Canadian Technical Report of
Fisheries and Aquatic Sciences 1812

1991

A Computer Software Package for Instream Flow Analysis by the Flow Duration Method

by

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Cat. No. Fs 97-13/1812E ISSN 0706-6457

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Correct citation for this publication:

Caissie, D. 1991. A Computer Software Package for Instream Flow Analysis by the Flow Duration Method. Can. Tech. Rep. Fish. Aquat. Sci. 1812: 21p.

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ABSTRACT

Caissie, D. 1991. A Computer Software Package for Instream Flow Analysis by the Flow Duration Method. Can. Tech. Rep. Fish. Aquat. Sci. 1812: 21p.

Proposed water abstraction projects require fisheries biologists, hydrologists and engineers to predict the level of impact on the aquatic resources and to specify the amount of water which must be left in the stream. Many instream flow methods are used and some of them require an analysis of daily streamflow for many years of record. The objective of this report is to present a computer software package that runs on a microcomputer to perform this analysis by flow duration method. The program can analyze up to 100 years of daily discharge. The results are presented both in tabular and graphic format. The source codes of the main program and subroutines are given. The program is illustrated by means of a numerical application on the Renous River, New Brunswick.

RÉSUMÉ

Caissie, D. 1991. A Computer Software Package for Instream Flow Analysis by the Flow Duration Method. Can. Tech. Rep. Fish. Aquat. Sci. 1812: 21p.

La conception et l'aménagement des projets hydrauliques ou toutes autre ouvrages dans le milieu aquatique exige, de la part des concepteurs (ingénieurs, hydrologues, et biologistes), une analyse détaillée de leurs impacts sur les rivières et les cours d'eau. Parmi cet impact notons le débit environnemental ou réservé a assurer afin de protéger la vie faunique et l'habitat du poisson. Certaines de ces méthodes utilisent l'analyse des débits sur une base journalière et pour plusieurs années d'enregistrement. L'objectif de ce rapport est de présenter un logiciel fonctionnant sur micro-ordinateur et qui permet l'analyse par la méthode du débit classé. Le logiciel peut analyser jusqu'à 100 années de données du débit journalier. Les résultats sont présentés sous forme de tableau et graphique. Les codes sources du programme principal et des sous-programmes sont fournis et le fonctionnement du logiciel est illustré à l'aide d'une application numérique sur la rivière Renous au Nouveau-Brunswick.

PREFACE

The software package presented in this report was developed for research purposes. Users are responsible for the decisions on application of the results obtained. A listing of the program source codes is provided in appendix so that the users can follow the programming structure, verify the results, and make changes to the program if desired.

For a compiled version of the software, the source codes, and the data files described in the present report please write to:

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1.0 INTRODUCTION

With the increase in a wide range of water related engineering projects such as hydroelectric generation, reservoirs, irrigation, aquaculture, and others, water withdrawal from water courses is on the rise. Conflicts often develop between the increased water demands and the protection of aquatic resources. This is the result of public awareness of the environment and consequent requirements to conduct Environmental Impact Assessments (EIA).

In 1986, the Department of Fisheries and Oceans established a policy for the management of fish habitat (Department of Fisheries and Oceans 1986). The long term policy objective is the achievement of an overall net gain of productive capacity of habitats although this is often confused with one of the guiding principles of no net loss of productive capacity. In addition, the federal government has passed an Order-in-Council requiring virtually all projects with federal funding or decision making authority to undergo review through the ENVIRONMENTAL ASSESSMENT REVIEW PROCESS (EARP). Similar provincial reviews often apply as well.

Many different instream flow methods are presently being used during the EARP to determine the amount of water that must be left in the stream to maintain aquatic resources. EA Engineering, Science, and Technology Inc. (1986) identified 75 such methods. Reiser et al. (1989) conducted a survey on the status of instream flow practices in North America and identified 18 of the most widely used and recognized methods. Wesche and Rechard (1980) presented a compilation and review of 16 different instream flow methods used in the United States. IEC Beak Consultants Ltd. (1985) presented a review of the instream flow methods applied in Canada to protect fish habitat below hydropower facilities. The document was prepared for the Canadian Electrical Association but the methods described in the report also apply to other projects.

