(SLOP1+SLOP2)/2.0*DX
      GO TO 68
   21 IF(ABS(TEMP-SLOP2)-0.00001) 555,555,556
  556 TEMP=SLOP2
      DEPTH=YSTRT+(SLOP1+SLOP2)/2.0*DX
      GO TO 43
555   IF(UPDWN)4,5,5
4     XTOPW=(TOPW(2)-TOPW(1))/REACH*(START+DX)+TOPW(1)
      XAR=(AREA(2)-AREA(1))/REACH*(START+DX)+AREA(1)
      XCO=(CO(2)-CO(1))/REACH*(START+DX)+CO(1)
      XALF=(ALFF(2)-ALFF(1))/REACH*(START+DX)+ALFF(1)
5     WS=(Y3(2,LL2)-Y3(1,LL1))/REACH*(M*DX)+Y3(1,LL1)+DEPTH
55    CONTINUE
C
C     FIND WATER STAGE AT ENDING STATION FOR THIS DEPTH
C
      WS=DEPTH+Y3(2,LL2)
C
C     TRANSFER ENDING STATION DATA TO INITIAL STATION
C
      STATN(1)=STATN(2)
      CRELV(1)=CRELV(2)
      LL(1)=LL(2)
      INDEX=LL(2)
      DO 65 K=1,INDEX
      Y3(1,K)=Y3(2,K)
```

```
      DO 65 M=1,5
      AP(1,K,M)=AP(2,K,M)
      TW(1,K,M)=TW(2,K,M)
 65   CONTINUE
      DO 66 M=1,5
      JCC(1,M)=JCC(2,M)
 66   CONTINUE
C
C     CALCULATE AREA AND VOLUME BETWEEN STATIONS
C
      SREAR=(ZTOP+XTOPW)/2.0*ABS(STATM(2)-STATM(1))/43560.0
      VOLUM=(ZAR+XAR)/2.0*ABS(STATM(2)-STATM(1))/43560.0
      STATM(1)=STATM(2)
C
C     STORE CALCULATED DATA AT THIS STATION
C
      ZSTA        =STATM(2)
      ZWS        =WS
      ZDPTH        =DEPTH
      ZTOP        =XTOPW
      ZAR        =XAR
      ZCO        =XCO
      ZALF=XALF
      ACVOL=ACVOL+VOLUM
      ACARE        =ACARE      +SREAR
      IERR=1
      RETURN
      END
```

APPENDIX 6: E071 - COMPUTER PROGRAM

```
      PROGRAM WSPRF
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SQ(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LL(2)
      DIMENSION ISTA(15),STATM(2),CRELV(2),JCC(2,5),ICC(20,5),SNC(20)
      DIMENSION IBUF(125),IA(20)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,   TOPW,CO,AREA,STATN,LL
      COMMON IA
      COMMON R,E,NT,ALFA,UPDWN,NQ,NS,NST1,NST2,NST,NOST,WS,NRE
      COMMON IERR,IQ,IS,DEPTH,IST,SQ,XFC,SFC,NFC,ICC,SNC,NCC
      EQUIVALENCE (ZSTA,IA(1)),(ZWS,IA(3)),(ZDPTH,IA(5)),(ZTOP,IA(7)),
     1            (ZAR,IA(9)),(ZCO,IA(11)),(ACARE,IA(13)),(ACVOL,IA(15))
     2           ,(SLPL,IA(17)),(SLPR,IA(19))
301   FORMAT(1H0,12HDISCHARGE = ,F10.1)
302   FORMAT(1H0,24HROUGHNESS COEFFICIENTS =,5F10.3)
999   CALL LOCATE(40,88,MMM)
      WRITE(40)MMM
      CALL DOPEN(IBUF,40,20,6)
      IREC=0
C
C     READ WATER SURFACE PROFILE CONTROL DATA
C
      CALL WSRED
C
C     LOOP FOR EACH STAGE
C
      DO 30 IS=1,NS
C
C     SET DISCHARGE AND FRICTION COEFFICIENTS AT INITIAL STATION
C
      DO 10 J=1,5
      FC(J)=XFC(1,J)
      JCC(1,J)=ICC(1,J)
      JCC(2,J)=ICC(1,J)
10    CONTINUE
      IQ=1
C
C     READ INITIAL SECTION DATA AND PRINT HEADINGS
C
      REWIND NT
      READ(NT)NCAAL
C
C     DETERMINE IF TAPE TO BE READ UPSTREAM OR DOWNSTREAM
C
      IF(UPDWN)74,75,75
74    NTAP=NST2-1
      DO 76 K=1,NTAP
      READ(NT)
76    CONTINUE
      GO TO 81
75    IF(NST1-1)81,81,82
82    NTAP=NST1-1
      DO 83 K=1,NTAP
      READ(NT)
83    CONTINUE
81    READ(NT)STATN(1),STATM(1),CRELV(1),NRE,(R(I),E(I),I=1,NRE),LL1,
     1(Y3(1,K),(TW(1,K,M),AP(1,K,M),M=1,5),K=1,LL1)
      WS=SI(IS)
      LL(1)=LL1
      CALL WSTAP
```

```
      JFC=2
      KCC=2
C
C     TRANSFER TO BOTTOM OF LOOP IF ERROR PRESENT
C
      GO TO(14,30),IERR
C
C     DETERMINE SECTION INTERCEPTS FOR INITIAL STATION
C
14    CALL SCINT(WS,NRE,R,E,SLPL    ,SLPR    )
C
C     DETERMINE SECTION CHARACTERISTICS FOR INITIAL STATION
C
      CALL WSCHR(LL(1),DEPTH,Y3,TW,AP,FC,ZTOP,ZCO,ZAR,CRELV(1),JCC,1)
C
C     PRINT AND STORE INITIAL STATION DATA
C
      CALL STAT(ZSTA,ISTA)
      WRITE(61,388)ISTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
 388  FORMAT(1H0,15A1,2F8.2,5E13.6,2E12.5)
      IREC=IREC+1
      CALL DPUT(IBUF,IREC,IA)
C
C     ENTER ITERATION PROCESS FOR THIS CHANNEL
C
C
C     LOOP FOR EACH STATION
C
      DO 40 IST=1,NST
C
C     ENTER INTERPOLATION AND ITERATION PROCESS FOR THIS STATION
C
      IF(UPDWN)77,78,78
77    DO 80 M=1,2
      BACKSPACE NT
80    CONTINUE
78    READ(NT)STATN(2),STATM(2),CRELV(2),NRE,(R(I),E(I),I=1,NRE),LL2,
     1(Y3(2,K),(TW(2,K,M),AP(2,K,M),M=1,5),K=1,LL2)
      LL(2)=LL2
C
C     DETERMINE IF CHANNEL DESIGNATION TO BE CHANGED AT THIS STATION
C
      IF(KCC-NCC)42,42,46
42    IF(ABS(SNC(KCC)-STATN(2))-0.01)43,43,46
43    DO 45 J=1,5
      JCC(2,J)=ICC(KCC,J)
45    CONTINUE
      KCC=KCC+1
46    CALL RCINT(STATM,CRELV,JCC)
      GO TO(949,30),IERR
C
C     CALCULATE SECTION INTERCEPTS AT THIS WATER SURFACE
C
949   CALL SCINT(WS,NRE,R,E,SLPL,SLPR)
      CALL STAT(ZSTA    ,ISTA)
      WRITE(61,388)ISTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
      IREC=IREC+1
      CALL DPUT(IBUF,IREC,IA)
C
C     DETERMINE IF DISCHARGE IS TO BE CHANGED AT THIS STATION
C
      IF(IQ+1-NQ)21,21,12
```

