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COMPUTER APPLICATIONS (G 900)

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G 900 COMPUTER APPLICATIONS

The Data Processing Section of the Coordinating Division has available a fast computation service through the use of the IBM 360 System. With this computer, voluminous and repetitive computations can be performed at marked savings in engineering time and costs. Three programs of common application in storm drain design have been developed: the Traverse Analysis, the Backwater and Downwater Curve, and the Reservoir Analysis. Others will be developed as the need arises. The designer is urged to make use of these data processing services in the solution of design problems.

G 910 TRAVERSE ANALYSIS

The Traverse Analysis Program computes latitudes, departures, coordinates, and error of closure of a distance and bearing traverse. Traverses can be adjusted, upon request, by either the compass, transit, or least square method or any combination of these methods. The program also provides, upon request, for area computation of closed traverses. The program will obtain solutions for any combination of two unknowns, distance and/ or bearing, and wi11 solve inverses if coordinates are coded in place of bearings and distances.

It is assumed that the user is familiar with traverse computations and the compass and transit methods of adjustment. The least square method of adjustment (Rappeleye Method) is applied to the balancing of distances in a traverse (the bearings are held). The compass and transit rules balance both distances and bearings. For each traverse, the misclosure is computed as a ratio of the sum of all courses divided by the length of the error course.

A useful feature of the traverse program is the ability to store and recall data Distances, bearings, and coordinates are stored by listing a memory number in the Store Data column, and are recalled by listing the same number in the appropriate Recall column. The data will remain at the memory number until new data are stored using the same number. This storage allows computing interdependent traverses without reading in the data of a previous traverse. Unknowns cannot be recalled into their own traverse, only in subsequent traverses.

G 911 INPUT CODING

An example traverse is shown in Figure G 911. The course bearing or deflection must be given in the direction of the traverse solution (see arrows on sample traverse). The Traverse Input Forms (Figures G 911A and B) illustrate the description of input coding.

Figure G 911A gives the data for the first traverse solution, which calculates the longer of two possible unknown distances. An alternate solution (Figure G 911B) calculates the shorter unknown distance. Note that no distances, bearings, or coordinates need be given on Figure G 911B, since all the data can be recalled from the input form of the first solution. The designer must determine which traverse solution is applicable to the project.

The minimum input data required to compute a traverse are as follows:

1. Complete header card information,
2. Course numbers (at least 2 courses required),
3. Beginning point (000) coordinates (if any),
4. Bearing and distance of known courses,
5. Coordinates of inverse courses,
6. Ending point (999) coordinates (if problem contains unknowns),
7. Trailer card number (09998).

The *header card* identification information is as follows:

Columns 1-5: Tract or work order number
Columns 6-11: Date of computation
Columns 12-47: Job title (may be abbreviated)

The remaining data at the top of the input form are for the engineer's information.

The traverse information shown in the body of the input form must start with course number 000 (begin traverse) on the first line and end with course number 999 (close traverse). The input data, one line per course, are filled in as follows:

Columns 1-5: *Tract or Work Order Number.*

Columns 6-8: Traverse Number is entered only once on course line 000.

Columns 9-11: Course Number is used only for identification of traverse course (or legs). The course numbers are recorded in the computer memory in the order they are read. Numbers 000 and 999 must not be used for traverse legs.

Columns 12-27: Description of a point or a course on the course line. One letter or number is used per space between tick marks. Abbreviations and Fortran symbols may be used.

Columns 28 and 29: In lieu of repeating a course distance, it is recalled from a previous course by placing the previous course Store Data number in the Distance Recall column on the course line. Only known data can be recalled within the same traverse. In subsequent traverses, both known and calculated data may be recalled.

Columns 30-37: If the distance of a course is known, it is placed under Distance on that course line. If unknown, it is left blank. A distance may be given with a bearing, but neither is given with coordinates. If the distance is to be recalled, a Store Data number is assigned for that course and listed in its appropriate column.

Columns 38 and 39: Bearing Recall is the same as Distance Recall (columns 28, 29) except that it applies to a course bearing in lieu of a course distance.