For any project, the number of instream flow methods available makes the selection of a particular one very difficult. Consequently, many instream studies involve a number of methods of which the results are then compared. For the purpose of the present report, instream flow methods are divided into three different categories (IEC Beak Consultants Ltd. 1985): 1) discharge methods; 2) hydraulic rating methods; and 3) habitat preference methods. A description of each category is given and the report then focuses on the application on one particular approach of the discharge methods, the flow duration method.

Discharge Methods

The discharge methods are the most widely used because of their simplicity. These methods are based on a fixed percentage of a flow; the Tennant or Montana Method (Tennant 1976) is a prime example. Some other methods are based on a fixed percentage of a flow duration such as the Aquatic Base Flow (ABF - U.S. Fish and Wildlife Service 1981; Kulik 1990). These methods, which are largely based on historical streamflow records, are preferred at reconnaissance level because they do not require any field work. Some of the discharge methods are based on flow duration analysis and require calculations of daily streamflow for many years of record. These calculations are most effectively carried out using a digital computer.

Hydraulic Rating Methods

Hydraulic rating methods are a combination of hydrology and hydraulics. Upon determining the hydrology of the stream or streamflow, hydraulic simulations are carried out using representative transects of specific habitat to determine useable habitat estimated by the wetted perimeter. These methods require some field work to collect physical characteristics (velocity, depth, etc..) of the stream (Isaacson 1976).

Habitat Preference Methods

The habitat preference methods (such as the Instream Flow Incremental Methodology - IFIM) incorporate biology with both the hydrology and the hydraulics of the stream to simulate the stream environment. These methods require the most data because they link the physical characteristics of the stream to the habitat preference of the fish for different life stages and species (Bovee 1982).

The objective of the present report, is to develop a software package for use with a micro-computer to facilitate the instream flow needs calculations using flow duration analysis. The software carries out the analysis using daily streamflow data and dumps the results into a data file for printing. In addition, a graphical representation of the flow duration curve is produced.

2.0 FLOW DURATION ANALYSIS

A flow duration analysis is performed when a nonparametric cumulative distribution function of daily streamflow is established for a hydrometric station. Such an analysis consists of ranking daily streamflow observation q_{ij} for i=1,..., 365 and j=1,..., n, where i represents the day of the year, j the year and n the number of years of record. The study can be carried out for only a portion of the year (e.g. monthly or seasonally), then $i=d_1,..., d_2$, for which d_1 represent the start and d_2 the end of the season. A flow duration curve is constructed by plotting the ranked flows (q_k) as a function of its corresponding plotting position p_k. Here, q_1 and q_{365n} represent the highest and lowest flow on record. The plotting position p_k is an estimate of the probability p associated to any particular ranked flow.

In the present software, the California plotting position (Viessman et al. 1977) is used which is given by:

[1] $$p_k = k / (365 \cdot n) \quad \text{or} \quad p_k = k / (d \cdot n)$$

where d is the duration of the season between day d_1 and d_2.

Many formulas for the plotting position are available, but because of the large sample size in most of the flow duration analyses, these formulas give approximately the same results (Cunnane 1978). For example, the sample for 10 years of record is 10x365 + 2 = 3652 observations for an annual flow duration, including leap year days.

To every ranked discharge q_k, corresponds a probability, p_k. In flow duration analysis the probability of interest is the probability, p, of a particular discharge Q being exceeded. p, also known as the exceedance probability, is defined by:

[2] $p = P(Q>q_{p\%})$ or,

[3] $p = 1 - P(Q\leq q_{p\%})$

In equation [2] and [3], $q_{p\%}$ corresponds to the value of the mean daily discharge that is exceeded p% of the time. The software presented in the present report calculates p for 41 $q_{p\%}$ ranging from the minimum to the maximum observed daily streamflow of the time series. Note that 41 is arbitrary and any number of flows could have been chosen.