```
21    IF(ABS(SQ(IQ+1)-STATN(1))-0.01)11,11,12
11    IQ=IQ+1
      WRITE(61,301)Q(IQ)
C
C     DETERMINE IF FRICTION COEFFICIENTS TO BE CHANGED AT THIS STATION
C
12    IF(JFC-NFC)22,22,40
22    IF(ABS(SFC(JFC)-STATN(1))-0.01)13,13,40
13    DO 15 J=1,5
      FC(J)=XFC(JFC,J)
15    CONTINUE
      JFC=JFC+1
      WRITE(61,302)FC
40    CONTINUE
30    CONTINUE
      CALL DCLOS(IBUF)
      READ(60,201)IPLOT,HSCAL,VSCAL
201   FORMAT(I5,5X,2F10.3)
      IF(IPLOT)999,999,998
  998 CALL PLOTS(0,0,0)
      CALL WSPLT(NOST,NCAAL,HSCAL,VSCAL,UPDWN)
      CALL PLOT(0.0,0.0,999)
      GO TO 999
      END

      SUBROUTINE SCINT(WS,N,R,E,SLPLT,SLPRT)
      DIMENSION R(1),E(1)
      DO 10 K=1,N
      IF(WS-E(K))10,11,12
10    CONTINUE
      SLPLT=0.0
      GO TO 20
 11   SLPLT=R(K)
      GO TO 20
 2    SLPLT=R(K-1)+(E(K-1)-WS)/(E(K-1)-E(K))*(R(K)-R(K-1))
 0    DO 30 K=1,N
      L=N-K+1
      IF(WS-E(L))30,31,32
 0    CONTINUE
      SLPRT=0.0
      GO TO 99
 1    SLPRT=R(L)
      GO TO 99
 2    SLPRT=R(L)+(WS-E(L))/(E(L+1)-E(L))*(R(L+1)-R(L))
 9    RETURN
      END

      SUBROUTINE WSPLT(NOST,NCAAL,        HSCAL,VSCAL,UPDWN)
      DIMENSION ISTA(15),NCAAL(6)
      DIMENSION IBUF(125),IA(20),MSG(11)
      DIMENSION LCHAR(32),IPL1(15),IPL2(7)
      DATA ((IPL1(I),I=1,5)=4HELEV,4HATIO,4HN IN,4H FEE,4HT    )
      DATA((IPL2(I),I=1,7)=4HWATE,4HR SU,4HRFAC,4HE PR,4HOFIL,4HE FO,
     1 4HR    )
      DATA (MSG=41HSET PEN ON PLAIN PAPER AGAINST RIGHT STOP)
      EQUIVALENCE (STA,IA(1)),(WS,IA(3)),(DEPTH,IA(5))
 )0   FORMAT(1H1,59HPROFILE WILL NOT FIT IN 27 INCHES WITH GIVEN VERTICA
     1L SCALE)
      CALL FACTOR(0.5)
      CALL DOPEN(IBUF,40,20,6)

      DETERMINE MAXIMUM AND MINIMUM STATION VALUES
```

```
C
      CALL DGET(IBUF,1,IA)
      ST1=STA
      CALL DGET(IBUF,NOST,IA)
      ST2=STA
      IF(ST1-ST2)27,28,28
27    SGN=1.0
      GO TO 29
28    SGN=-1.0
C
C     DETERMINE MAXIMUM AND MINIMUM BOTTOM ELEVATION AND WATER SURFACE
C
29    WSMX=-9999.0E30
      WSMN=+9999.0E30
      DO 17 K=1,NOST
      CALL DGET(IBUF,K,IA)
      IF(WS-WSMX)18,18,19
19    WSMX=WS
18    IF((WS-DEPTH)-WSMN)26,17,17
26    WSMN=WS-DEPTH
17    CONTINUE
C
C     DETERMINE IF PLOT WILL FIT ON PLOTTER WITH GIVEN SCALES
C
      XMIN=IFIX(WSMN)-VSCAL
      XMAX=IFIX(WSMX)+VSCAL
      XINCH=(XMAX-XMIN)/VSCAL
      IF(XINCH-27.0)10,10,11
11    WRITE(61,300)
      GO TO 9999
C
C     POSITION PEN, PLOT AND LABEL ELEVATION AXIS
C
10    CALL SETMSG(1,MSG)
      CALL EPLOT(1,3.0,2.0)
      CALL SCALE(1.0,1.0/VSCAL,0.0,0.0)
      CALL EGRID(1,0.0,0.0,VSCAL/2.0,IFIX(XINCH)*2)
      CALL EPLOT(1,0.0,0.0)
      CALL SCALE(1.0,1.0,0.0,0.0)
      Y=-1.05
      YV=XMIN-VSCAL
      N=XINCH+1
      DO 12 K=1,N
      Y=Y+1.0
      YV=YV+VSCAL
      CALL PUTDC(YV,2,LCHAR,1,6)
      CALL ECHAR(-0.70,Y,0.1,0.1,0.0,LCHAR,6)
12    CONTINUE
      CALL A4A1(IPL1,1,5,LCHAR,1)
      CALL ECHAR(-0.90,1.0,0.2,0.2,1.5707,LCHAR,17)
C
C     PLOT AND LABEL STATION AXIS
C
      CALL EPLOT(1,0.0,0.0)
      CALL SCALE(1.0/HSCAL,1.0,ST1*SGN-0.5*HSCAL,0.0)
      DO 13 K=1,NOST
      CALL DGET(IBUF,K,IA)
      CALL EPLOT(2,STA*SGN,0.0)
      CALL EPLOT(1,STA*SGN,0.04)
      CALL EPLOT(2,STA*SGN,-0.04)
      CALL STAT(STA    ,ISTA)
      CALL ECHAR(STA*SGN+0.05*HSCAL,-1.60,0.1,0.1,1.5707,ISTA,15)
```

```
      CALL EPLOT(1,STA*SGN,0.0)
 13   CONTINUE
      CALL A4A1(IPL2,1,7,LCHAR,1)
      CALL MOVE(NCAAL,1,6,LCHAR,27)
      CALL ECHAR(ST1*SGN+HSCAL,-2.0,0.2,0.2,0.0,LCHAR,32)
C
C     PLOT WATER SURFACE PROFILE
C
      CALL EPLOT(1,ST1*SGN,0.0)
      CALL SCALE(1.0/HSCAL,1.0/VSCAL,ST1*SGN,XMIN)
      DO 20 K=1,NOST
      CALL DGET(IBUF,K,IA)
      IF(K-1)24,24,25
 24   CALL EPLOT(1,STA*SGN,WS)
 25   CALL EPLOT(2,STA*SGN,WS)
      CALL PUTDC(WS,2,LCHAR,1,6)
      CALL ECHAR(STA*SGN+0.05*HSCAL,WS   +0.05*VSCAL,0.1,0.1,1.5707,
     1LCHAR,6)
      CALL EPLOT(1,STA*SGN,WS)
 20   CONTINUE
C
C     PLOT BOTTOM ELEVATION PROFILE
C
      DO 30 K=1,NOST
      L=NOST-K+1
      CALL DGET(IBUF,L,IA)
      IF(K-1)34,34,35
 34   CALL EPLOT(1,STA*SGN,WS   -DEPTH    )
      GO TO 36
 35   CALL DASLN(XSTA,XWS-XDP,STA*SGN,WS-DEPTH,0.25,HSCAL)
 36   CALL PUTDC(WS-DEPTH,2,LCHAR,1,6)
      CALL ECHAR(STA*SGN+0.05*HSCAL,WS   -DEPTH    -0.65*VSCAL,0.1,0.1,
     1   1.5707,LCHAR,6)
      XSTA=STA*SGN
      XWS=WS
      XDP=DEPTH
 30   CONTINUE
      CALL EPLOT(1,ST2*SGN+3.0*HSCAL,XMIN)
 999  CALL EPLOT(999,0.0,0.0)
      RETURN
      END