Column 40: RLU means right or left deflection or unknown bearing. In conjunction with R or L, the deflection angle must be given under Bearing, and columns 41 and 51 must be left blank. U is listed when the bearing is unknown. All data are listed on the line for that course.

Columns 41 and 51: NS means north or south, and EW means east or west. These indicate the direction of the bearing. For bearings due north, due south, due east, or due west, the following shall be used:

Due north-use NE or NW 00°-00'-00.0"
Due south-use SE or SW 00°-00'-00.0"
Due east -use NE or SE 90°–00'-00.0"
Due west -use NW or SW 90°-00'-00.0"
If the bearing is unknown or coordinates are given for the course, these columns are left blank.

Columns 42-50: A course bearing angle or deflection angle is listed under Bearing. If a course bearing or deflection angle is unknown, or if course coordinates are given, the column is left blank. (See also columns 40, 41, and 51 above.)

Columns 52 and 53: Coordinate Recall is the same as distance or bearing recall except that it applies to course coordinates. (See columns 28, 29.) A coordinate recall cannot be used where a distance and/or bearing is listed.

Columns 54-73: The north-south coordinates are listed under North, and the east-west coordinates are listed under East. When course coordinates are given, inversing must be carried out before an unknown distance and/or bearing can be calculated If coordinates are unknown, the columns are left blank. For a closed traverse, the beginning coordinates (course 000) are listed. For a traverse adjustment or area computation, the end coordinates (course 999) are listed or recalled from course 000. The coordinates listed or stored on any course are those at the end of that course.

Columns 74 and 75: A number allotted to the Store Data column of a course commits the course data to computer memory. The data may be recalled by placing the number in the recall columns. The Store Data number need not be allotted in sequence but must not be repeated in any traverses where the data may be recalled.

Column 76: SEG means segment of area of a circular curve. If it lies inside the traverse, the area of the circular segment (between long chord and arc) is added to the traverse area. If it lies outside the traverse, the area of the circular segment is subtracted from the traverse area. A for added and S for subtracted is marked in this column at the first radial course. The area of a circular arc section cannot be computed for an interior angle greater than 180°; the angle must be broken into segments of less than 180ø.

Column 77: When the area of a closed traverse is to be computed, an A is marked on the zero course line of this column. To obtain a printout of curve data, both columns 76 and 77 must be marked as shown above.

Columns 78-80: To adjust the traverse, the zero course card is marked with a C, T, or L in their respective columns. C means the adjustment is to be made by the compass rule; T, the transit rule; and L, the least square rule. Any one or all adjustments may be required at the same time.

The *trailer card* is marked in columns 1 to 5 and follows the end traverse card. If more problems are to be processed in the same run, 09998 is marked; if not, 09999 is marked. This ends all traverse, course, and store data number series for that run and makes the numbers available for use again in subsequent runs.

G 912 OUTPUT TABULATION

The output tabulation sheet consists of heading information, traverse course data, and misclosure and area data, as shown on the sample output sheets (Figures G 912A and B).

The traverse data are tabulated under every heading for each course (one course per line). Course 1 is from point 0 to point 1, course 2 is from point 1 to point 2, etc. The unknown bearing or distance calculated by the program is followed by the letter U. Curve data are interjected be-

tween the curve's two radial courses. SEG is the area (sq. ft.) between the arc and the chord. SMSEG is the algebraic sum of the SEG areas in the order of the course numbers.

The 999 course line gives the total closure error, the north-south coordinate error, and the east-west coordinate error. The error of closure is the perimeter divided by the total error. The perimeter and the error of closure are given on the next line. On forced closure problems and problems where the total error is less than 0.00001, the statement CLOSURE IS FLAT is printed. The bearing error is given next. Finally, for area problems, the area is given in square feet and acres.

The listing machine will automatically index to the next sheet after every traverse has been printed.

G 920 WAJER SURFACE COMPUTATIONS

The Backwater and Downwater Curve program performs water surface computations for circular or rectangular free water surface flow. The distance to a predetermined depth or the depth at a predetermined distance can be resolved from a known control depth. Also, in a continuous series of slopes (e.g., vertical curve), the depth at the end of each slope can be resolved. There are certain limitations to this program, however, which the designer must know to apply and interpret the computations properly.