3.0 FLOW DURATION ANALYSIS SOFTWARE

3.1 General program features and limitations

The **FLO**w **DUR**ation analysis program FLODUR was written in Microsoft QuickBASIC Version 4.5 (Microsoft QuickBASIC 1988). FLODUR was designed to operate on an IBM compatible personal computer with the following system requirements:

a) a graphics monitor is not required for the analysis, but is needed for displaying the flow duration curve on the screen.

b) the program should be run on an AT or faster computer and although a co-processor is not required, it greatly increases calculation speed.

c) the software is designed to operate on a hard disk but it can run using one or two floppy drives.

d) the program accepts daily streamflow data in ASCII in accordance with format 79-041 as described in Environment Canada (1980).

e) the program is designed to operate using several types of graphic cards. During the first run of the program a configuration should be carried out. The information from this configuration will be saved in a file named SET.PC. However, if a HERCULES graphics card is used, a secondary program (MSHERC.COM) should be run at the DOS (Disk Operating System) prompt before running FLODUR.

f) a printer linked to the system is not required for the operation of the program, but is required if any printing of output such as results or graphics is desired.

No data entry package is provided here. It is assumed that all necessary data have been gathered by the user for the hydrometric station(s) to be analyzed. If any statistical tests are to be performed on the data, such as tests of independence or homogeneity, they must be performed using other statistical packages. For consistency in naming data files, the Environment Canada data file names have been retained with the extension ENV. In addition, the results of the flow duration analysis have the Environment Canada station name but with the extension FDA.

The software is limited to the analysis of a hydrometric station with a maximum of a 100 years of daily streamflow. The number of points for the flow duration analysis is set at 41 different ranked flows $q_{p\%}$ ranging from a frequency of 0% to 100%. Most of the limitations of the software can be modified using the source codes provided in Appendix A and a QuickBASIC compiler. It should be noted that in the source codes listing (Appendix A), a bold (i.e. &) was used when the line had too many characters. The line containing this code should be viewed as a continuation of the previous line in the BASIC program.

3.2 Structure of FLODUR

FLODUR has four major modules which are presented in a main menu (Figure 1) and a quit option to terminate the program. These four major modules or subroutines are: <1> Configuration; <2> Input data; <3> Flow duration analysis; and <4> Flow duration curve. Quit program is also an option of the main menu, however there is no module for it.

Most of the modules are also sequentially linked. For example, a Flow duration analysis can not be carried out before having run the Input data module. A brief description of all 4 modules is provided followed by a more detailed description of Input data, Flow duration analysis, and Flow duration curve.

-Configuration

The subroutine CONFIG reads the information on the type of graphic card and puts this information into a file called SET.PC for future runs of the program. The Configuration module is run only during the first operation of the program or when the program is run on another computer with a different type graphic card.

-Input data

The subroutine IWDD reads Environment Canada daily streamflow data (format 79-041), identifies missing months, and prepares daily flow data for subsequent analysis.

-Flow duration analysis

The subroutine FLOWA identifies the number of days for every year (365 or 366) and performs a flow duration analysis based on the user defined season (or annually). The user can also select specific years for the analysis. The results are printed into a file and on the screen. Finally, the user can calculate discharges for different exceedance probabilities as defined by [3].

-Flow duration curve

The subroutine GRAF1 provides a graphical presentation of the flow duration analysis. The graph is plotted on the computer screen using a semi-logarithmic scale (discharge, y axis, is logarithmic).

3.2.1 Input data module

Following the configuration, Input data is selected from the main menu. At this stage, the program runs the subroutine IWDD which prompts the user for the data file name:

Enter input file name (ex: station.ENV)

_

The user enters the station file name with extension ENV, for example 01BO002.ENV, and the program reads all years of record with the following indication on the computer screen:

Reading data file, please wait ...
.... Year 1 = 1967
.... Year 2 = 1968
.... Year 3 = 1969
etc...

If any of the dotted lines are less than 36 dots (number of months times three), data are missing for a portion of that particular year.