      SUBROUTINE WSTAP
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SQ(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LL(2)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,   TOPW,CO,AREA,STATN,LL
      COMMON ZSTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
      COMMON R,E,NT,ALFA,UPDWN,NQ,NS,NST1,NST2,NST,NOST,WS,NRE
      COMMON IERR,IQ,IS,DEPTH,IST,SQ,XFC,SFC,NFC
 104  FORMAT(1H1,51X,6A1//1H ,33X,11HDISCHARGE =,F9.0,2X,
     1 15HINITIAL STAGE =,F6.2/1H0,43X,22HROUGHNESS COEFFICIENTS)
 5    FORMAT(1H ,41X,14HCLASSIFICATION,I2,3H = ,F7.4)
 2    FORMAT(1H0,18X,5HWATER,14X,3HTOP,30X,2(13H  ACCUMULATED),3X,
     1 18HSECTION INTERCEPTS/1H ,6X,7HSTATION,5X,13HSTAGE   DEPTH,5X
     2 5HWIDTH,8X,4HAREA,6X,24HCONVEYANCE  SURFACE AREA,5X,6HVOLUME,
     3 8X,4HLEFT,6X,5HRIGHT)
 00   FORMAT(1H0,17HINITIAL STAGE OF ,F7.2,27H BELOW BOTTOM ELEVATION OF
     1 ,F7.2)
 01   FORMAT(1H0,17HINITIAL STAGE OF ,F7.2,23H ABOVE TOP ELEVATION OF ,
     1F7.2)
      LL1=LL(1)
```

```
      WRITE(61,304)NCAAL,Q(IQ),WS
      DO 23  JJL=1,5
      IF(FC(JJL))23,23,24
24    WRITE(61,25)JJL,FC(JJL)
23    CONTINUE
      WRITE(61,22)
C
C     DETERMINE IF INITIAL STAGE OUT OF RANGE
C
      IF(WS-Y3(1,LL1))11,11,12
11    WRITE(61,900)WS,Y3(1,LL1)
77    IERR=2
      RETURN
12    IF(WS-Y3(1,1))14,14,15
15    WRITE(61,901)WS,Y3(1,1)
      GO TO 77
14    IERR=1
C
C     FIND DEPTH AT INITIAL STATION
C
      DEPTH=WS-Y3(1,LL1)
C
C     DETERMINE SECTION CHARACTERISTICS AT INITIAL STAGE
C
      ZDPTH   =DEPTH
      ZSTA   =STATN(1)
      ZWS   =WS
      ACARE   =0.0
      ACVOL   =0.0
      RETURN
      END

      SUBROUTINE WSRED
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SQ(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LL(2),ICC(20,5),SNC(20)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,    TOPW,CO,AREA,STATN,LL
      COMMON ZSTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
      COMMON R,E,NT,ALFA,UPDWN,NQ,NS,NST1,NST2,NST,NOST,WS,NRE
      COMMON IERR,IQ,IS,DEPTH,IST,SQ,XFC,SFC,NFC,ICC,SNC,NCC
      NT=11
      READ(60,201)ALFA,UPDWN
201   FORMAT(8F10.3)
      IF(UPDWN)50,60,50
60    CALL EXIT
50    READ(60,202)NS,NQ,NFC,NST1,NST2,NCC
202   FORMAT(6I5)
      READ(60,201)(SI(IS),IS=1,NS)
      DO 10 IQ=1,NQ
10    READ(60,201) SQ(IQ),Q(IQ)
      DO 20 IC=1,NFC
20    READ(60,201)SFC(IC),(XFC(IC,J),J=1,5)
      IF(NCC)1,1,2
2     DO 30 NC=1,NCC
30    READ(60,203)SNC(NC),(ICC(NC,J),J=1,5)
203   FORMAT(F10.3,10I5)
1     NST=NST2-NST1
      NOST=NST+1
      RETURN
      END

      SUBROUTINE WSCHR(INDEX,DEPTH,Y3,TW,AP,FC,TOPW,CO,AREA,CRELV,JCC,I)
```

```
      DIMENSION Y3(2,50),TW(2,50,5),AP(2,50,5),FC(5),JCC(2,5)
      WS=DEPTH+Y3(I,INDEX)
      DO 10 K=2,INDEX
      IF(WS-Y3(I,K))10,11,11
 0    CONTINUE
      STOP
 1    RATIO=(WS-Y3(I,K))/(Y3(I,K-1)-Y3(I,K))
      TOPW=0.0
      CO=0.0
      AREA=0.0
      DO 20 J=1,5
      IF(CRELV+9998.0E30)42,42,41
 1    IF(WS-CRELV)43,43,42
 3    IF(JCC(I,J))20,20,42
 2    IF(FC(J))21,20,21
 1    IF(TW(I,K-1,J))20,20,22
 2    TP=(TW(I,K-1,J)-TW(I,K,J))*RATIO+TW(I,K,J)
      AR=(TP+TW(I,K,J))/2.0*(WS-Y3(I,K))
      IF(K-INDEX)23,24,24
 3    M=INDEX-1
      DO 30 L=K,M
      AR=AR+(TW(I,L,J)+TW(I,L+1,J))/2.0*(Y3(I,L)-Y3(I,L+1))
 0    CONTINUE
 4    WP=(AP(I,K-1,J)-AP(I,K,J))*RATIO+AP(I,K,J)
      TOPW=TOPW+TP
      AREA=AREA+AR
      IF(FC(J))51,52,52
 1    D=AR/TP
      FN=1.5613-1.08471*D+0.490179*D**2-0.124972*D**3+0.0173095*D**4-
     1  0.0012181*D**5+0.0000341199*D**6
      CO=CO+1.486*(AR**(5.0/3.0)/WP**(2.0/3.0))/FN
      GO TO 20
 2    CO=CO+1.486*(AR**(5.0/3.0)/WP**(2.0/3.0))/FC(J)
 0    CONTINUE
      RETURN
      END