The computations in this program are applicable only if the runoff quantity (Q), the roughness coefficient (n), and the channel width (or pipe diameter) are constant. If any one of the above values is changed, a new computation input form must be filled out, utilizing the previously calculated water surface if no control is available. Also, the results will not be reliable if the computed depth goes through critical depth (d_c) or goes beyond normal depth (d_c). The designer must determine d_c and d_u to select the applicable portions of the results.

The three types of solutions offered by this program are:

1. To find the distance from a control depth to a known depth D',

2. To find depth D' knowing the distance from the control depth,

3. To find depth D' at the end of each slope of a continuous series of slopes; i.e., vertical curve.

Each solution must be resolved independently. The program does not allow for these solutions to be combined

G 921 INPUT CODING

Two sample problems (backwater and downwater curves) and their profiles are shown on the Input Forms (Figures G 921, G 921A, and G 921B) for each of the three solutions given above. Each problem must be preceded by a header card giving the job title, the date submitted, and the run number (trial runs for same problem). The type of section, circular or rectangular, must be marked at the top of the input form. Although the form is made up of three groups of six lines each, the number of slopes or distances to be computed is not limited to six. The header card line is simply skipped, and the problem is continued on the next line.

The remaining data at the top of the input form are for the engineer's information.

The input data for each of the three problems are as follows:

I. To find the distance L from the control depth to a known depth D' (Figure G 921):

Columns 1-8: Starting station at control point

Columns 10-16: Starting invert elevation at control point

Columns 18-23: Runoff quantity, Q (cfs)

Columns 25-29: Pipe diameter or width of channel section (feet)

Columns 32-34: Manning's "n"

Columns 36-41: Invert slope (S,)

Columns 43-47: Control depth, D (feet) . *Columns 48-52:* Depth D' (feet)

Column 54: Select rectangular channel invert; flat (1) or "V" (2). If section is circular, leave blank

Column 56: Select control; downstream (1) or upstream (2) from depth D'

Column 59: Select the depth; decreasing (1) or increasing (2) from control depth to depth D'

Column 62: Depth D' is known (1).

Leave remaining columns blank

II. To find depth D' at a known distance from the control depth (Figure G 921A):

Columns 1-47: Same as I above

Columns 48-52: Depth D' is unknown-leave blank

Columns 54, 56, 59: Same as I above

Column 62: Depth D' is unknown (2)

Column 65: One increment (list 1)

Columns 67-72: The horizontal distance from the control depth to depth D'.

III. To find depth D' at the end of each slope of a continuous series of slopes; i.e., vertical curve (Figure G 921B):

a)   First Line-First Slope:

Columns 1-47: slope as I above Columns 48-62: Same as II above

Columns 64, 65: The number of increments (different slopes) in the vertical curve

Columns 67-72: The horizontal length of the first slope.

b)   Second Line-Second Slope: Columns 34-41: The next invert slope (Si)

Column 59: Same as I above

Columns 67-72: The horizontal length of that specific slope.

c)   Third Line-Third Slope: etc.

(One line for each additional slope)

G 922 OUTPUT TABULATION

The output tabulation sheet gives the problem title and lists the station, depth, and water surface elevation for each reach based on a 3% change of velocity. Figures G 922 and G 922A are sample output sheets for the six sample problems shown on the input forms.

In problems I and II, D' (or L) is given to limit the calculation. However, in problem III (Downwater), normal depth is reached before the calculations of the last distance (154.83) can be completed. The designer must delete the depths below the predetermined normal depth (d_n=1.20), as shown on Figure G 922A.

G 930 RESERVOIR ANALYSIS

The Reservoir Analysis program computes an analytical solution to the reservoir problem. With predetermined input data, the program plots the inflow hydrograph and, knowing the reservoir rating curve values, applies the formula Inflow = outflow + storage to calculate the outflow hydrograph. The clock time for this program is for a 24-hour period (from 0 to 1440 minutes) for each day of storm analyzed. Results can be given for a four-day 50-year storm or for the fourth day only at 100% runoff. See Section G 221 for further description of a four-day pattern storm.