When the subroutine IWDD identifies missing months, it gives a value of -9999 for every missing day. Also, every month comprises 31 days and if the actual month is less than 31 days (e.g. February), the program puts a value of -1111 at the end of the month to complete the 31 day month. This format was used to be consistent with the format 79-041 (Environment Canada 1980) which uses -9999 for missing values and which uses 31 days for every month of the year using values of -1111 to complete the months with less than 31 days.

Once all the data are read from the data file, the program returns to the main menu.

3.2.2 Flow duration analysis module

The first task of this module is to identify days with a value of -1111, eliminate them and calculate the number of days for every year (365 or 366). When this process is completed, the user can select a flow duration analysis for specific years of record by entering (S) or for all years of record by entering (A). Note that if during the execution of the previous module (Input data), one or more dotted lines were not complete (e.g. less than 36 dots) and the user wants to eliminate these years, they can be eliminated by selecting (S) in the present option. For the analysis of specific years, the program print the year one by one with the **Yes** or **No** option to analyze any specific year. Default values are provided to the user in bracket (e.g. [Y]) and the option in bracket can be selected by pressing the **ENTER** key only. Following this selection the program will eliminate unwanted years from the analysis.

The next option in the module is the selection of specific seasons. This is possible by selecting (S) for a specific season or by selecting (A) to carry out a flow duration analysis on an annual basis. In the selection of a seasonal analysis, the season can be defined as a particular month by specifying the day of year for the beginning and the end of the month (e.g. 213 to 243 for August). The analysis can also be carried out for any desired season (e.g. spawning season for example) again by specifying the day of year for the beginning and the end of the season. The program next calculates exceedance probabilities given by equation [3] for 41 discharges ($q_{p\%}$) ranging from the minimum to the maximum observed flow of the particular season. Because of the wide range in daily streamflow between the minimum and maximum discharge, the following equation was used to identify 41 points (X_i, Y_i) on the flow duration curve:

[4] $X_i = p\%$ given by [3] for $q_{p\%}$

[5] $Y_i = q_{p\%} = \exp[\, i\ \{(\ln(q_{0\%})-\ln(q_{100\%}))/40\} + \ln(q_{100\%})]$

where $i=0,1,2,\ldots,40$, $q_{0\%}$ is the largest flow for the selected season or for $p=0\%$ and $q_{100\%}$ the smallest or for $p=100\%$. The other two functions are the exponential (exp) and natural logarithmic (ln).

When the program is calculating exceedance probabilities for given flows, the following message will be displayed on the screen:

Please wait ... 20

The first number that will appear corresponds to the number of years of record and this number will decrease until all of the years of record are analyzed. The program will then prompt the user for an output file name to store the results. This file can conveniently be called 01BO002.FDA (i.e. station name with the extension FDA). Statistics such as maximum and minimum flow, and the number of daily streamflow observations will also appear as part of the analysis.

If the user wishes to calculate a discharge for a given exceedance probability, the probability in percentage is specified. The program will keep prompting for more calculation of discharge until the user enters EX to exit the loop and the module will terminate.

3.2.3 Flow duration curve module

This module graphs the flow duration curve calculated during the flow duration analysis module and displays it on the computer screen. The first option of the module identifies the maximum and minimum discharge for the curve. The user can keep the actual maximum and minimum discharge or can enter other preferred flows. This option is provided to permit comparison of multiple flow duration analysis curves. *Note the minimum discharge must be non-zero because of the logarithmic scale of discharge.*

The module requires information from the file SET.PC and can not be executed if that file does not exist. If any problems occurs within this module, one should make sure that the file SET.PC exists. The module draws the border, puts the labels and the title on the axes, and draws the flow duration curve.

4.0 NUMERICAL APPLICATION

A numerical application will be presented for the Renous River at McGraw Brook in the province of New Brunswick (hydrometric station : 01BO002) to illustrate the application of the software. The instream flow analysis was carried out using Aquatic Base Flow (ABF - U.S. Fish and Wildlife Service 1981; Kulik 1990). The ABF method is defined as the median flow for the month of August. The percentile of interest for the ABF method is then the 50% probability on the flow duration curve.