      SUBROUTINE RCINT(STATM,CRELV,JCC)
      DIMENSION Q(40),SI(20),NCAAL(6),FC(5),XFC(20,5),SQ(40),SFC(20)
      DIMENSION Y3(2,50),AP(2,50,5),TW(2,50,5),R(70),E(70)
      DIMENSION TOPW(2),CO(2),AREA(2),STATN(2),LL(2)
      DIMENSION ICC(20,5),SNC(20),STATM(2),CRELV(2),JCC(2,5)
      COMMON Q,SI,NCAAL,FC,Y3,TW,AP,   TOPW,CO,AREA,STATN,LL
      COMMON ZSTA,ZWS,ZDPTH,ZTOP,ZAR,ZCO,ACARE,ACVOL,SLPL,SLPR
      COMMON R,E,NT,ALFA,UPDWN,NQ,NS,NST1,NST2,NST,NOST,WS,NRE
      COMMON IERR,IQ,IS,DEPTH,IST,SQ,XFC,SFC,NFC,ICC,SNC,NCC
70    FORMAT(1H0,38HUNABLE TO CONVERGE AFTER 20 ITERATIONS)
02    FORMAT(1H0,18HDEPTH OUT OF RANGE)
68    FORMAT(1H0,7HDEPTH =,F6.2/1H ,20HITERATION INTERVAL =,I3/1H ,
     1 25HINTERPOLATION INCREMENT =,F10.2/1H ,20HREACH BOTTOM SLOPE =,
     2 E15.7/1H ,28HDISTANCE FROM LAST STATION =,F10.3/1H ,11HTOP WIDTH
     3=,E15.7/1H ,12HCONVEYANCE =,E15.7/1H ,6HAREA =,E15.7)
64    FORMAT(1H0,37HSUPER-CRITICAL FLOW AT A DISTANCE OF ,F10.3,
     1 18H PAST LAST STATION/1H ,11HTOP WIDTH =,E13.6,7H AREA =,E13.6,
     2 13H CONVEYANCE =,E13.6)
      LL1=LL(1)
      LL2=LL(2)

      DETERMINE REACH CONTROL DATA

      REACH=ABS(STATN(1)-STATN(2))
      DX=REACH/10.0
```

```
      IF(UPDWN)532,532,533
533   SLOPE=(Y3(2,LL2)-Y3(1,LL1))/REACH
      GO TO 534
532   SLOPE=(Y3(1,LL1)-Y3(2,LL2))/REACH
C
C     ENTER ITERATION PROCESS FOR THIS REACH
C
534   DO 55 M=1,10
      ICOUT=0
      START=FLOAT(M   )*DX
      IF(UPDWN)11,12,12
11    START=START-DX
12    YSTRT=DEPTH
      IGO=0
C
C     CHECK FOR EXCESS NUMBER OF ITERATIONS
C
43    ICOUT=ICOUT+1
      IF(ICOUT-20)68,68,969
969   MO=1
C
C     ERROR DISCOVERED - PRINT DATA TO THIS POINT WITH PERTINENT DATA
C
61    GO TO(1,2),MO
1     WRITE(61,970)
      GO TO 3
2     WRITE(61,902)
3     WRITE(61,968)DEPTH,M,DX,SLOPE,START,XTOPW,XCO,XAR
      IERR=2
      RETURN
C
C     CALCULATE INITIAL AND ENDING STATION TOP WIDTHS, AREAS AND
C     CONVEYANCES FOR INTERMEDIATE POINT CALCULATIONS
C
68    DO 90 I=1,2
C
C     CHECK FOR ALLOWABLE RANGE OF DEPTH
C
      INDEX=LL(I)
      IF(DEPTH)44,44,45
45    IF((DEPTH+Y3(I,INDEX))-Y3(I,1))46,46,44
44    MO=2
      GO TO 61
46    CALL WSCHR(LL(I),DEPTH,Y3,TW,   AP,FC,TOPW(I),CO(I),AREA(I),
     1CRELV(I),JCC,I)
90    CONTINUE
C
C     FIND TOP WIDTH, AREA AND CONVEYANCE AT INTERMEDIATE POINT
C
      XTOPW=(TOPW(2)-TOPW(1))/REACH*START+TOPW(1)
      XAR=(AREA(2)-AREA(1))/REACH*START+AREA(1)
      XCO=(CO(2)-CO(1))/REACH*START+CO(1)
C
C     CALCULATE SLOPE AT THIS DEPTH
C
      SE=(Q(IQ)/XCO)**2
      FROD2=(ALFA*Q(IQ)**2*XTOPW)/32.2/XAR/XAR/XAR
      IF(FROD2-1.0)224,225,225
224   SLOP2=(-1.0*SIGN(1.0,UPDWN))*(SLOPE-SE)/(1.0-FROD2)
      GO TO 226
225   FROD2=0.01
      WRITE(61,964)START,XTOPW,XAR,XCO
```

```
      GO TO 224
226   IF(IGO)19,19,21
C
C     SAVE CALCULATED SLOPE OF FIRST ITERATION
C
19    SLOP1=SLOP2
      IGO=1
C
C     CALCULATE NEW DEPTH
C
21    YLAST=DEPTH
      DEPTH=YSTRT+(SLOP1+SLOP2)/2.0*DX
      IF(ABS(YLAST-DEPTH)-0.001)555,555,43
555   IF(UPDWN)4,5,5
4     XTOPW=(TOPW(2)-TOPW(1))/REACH*(START+DX)+TOPW(1)
      XAR=(AREA(2)-AREA(1))/REACH*(START+DX)+AREA(1)
      XCO=(CO(2)-CO(1))/REACH*(START+DX)+CO(1)
5     WS=(Y3(2,LL2)-Y3(1,LL1))/REACH*(M*DX)+Y3(1,LL1)+DEPTH
55    CONTINUE
C
C     FIND WATER STAGE AT ENDING STATION FOR THIS DEPTH
C
      WS=DEPTH+Y3(2,LL2)
C
C     TRANSFER ENDING STATION DATA TO INITIAL STATION
C
      STATN(1)=STATN(2)
      CRELV(1)=CRELV(2)
      LL(1)=LL(2)
      INDEX=LL(2)
      DO 65 K=1,INDEX
      Y3(1,K)=Y3(2,K)
      DO 65 M=1,5
      AP(1,K,M)=AP(2,K,M)
      TW(1,K,M)=TW(2,K,M)
65    CONTINUE
      DO 66 M=1,5
      JCC(1,M)=JCC(2,M)
66    CONTINUE
C
C     CALCULATE AREA AND VOLUME BETWEEN STATIONS
C
      SRFAR=(ZTOP+XTOPW)/2.0*ABS(STATM(2)-STATM(1))/43560.0
      VOLUM=(ZAR+XAR)/2.0*ABS(STATM(2)-STATM(1))/43560.0
      STATM(1)=STATM(2)
C
C     STORE CALCULATED DATA AT THIS STATION
C
      ZSTA        =STATN(2)
      ZWS       =WS
      ZDPTH        =DEPTH
      ZTOP        =XTOPW
      ZAR       =XAR
      ZCO       =XCO
      ACVOL=ACVOL+VOLUM
      ACAPE        =ACARE      +SRFAR
      IERR=1
      RETURN
      END
```

ANNEX A: EXAMPLE OF E070 OUTPUT