The data required to allow the computer to calculate the reservoir inflow hydrograph are the following:

1. Time of concentration of peak inflow (tc) in minutes

2. Amount of peak runoff (Q) in cfs. From these values, the multiplying factor (MF) is derived as follows:

$$MF = Q/BPRR$$

The reservoir rating curve values required to allow the computer to formulate the outflow and storage curves are as follows:

1. The elevation (or depth) in feet

2. The outflow rate (Q out) in cubic feet per second for given elevations

3. The storage volume in cubic feet for given elevations.

G 931 INPUT CODING

The data required to compute a reservoir problem are illustrated on the input form Figure G 931. The sample problem chosen is the one calculated on Figure G 528. The information above the header card is for use by the design office and data service personnel. Note that the output tabulates the input data (see Figure G 931).

The information required on the header card is explained in the notes at the bottom of Figure G 931. The values of MF and t_c select the runoff rates for the inflow hydrograph from a programmed table like Figure G 252F. The No. *Pts.* gives the number of values which define the reservoir rating curve.

The values listed under *Elevation, Q out,* and *Storage* give the water surface elevation in the reservoir and the outflow rate and storage capacity at that elevation. Each line is a point on the reservoir rating curve. A maximum of 45 points can be used, including the first point (reservoir floor elevation with zero storage and zero outflow), the last point (maximum storage elevation allowed), and the last entry (machine language for end of curve). The values are taken from precalculated curves such as the *Outflow Conduit Discharge-Head Curve* and the *Storage-Basin Volume-Depth Curve* and shown on Figure G 526C. The elevation points chosen are those that best define the outflow rate curve.

The inflow hydrograph can be modified to allow for interpolation of the table (Figure G 252F). Care must be taken to ensure that consecutive runoff factors are increasing. These values can be extended to the nearest thousandth if necessary. The maximum number of points on the inflow hydrograph is 50.

A limitation to this program is that the outflow rate must not exceed the inflow when the inflow is increasing (the upward portion of the inflow hydrograph). When this occurs, the computation ceases and the designer must calculate the problem by hand, as shown in Figure G 528. An important factor contributing to this situation is an inadequate storage capacity. The reservoir will then fill very quickly, providing a high outflow rate before the inflow rate reaches its peak.

G 932 OUTPUT TABULATION

The reservoir analysis program always computes two solutions:

1. A one-day storm of 100% runoff, starting with reservoir empty, and

2. A four-day storm of 10% (of 100%) runoff on the first day, 40% runoff on the second day, 30% runoff on the third day, and 100% runoff on the fourth day, starting each day with the reservoir storage remaining from the previous day. The output tabulation headings will state which solution is calculated (such as starting 100% or first day 10%) and the amount of storage in the reservoir at the start of each day (such as reservoir empty or reservoir storage = 38,962).

The results of the computations are presented to the designer in the format shown on Figure G 932. The TMIE column represents the clock time for a 24-hour storm (0 to 1440 minutes). The IN column is the rate of inflow (cfs) into the reservoir at the specified clock time. The MASS IN column is the cumulative volume (cubic feet) of inflow at the specified clock time. These three column represent the inflow hydrograph calculations.

The outflow and storage calculations are shown in the last three columns. The MASS OUT column is the cumulative volume (cubic feet) of outflow for the specified clock time. The ELEV column is the reservoir water surface elevation at the specified clock time. This elevation is representative of the volume of water stored. The OUT column is the rate of outflow (cfs) from the reservoir at the specified time.

To correlate the clock time used by the program with that of the table (Figure G 252F), 1062 minutes of program clock time are equal to 0 minutes of table clock time. Note the peak inflow (300.3 cfs) at 1158 minutes, and the peak outflow (59.9 cfs) and maximum elevation (207.5 feet) at 1182 minutes. The significance of elevation 207.5 is that the reservoir would not overflow (nor be unduly oversized) for the storm specified and the outflow allowed.

The results of the program calculations are comparable to those calculated by hand on Figure G 528. The program computes more points on the inflow hydrograph and generally provides a higher degree of accuracy than that shown on Figure G 528. But the chief advantage of this program is the saving in computation time and the ease with which many trial runs can be made to arrive at an optimum solution.