The data were provided for station 01BO002 by the Water Resources Branch of Environment Canada Ottawa (Inland Waters Directorate) and our file name is therefore 01BO002.ENV (station name with extension ENV). A portion of this data file is presented in Table 1.

To run the program, the following instructions are written at the DOS prompt:

A:> **FLODUR**

The execution of the program was carried out using all years of record. However, the beginning of the season was set at day 213 with the end at day 243 (month of August). The program prompted the user for name of the output file in which the results are to be saved. The name of this file was selected to reflect the station name (i.e. 01BO002) with extension FDA for flow duration analysis (01BO002.FDA). The content of this file is shown in Table 2. The results are also shown on the computer screen.

To calculate the 50% flow duration for the month of August, the user enters 50 and the program calculates $q_{50\%}$ which is equal to 3.057 m^3/s. The program will keep prompting for probabilities until the user enters EX to exit.

Following the flow duration analysis, the flow duration curve is displayed on the screen by selecting the flow duration curve option from the main menu. The program prompts the user to change the maximum and/or minimum discharge. If the maximum and minimum discharges are not changed the resulting curve is as shown in Figure 2.

5.0 DISCUSSION

Some of the instream flow methods, especially the discharge and hydraulic rating methods, have been criticized because they do not take into account the biology of the stream. All instream flow studies should have some biological considerations. However, for many small projects, detailed habitat preference methods are not always feasible due to economic factors. Instead, discharge methods are being used. These methods are also used for larger projects at the reconnaissance level. If any of the discharge methods are to be used, either because of economics or for comparison with results of habitat preference methods (Mathur et al. 1985), then it becomes important to have computer programs which make their application more efficient.

In the present report, we provided a user-friendly software to carry out analysis which otherwise demands tedious calculations. We hope that this tool, in the hands of the fisheries biologist and hydrologist, will simplify the application of flow duration analysis for estimating instream flow needs.

ACKNOWLEDGEMENTS

The author would like to thank the following people for their contribution to this report: N. El-Jabi and R. Alexander kindly reviewed the report; the Data Control Section of Environment Canada for the provision of hydrometric data.