```
CANAL C3AMOE

ELEVATION LIMIT =    130.00

********** CHANNEL STATION =      0 + 00.00  =  FLOOD PLAIN STATION =      0 + 00.00  **********

CRITICAL ELEVATION DOES NOT APPLY

RANGES FOR COEFFICIENT CLASSIFICATION NO. 1 =
           0-   990.00,    1190.00- 4420.00,    4770.00- 20000.00,

RANGES FOR COEFFICIENT CLASSIFICATION NO. 2 =
       990.00- 1190.00,    4420.00- 4770.00,

INPUT RANGES AND ELEVATIONS
    100.00      23.40
    800.00      20.10
    990.00      21.80
   1010.00      10.90
   1060.00      10.70
   1100.00      13.70
   1120.00      13.30
   1180.00      18.10
   1190.00      25.10
   1230.00      22.40
   1350.00      22.00
   1400.00      20.00
   3090.00      20.00
   3100.00      33.00
   4300.00      33.00
   4310.00      20.00
   4420.00      20.00
   4482.00     -11.00
   4707.00     -11.00
   4770.00      20.30
   5400.00      21.90

RE-DEFINED SECTION RANGES AND ELEVATIONS
     23.40     100.00
    100.00      23.40
    800.00      20.10
    990.00      21.90
   1010.00      10.90
   1060.00      10.70
   1100.00      13.70
   1120.00      13.30
   1130.00      18.10
   1190.00      25.10
   1230.00      22.40
   1350.00      22.00
   1400.00      20.00
   1400.00      20.00
   3090.00      20.00
   3100.00      33.00
   3100.00      33.00
   4330.00      33.00
   4310.00      20.00
   4310.00      20.00
   4420.00      20.00
   4482.00     -11.00
   4707.00     -11.00
   4770.00      20.30
```

5400.00	21.90
5478.10	100.00

TOP WIDTHS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	4904.70200	550.00000	0	0	0
33.00	4770.70027	550.00000	0	0	0
33.00	3570.69999	550.00000	0	0	0
25.10	3542.74625	550.00000	0	0	0
23.40	3511.54562	547.57143	0	0	0
22.40	3282.07112	546.14286	0	0	0
22.00	3076.20724	545.57143	0	0	0
21.90	3052.24127	545.42857	0	0	0
21.80	2999.00033	545.28571	0	0	0
20.30	1872.73872	540.39056	0	0	0
20.10	1802.65395	539.33532	0	0	0
20.00	1800.00000	538.80770	0	0	0
20.00	0	538.80697	0	0	0
18.10	0	524.98289	0	0	0
13.70	0	444.25327	0	0	0
13.30	0	411.58588	0	0	0
10.90	0	365.54654	0	0	0
10.70	0	312.07732	0	0	0
-11.00	0	225.00000	0	0	0

WETTED PERIMETERS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	4981.73209	569.95743	0	0	0
33.00	4792.22616	569.95743	0	0	0
33.00	3592.22565	569.95743	0	0	0
25.10	3549.94765	569.95743	0	0	0
23.40	3515.60724	566.99298	0	0	0
22.40	3284.69765	565.24918	0	0	0
22.00	3073.27256	564.55167	0	0	0
21.90	3054.16446	564.37729	0	0	0
21.80	2999.92265	564.20291	0	0	0
20.30	1873.64173	558.45271	0	0	0
20.10	1802.75453	557.23652	0	0	0
20.00	1800.00020	556.62842	0	0	0
20.00	0	556.62759	0	0	0
18.10	0	540.82605	0	0	0
13.70	0	456.72806	0	0	0
13.30	0	423.73048	0	0	0
10.90	0	375.86482	0	0	0
10.70	0	322.29355	0	0	0
-11.00	0	225.00000	0	0	0

********** CHANNEL STATION = 83 + 50.00 = FLOOD PLAIN STATION = 83 + 50.00 **********

CRITICAL ELEVATION DOES NOT APPLY

RANGES FOR COEFFICIENT CLASSIFICATION NO. 1 =
0- 1800.00, 2150.00- 20000.00,

RANGES FOR COEFFICIENT CLASSIFICATION NO. 2 =
1800.00- 2150.00,

INPUT RANGES AND ELEVATIONS

160.00	25.00
200.00	22.40
300.00	20.90
450.00	21.10
500.00	16.30
600.00	21.00

[illegible]	[illegible]
1600.00	22.30
1700.00	21.20
1800.00	21.20
1862.00	-10.10
2087.00	-10.10
2150.00	20.30
2250.00	20.30
2260.00	33.00
4900.00	29.10

RE-DEFINED SECTION RANGES AND ELEVATIONS

85.00	100.00
160.00	25.00
200.00	22.40
300.00	20.90
450.00	21.10
500.00	16.30
600.00	21.00
1300.00	20.70
1600.00	22.30
1700.00	21.20
1700.00	21.20
1800.00	21.20
1862.00	-10.10
2087.00	-10.10
2150.00	20.30
2150.00	20.30
2250.00	20.30
2260.00	33.00
4000.00	29.10
4070.90	100.00

TOP WIDTHS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	3635.90200	350.00000	0	0	0
33.00	3501.99016	350.00000	0	0	0
29.10	1751.02919	350.00000	0	0	0
25.00	1743.70079	350.00000	0	0	0
22.40	1701.65354	350.00000	0	0	0
22.30	1694.90814	350.00000	0	0	0
21.20	1314.45866	350.00000	0	0	0
21.20	1214.43317	349.99980	0	0	0
21.10	1188.96325	349.80192	0	0	0
21.00	1087.42618	349.60383	0	0	0
20.90	750.42812	349.40575	0	0	0
20.70	239.76532	349.00958	0	0	0
20.30	226.77305	348.21725	0	0	0
20.30	126.76988	348.21705	0	0	0
16.30	0	332.00464	0	0	0
-10.10	0	225.00000	0	0	0

WETTED PERIMETERS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	3702.95055	364.40387	0	0	0
33.00	3513.44463	364.40387	0	0	0
29.10	1757.44542	364.40387	0	0	0
25.00	1746.42866	364.40387	0	0	0
22.40	1703.03499	364.40387	0	0	0
22.30	1696.24029	364.40387	0	0	0
21.20	1315.23965	364.40387	0	0	0
21.20	1215.21401	364.40365	0	0	0
21.10	1189.69459	364.18198	0	0	0
21.00	1088.10311	363.96008	0	0	0

20.90	751.04826	363.73819	0	0	0
20.70	240.27353	363.29440	0	0	0
20.30	227.05856	362.40683	0	0	0
20.30	127.05538	362.40661	0	0	0
16.30	0	344.32718	0	0	0
-10.10	0	225.00000	0	0	0

********** CHANNEL STATION = 163 + 00.00 = FLOOD PLAIN STATION = 163 + 00.00 **********

CRITICAL ELEVATION DOES NOT APPLY

RANGES FOR COEFFICIENT CLASSIFICATION NO. 1 =
0- 760.00, 900.00- 1030.00, 1150.00- 3860.00, 4215.00- 20000.00,

RANGES FOR COEFFICIENT CLASSIFICATION NO. 2 =
760.00- 900.00, 1030.00- 1150.00, 3860.00- 4215.00,

INPUT RANGES AND ELEVATIONS

100.00	23.10
200.00	21.70
760.00	21.60
800.00	15.30
850.00	17.60
900.00	22.50
1030.00	23.00
1050.00	15.10
1100.00	14.50
1150.00	22.60
1900.00	22.90
1920.00	19.10
1950.00	22.10
2000.00	22.10
2080.00	17.10
2100.00	22.20
2250.00	22.10
2260.00	33.00
3750.00	33.00
3760.00	22.70
3860.00	22.50
3925.00	-9.30
4150.00	-9.30
4215.00	22.90
4250.00	26.10
4300.00	22.60
5600.00	21.60

RE-DEFINED SECTION RANGES AND ELEVATIONS

23.10	100.00
100.00	23.10
200.00	21.70
760.00	21.60
800.00	15.30
850.00	17.60
900.00	22.50
1030.00	23.00
1050.00	15.10
1100.00	14.50
1150.00	22.60
1900.00	22.90
1920.00	19.10
1950.00	22.10
1950.00	22.10

2000.00	22.10
2080.00	17.10
2100.00	22.20
2250.00	22.10
2260.00	33.00
2260.00	33.00
3750.00	33.00
3760.00	22.70
3860.00	22.50
3925.00	-9.30
4150.00	-9.30
4215.00	22.90
4250.00	26.10
4300.00	22.60
5600.00	21.60
5678.40	100.00

TOP WIDTHS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	5940.30200	615.00000	0	0	0
33.00	4906.30027	615.00000	0	0	0
33.00	3416.29999	615.00000	0	0	0
26.10	3389.47979	615.00000	0	0	0
23.10	3302.13616	615.00000	0	0	0
23.00	3292.18215	615.00000	0	0	0
22.90	3256.22814	614.74684	0	0	0
22.70	2685.45499	613.83678	0	0	0
22.60	2350.16549	613.38175	0	0	0
22.50	2136.30459	612.30944	0	0	0
22.20	1722.72193	605.41807	0	0	0
22.10	1434.44875	603.12395	0	0	0
22.10	1384.32799	603.11865	0	0	0
21.75	821.42343	593.93246	0	0	0
21.60	127.80495	591.63534	0	0	0
19.10	39.84314	518.33426	0	0	0
17.60	9.96978	474.35361	0	0	0
17.10	0	453.92587	0	0	0
15.30	0	383.38600	0	0	0
15.10	0	377.83258	0	0	0
14.50	0	321.69128	0	0	0
-9.30	0	225.00000	0	0	0

WETTED PERIMETERS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	5115.36036	632.84507	0	0	0
33.00	4925.85452	632.84507	0	0	0
33.00	3435.85386	632.84507	0	0	0
26.10	3397.35724	632.84507	0	0	0
23.10	3304.70797	632.84507	0	0	0
23.00	3294.61752	632.84507	0	0	0
22.90	3258.52689	632.57287	0	0	0
22.70	2687.47074	631.57792	0	0	0
22.60	2352.08194	631.08944	0	0	0
22.50	2138.12519	629.95764	0	0	0
22.20	1724.25581	622.83067	0	0	0
22.10	1435.89462	620.45502	0	0	0
22.10	1385.75369	620.45264	0	0	0
21.70	922.56026	610.95240	0	0	0
21.60	128.87124	608.57674	0	0	0
19.10	40.15656	533.11669	0	0	0
17.60	10.03914	487.84965	0	0	0
17.10	0	466.99406	0	0	0
15.30	0	391.94634	0	0	0
15.10	0	389.24563	0	0	0

14.50	0	332.77307	0	0	0
-9.30	0	225.00000	0	0	0

********** CHANNEL STATION = 231 + 00.00 = FLOOD PLAIN STATION = 231 + 00.00 **********

CRITICAL ELEVATION DOES NOT APPLY

RANGES FOR COEFFICIENT CLASSIFICATION NO. 1 =
0- 790.00, 1000.00- 2020.00, 2370.00- 2840.00, 3500.00- 20000.00,

RANGES FOR COEFFICIENT CLASSIFICATION NO. 2 =
790.00- 1000.00, 2020.00- 2370.00, 2840.00- 3500.00,

INPUT RANGES AND ELEVATIONS

100.00	25.30
450.00	23.30
550.00	20.80
790.00	24.30
820.00	14.30
850.00	14.30
900.00	23.80
1000.00	26.80
1100.00	28.80
1110.00	34.00
1910.00	34.00
1920.00	24.10
2000.00	24.00
2020.00	24.40
2085.00	-8.50
2310.00	-8.50
2370.00	24.70
2840.00	24.30
3000.00	23.90
3330.00	18.00
3500.00	23.60
5200.00	23.70
5400.00	25.30

RE-DEFINED SECTION RANGES AND ELEVATIONS

25.30	100.00
100.00	25.30
450.00	23.30
550.00	20.30
790.00	24.30
820.00	14.30
820.00	14.30
850.00	14.30
900.00	23.80
1000.00	26.80
1100.00	28.80
1110.00	34.00
1110.00	34.00
1910.00	34.00
1920.00	24.10
2000.00	24.00
2020.00	24.40
2085.00	-8.50
2310.00	-8.50
2370.00	24.70
2840.00	24.30
3000.00	23.90
3330.00	18.00

```
  3500.00     23.60
  5200.00     23.70
  5400.00     25.30
  5474.70    100.00

TOP WIDTHS BY  N  CLASSIFICATION AT EACH DISTINCT ELEVATION
   100.00        4229.40700        1220.00000        0        0        0
    34.00        4097.40023        1220.00000        0        0        0
    34.00        3297.39974        1220.00000        0        0        0
    28.80        3271.74757        1220.00000        0        0        0
    26.80        3165.72731        1220.00000        0        0        0
    25.30        3161.21212        1170.00000        0        0        0
    24.70        2990.60606        1150.00000        0        0        0
    24.40        2537.80303        1139.45783        0        0        0
    24.30        2385.20202        1135.74621        0        0        0
    24.10        2301.28571        1047.72296        0        0        0
    24.00        2179.42857        1003.71133        0        0        0
    23.90        2142.57143         959.69971        0        0        0
    23.80        2105.71429         950.09486        0        0        0
    23.70        2068.85714         943.29704        0        0        0
    23.60         344.50000         936.49921        0        0        0
    23.30         271.42857         906.99858        0        0        0
    20.80                 0         661.16004        0        0        0
    18.00                 0         385.82087        0        0        0
    14.30                 0         341.25041        0        0        0
    14.30                 0         311.25003        0        0        0
    -8.50                 0         225.00000        0        0        0

WETTED PERIMETERS BY  N  CLASSIFICATION AT EACH DISTINCT ELEVATION
   100.00        4296.72094        1239.13267        0        0        0
    34.00        4119.04350        1239.13267        0        0        0
    34.00        3310.04276        1239.13267        0        0        0
    28.80        3276.67313        1239.13267        0        0        0
    26.80        3168.15349        1239.13267        0        0        0
    25.30        3161.77876        1189.11017        0        0        0
    24.70        2980.92182        1169.10117        0        0        0
    24.40        2537.99323        1158.47704        0        0        0
    24.30        2385.34936        1154.71423        0        0        0
    24.10        2301.34597        1066.55590        0        0        0
    24.00        2179.48635        1022.47673        0        0        0
    23.90        2142.62779         978.39757        0        0        0
    23.80        2105.76924         968.72441        0        0        0
    23.70        2068.91068         961.85036        0        0        0
    23.60         344.55252         954.97631        0        0        0
    23.30         271.47804         925.24207        0        0        0
    20.80                 0         677.45672        0        0        0
    18.00                 0         399.93713        0        0        0
    14.30                 0         352.57940        0        0        0
    14.30                 0         322.57887        0        0        0
    -8.50                 0         225.00000        0        0        0

********** CHANNEL STATION =    301 + 00.00   =  FLOOD PLAIN STATION =    301 + 00.00  **********

CRITICAL ELEVATION DOES NOT APPLY

RANGES FOR COEFFICIENT CLASSIFICATION NO. 1 =
          0-   150.00,      515.00-  3650.00,     3990.00- 20000.00,

RANGES FOR COEFFICIENT CLASSIFICATION NO. 2 =
      150.00-   515.00,     3650.00-  3990.00,

INPUT RANGES AND ELEVATIONS
```

100.00	27.00
150.00	26.70
220.00	-8.10
445.00	-8.10
515.00	25.50
615.00	25.20
620.00	33.00
2115.00	33.00
2120.00	26.40
2300.00	28.00
2350.00	25.20
2600.00	25.60
2680.00	21.40
2850.00	26.70
3000.00	20.50
3080.00	27.30
3150.00	22.00
3650.00	28.50
3730.00	17.60
3850.00	14.50
3950.00	18.00
3990.00	30.00
4050.00	24.60
4900.00	24.60
5000.00	26.10

RE-DEFINED SECTION RANGES AND ELEVATIONS

27.00	100.00
100.00	27.00
150.00	26.70
220.00	-8.10
445.00	-8.10
515.00	25.50
615.00	25.20
620.00	33.00
620.00	33.00
2115.00	33.00
2120.00	26.40
2300.00	28.00
2350.00	25.20
2600.00	25.60
2680.00	21.40
2850.00	26.70
3000.00	20.50
3080.00	27.30
3150.00	22.00
3650.00	28.50
3730.00	17.60
3850.00	14.50
3950.00	18.00
3990.00	30.00
4050.00	24.60
4900.00	24.60
5000.00	26.10
5073.90	100.00

TOP WIDTHS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	4341.90200	705.00000	0	0	0
33.00	4207.90018	705.00000	0	0	0
33.00	2712.89984	705.00000	0	0	0
30.00	2702.70429	705.00000	0	0	0

28.50	2680.93968	700.00000	0	0	0
28.00	2635.22327	694.66361	0	0	0
27.30	2479.97030	687.19266	0	0	0
27.00	2405.94164	683.99083	0	0	0
26.70	2282.21298	680.78899	0	0	0
26.40	2191.60361	676.98371	0	0	0
26.10	2134.97152	673.17842	0	0	0
25.60	2007.75137	666.83629	0	0	0
25.50	1917.90258	665.56786	0	0	0
25.20	1548.35623	661.13758	0	0	0
24.60	1395.36236	652.27701	0	0	0
24.60	545.34463	652.27553	0	0	0
22.00	84.61124	613.88122	0	0	0
21.40	32.34243	605.02066	0	0	0
20.50	0	591.72981	0	0	0
18.00	0	554.81078	0	0	0
17.60	0	538.80850	0	0	0
14.50	0	317.54310	0	0	0
-8.10	0	225.00000	0	0	0

WETTED PERIMETERS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	4411.49748	723.42116	0	0	0
33.00	4221.98159	723.42116	0	0	0
33.00	2726.98095	723.42116	0	0	0
30.00	2711.16900	723.42116	0	0	0
28.50	2696.52873	718.20101	0	0	0
28.00	2639.85052	712.75732	0	0	0
27.30	2483.22833	705.13617	0	0	0
27.00	2408.58879	701.86996	0	0	0
26.70	2284.37262	698.60375	0	0	0
26.40	2193.26576	694.66364	0	0	0
26.10	2136.28661	690.72352	0	0	0
25.60	2008.69133	684.15666	0	0	0
25.50	1918.76488	682.84329	0	0	0
25.20	1548.98499	678.20990	0	0	0
24.60	1395.87009	668.94313	0	0	0
24.60	545.85225	668.94159	0	0	0
22.00	84.73095	628.78711	0	0	0
21.40	32.41920	619.52034	0	0	0
20.50	0	605.62018	0	0	0
18.00	0	567.00862	0	0	0
17.60	0	550.78725	0	0	0
14.50	0	327.99405	0	0	0
-8.10	0	225.00000	0	0	0

********** CHANNEL STATION = 348 + 50.00 = FLOOD PLAIN STATION = 348 + 50.00 **********

CRITICAL ELEVATION DOES NOT APPLY

RANGES FOR COEFFICIENT CLASSIFICATION NO. 1 =
0- 100.00. 200.00- 840.00. 920.00- 3300.00. 3655.00- 20000.00.

RANGES FOR COEFFICIENT CLASSIFICATION NO. 2 =
100.00- 200.00. 840.00- 920.00. 3300.00- 3655.00.

INPUT RANGES AND ELEVATIONS

80.00	29.40
100.00	19.40
200.00	24.30
500.00	25.30
840.00	24.40
850.00	20.40

920.00	26.40
1800.00	26.40
1900.00	34.00
3200.00	34.00
3210.00	24.70
3300.00	26.40
3365.00	-7.30
3590.00	-7.30
3655.00	26.00
4200.00	24.20
4600.00	15.20
4750.00	24.20
5200.00	26.50

RE-DEFINED SECTION RANGES AND ELEVATIONS

9.40	100.00
80.00	29.40
100.00	19.40
200.00	24.30
500.00	25.30
840.00	24.40
850.00	20.40
920.00	26.40
920.00	26.40
1800.00	26.40
1900.00	34.00
1900.00	34.00
3200.00	34.00
3210.00	24.70
3300.00	26.40
3365.00	-7.30
3590.00	-7.30
3655.00	26.00
4200.00	24.20
4600.00	15.20
4750.00	24.20
5200.00	26.50
5273.50	100.00

TOP WIDTHS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	4729.10200	535.00000	0	0	0
34.00	4597.10017	535.00000	0	0	0
34.00	3297.09854	535.00000	0	0	0
29.40	3222.42749	535.00000	0	0	0
26.50	3172.45127	535.00000	0	0	0
26.40	3151.26274	535.00000	0	0	0
26.40	2271.23757	534.99864	0	0	0
26.00	2170.59529	529.56182	0	0	0
25.30	1782.48281	518.67864	0	0	0
24.70	1043.14831	509.35020	0	0	0
24.40	689.68599	504.68598	0	0	0
24.30	609.64299	502.88124	0	0	0
24.20	559.60000	499.03568	0	0	0
20.40	319.77778	352.90453	0	0	0
19.40	256.66667	329.61563	0	0	0
15.20	0	312.31655	0	0	0
-7.30	0	225.00000	0	0	0

WETTED PERIMETERS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	4795.49364	552.39720	0	0	0
34.00	4608.81616	552.39720	0	0	0
34.00	3308.81431	552.39720	0	0	0

29.40	3228.34969	552.39720	0	0	0
26.50	3175.23755	552.39720	0	0	0
26.40	3153.98264	552.39720	0	0	0
26.40	2273.95681	552.39581	0	0	0
26.00	2173.05811	546.84438	0	0	0
25.30	1784.49564	535.59171	0	0	0
24.70	1044.77363	525.94656	0	0	0
24.40	691.23933	521.12398	0	0	0
24.30	611.17114	519.24720	0	0	0
24.20	561.10412	515.32715	0	0	0
20.40	320.22823	366.36534	0	0	0
19.40	256.43983	341.56689	0	0	0
15.20	0	323.23053	0	0	0
-7.30	0	225.00000	0	0	0

********** CHANNEL STATION = 401 + 00.00 = FLOOD PLAIN STATION = 401 + 00.00 **********

CRITICAL ELEVATION DOES NOT APPLY

RANGES FOR COEFFICIENT CLASSIFICATION NO. 1 =
0- 2230.00, 2500.00- 4020.00, 4380.00- 20000.00,

RANGES FOR COEFFICIENT CLASSIFICATION NO. 2 =
2230.00- 2500.00, 4020.00- 4380.00,

INPUT RANGES AND ELEVATIONS

100.00	28.10
200.00	25.90
1700.00	25.40
1880.00	21.00
1950.00	25.70
2200.00	27.00
2230.00	29.10
2250.00	17.80
2320.00	18.00
2420.00	27.40
2500.00	27.60
2510.00	35.00
3800.00	35.00
3810.00	27.50
4020.00	27.50
4065.00	0
4315.00	0
4380.00	25.00
4650.00	25.90
4750.00	17.80
4800.00	29.80
5600.00	27.60

RE-DEFINED SECTION RANGES AND ELEVATIONS

28.10	100.00
100.00	28.10
200.00	25.90
1700.00	25.40
1880.00	21.00
1950.00	25.70
2200.00	27.00
2230.00	29.10
2250.00	17.80
2320.00	18.00
2420.00	27.40
2500.00	27.60

2510.00	35.00
2510.00	35.00
3800.00	35.00
3810.00	27.50
3810.00	27.50
4020.00	27.50
4065.00	0
4315.00	0
4380.00	25.00
4650.00	25.90
4750.00	17.80
4800.00	29.80
5600.00	27.60
5672.40	100.00

TOP WIDTHS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	5014.30200	630.00000	0	0	0
35.00	4884.30020	630.00000	0	0	0
35.00	3594.29973	630.00000	0	0	0
29.80	3569.93969	630.00000	0	0	0
29.10	3309.19827	630.00000	0	0	0
28.10	2922.42482	628.23009	0	0	0
27.60	2706.81082	627.34513	0	0	0
27.50	2700.28683	587.16814	0	0	0
27.50	2490.28041	587.12780	0	0	0
27.40	2483.89610	546.82751	0	0	0
27.00	2458.33333	541.20968	0	0	0
25.90	2192.21154	525.76065	0	0	0
25.70	1490.44753	522.95174	0	0	0
25.40	491.02574	518.73837	0	0	0
25.00	342.09972	513.12054	0	0	0
21.00	52.83951	446.54225	0	0	0
18.00	3.30247	396.60853	0	0	0
17.80	0	325.40727	0	0	0
0	0	250.00000	0	0	0

WETTED PERIMETERS BY N CLASSIFICATION AT EACH DISTINCT ELEVATION

100.00	5081.07722	645.79237	0	0	0
35.00	4897.22818	645.79237	0	0	0
35.00	3607.22746	645.79237	0	0	0
29.80	3575.11169	645.79237	0	0	0
29.10	3313.24242	645.79237	0	0	0
28.10	2924.82279	643.75949	0	0	0
27.60	2708.58732	642.74305	0	0	0
27.50	2702.01353	602.53964	0	0	0
27.50	2492.00703	602.49924	0	0	0
27.40	2485.60631	562.14445	0	0	0
27.00	2459.97783	556.29013	0	0	0
25.90	2193.71093	549.19075	0	0	0
25.70	1491.91428	537.26359	0	0	0
25.40	492.43426	532.87285	0	0	0
25.00	343.42576	527.01853	0	0	0
21.00	53.34752	457.33262	0	0	0
18.00	3.33422	405.06819	0	0	0
17.80	0	333.72065	0	0	0
0	0	250.00000	0	0	0

ANNEX B: EXAMPLE OF E081 OUTPUT

C3BMED

DISCHARGE = 19822. INITIAL STAGE = 23.04

ROUGHNESS COEFFICIENTS
CLASSIFICATION 1 = .7000
CLASSIFICATION 2 = .0300

STATION	WATER STAGE	DEPTH	TOP WIDTH	AREA	CONVEYANCE	ACCUMULATED SURFACE AREA	ACCUMULATED VOLUME	SECTION INTERCEPTS LEFT	RIGHT	ALPHA
0 + 00.00	23.04	34.54	3.976382E 03	2.001740E 04	4.453750E 06	0	0	1.76364E 02	5.40114E 03	1.00
83 + 50.00	23.21	33.31	2.064874E 03	1.370174E 04	4.319575E 06	5.790230E 02	3.231805E 03	1.87610E 02	2.25248E 03	1.00
163 + 00.00	23.39	32.59	3.925915E 03	1.517529E 04	3.665293E 06	1.125703E 03	5.866934E 03	9.97050E 01	5.60180E 03	1.00
231 + 00.00	23.64	32.14	2.027601E 03	1.166385E 04	2.858924E 06	1.590394E 03	7.961817E 03	3.89953E 02	4.23317E 03	1.00
301 + 00.00	23.90	32.00	1.063738E 03	1.174019E 04	3.676447E 06	1.838780E 03	9.842307E 03	1.55627E 02	3.96968E 03	1.00
348 + 50.00	24.06	31.36	1.044193E 03	1.169875E 04	3.194601E 06	1.953710E 03	1.112026E 04	9.06844E 01	4.74763E 03	1.00
401 + 00.00	24.20	24.26	7.839260E 02	8.594975E 03	2.460825E 06	2.063875E 03	1.234319E 04	1.74915E 03	4.77666E 03	1.00

ANNEX C: EXAMPLE OF E071 OUTPUT

C38MFD

DISCHARGE = 19822. INITIAL STAGE = 23.04

ROUGHNESS COEFFICIENTS
CLASSIFICATION 1 = .7000
CLASSIFICATION 2 = .0300

STATION	WATER STAGE	DEPTH	TOP WIDTH	AREA	CONVEYANCE	ACCUMULATED SURFACE AREA	ACCUMULATED VOLUME	SECTION INTERCEPTS LEFT	SECTION INTERCEPTS RIGHT
0 + 00.00	23.04	34.04	3.976382E 03	2.001740E 04	4.453750E 06	0	0	1.76364E 02	5.40114E 03
93 + 50.00	23.21	33.31	2.064867E 03	1.370086E 04	4.319461E 06	5.790223E 02	3.231721E 03	1.87615E 02	2.25248E 03
163 + 00.00	23.40	32.70	3.925968E 03	1.518241E 04	3.665935E 06	1.125707E 03	5.867419E 03	9.97031E 01	5.60180E 03
231 + 00.00	23.65	32.15	2.146409E 03	1.167818E 04	2.860706E 06	1.599675E 03	7.963975E 03	3.88701E 02	4.35476E 03
301 + 00.00	23.90	32.00	1.063799E 03	1.174053E 04	3.676540E 06	1.857612E 03	9.845643E 03	1.55626E 02	3.96968E 03
348 + 50.00	24.06	31.36	1.044379E 03	1.170065E 04	3.194825E 06	1.972555E 03	1.112371E 04	9.06807E 01	4.74766E 03
401 + 00.00	24.20	24.20	7.840974E 02	8.596486E 03	2.461215E 06	2.082742E 03	1.234686E 04	1.74907E 03	4.77667E 03