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Table 1. Portion of Renous River (New Brunswick) data file (01BO002.ENV) showing Environment Canada (1980) card format 79-041 for daily discharge.

```
Q01BO002966 12 3.40B 3.31B 3.23B 3.06B 3.00B 2.92B 2.83B 2.83B 3.23B 3.68B
Q01BO002966 13 3.51B 3.40B 3.23B 3.14B 3.00B 2.92B 2.83B 2.75B 2.67B 2.67B 2.51B
Q01BO002966 21 2.51B 2.37B 2.37B 2.24B 2.17B 2.10B 2.10B 2.04B 1.97B 1.90B    28
Q01BO002966 22 1.83B 1.83B 2.44B 3.31B 4.25B 5.18B 4.87B 4.67B 4.45B 4.25B
Q01BO002966 23 4.05B 3.88B 3.68B 3.60B 3.40B 3.23B 3.06B 2.92B-1111 -1111 -1111
Q01BO002966 31 2.67B 3.79B 5.64B 5.41B 5.10B 6.94B 10.4B 9.66B 8.89B 8.21B    31
Q01BO002966 32 7.67B 7.16B 6.80B 6.43B 5.97B 5.64B 5.30B 5.10B 4.87B 4.56B
Q01BO002966 33 4.36B 6.20B 8.35B 10.9B 15.0B 19.6B 26.2B 23.7B 21.7B 19.9B 18.3B
Q01BO002966 41 16.8B 15.3B 14.2B 13.8B 14.4B 15.1B 16.1B 16.8B 17.2B 18.5     30
Q01BO002966 42 17.6  16.6  15.7  15.9  18.3  21.0  24.8  29.4  28.9  27.8
Q01BO002966 43 34.5  58.9  66.0  56.4  53.2  54.4  41.6  36.8  34.5  31.4 -1111
Q01BO002966 51 37.1  38.5  39.6  42.5  40.2  42.2  47.0  39.4  34.3  35.4     31
Q01BO002966 52 36.8  36.8  38.5  37.9  40.2  47.0  51.3  51.8  53.0  71.6
Q01BO002966 53 86.1  75.3  63.4  53.8  49.0  47.9  41.9  34.8  30.3  27.5  22.7
Q01BO002966 61 19.9  17.6  15.1  13.6  12.5  11.8  15.3  17.0  17.4  14.4     30
Q01BO002966 62 19.4  20.1  15.0  11.8A 10.7E 10.4E 10.1E 13.6A 8.35  7.56
Q01BO002966 63 7.42  6.54  6.09  6.31  6.31  5.86  5.52  5.18  4.67  5.10 -1111
Q01BO002966 71 4.76  4.25  4.05  3.88  3.40  3.14  2.75  3.00  2.83  2.75     31
Q01BO002966 72 2.83  2.37  2.51  4.16  3.60  2.92  2.37  2.24  2.17  11.9
Q01BO002966 73 13.6  8.21  5.86  4.36  3.68  3.23  3.14  2.83  2.59  3.06  3.06
Q01BO002966 81 2.67  2.37  2.44  2.44  2.31  1.97  1.78  1.72  1.72  1.61     31
Q01BO002966 82 1.50  1.56  1.72  1.67  1.34  1.28  1.61  1.78  1.67  1.45
Q01BO002966 83 1.19  1.10  1.05  1.19  1.19  1.23  1.10  1.01 0.872 0.827 0.827
Q01BO002966 910.827 0.872  1.05  1.05  1.97  3.06  2.24  1.78  2.24  3.06     30
Q01BO002966 92 2.44  1.97  1.39  1.14  1.23  2.44  2.37  1.90  1.72  1.50
Q01BO002966 93 1.23  1.45  3.40  5.30  4.25  3.51  3.06  2.59  2.31  2.67 -1111
Q01BO002966101 3.51  3.96  4.25  3.60  3.60  3.79  3.51  3.00  2.59  2.51     31
Q01BO002966102 3.00  3.79  5.41  5.10  4.36  4.16  5.30  5.18  4.45  5.64
Q01BO002966103 11.8  10.1  8.21  7.16  6.09  5.18  4.76  4.45  4.25  4.36  4.36
Q01BO002966111 3.96  4.76  7.56  43.6  36.8  24.6  18.9  15.7  14.2  13.2     30
Q01BO002966112 14.4  15.3  13.2A 11.9  11.1  10.1  8.75B 9.03  9.34A 8.50B
Q01BO002966113 7.31B 6.54B 6.20B 6.31B 6.80B 7.31B 7.82B 9.03B 11.2B 16.4 -1111
Q01BO002966121 23.7  22.2  17.4  14.2  11.6  11.8  12.1  11.6  11.1  10.6     31
```

Format description for colums (from Environment Canada 1980; page 12)

Column(s) Number	
1	code for type of data and units: Q - daily discharges in cubic meters per second
2-8	station number e.g. 01BO002
9-11	year, e.g. "966" for 1966
12-13	month, e.g. " 1" for January
14	code for time interval: 1 - daily figures from day 1 to day 10 2 - daily figures from day 11 to day 20 3 - daily figures from day 21 to day 31
15-80	ten or eleven 6-character data fields; **(see original publ. for more details)**

TABLE 2. Results of August flow duration analysis for Renous River (New Brunswick)

```
**********************************
*                                *
*     Flow Duration Anaysis      *
*                                *
*     FLODUR : Version 1.0       *
*                                *
**********************************
```

Results data file = 01BO002.FDA

Analysis carried out 02-01-1991 at 16:05:41

The following years of records were used in the analysis

```
Year  1 = 1966
Year  2 = 1967
Year  3 = 1968
Year  4 = 1969
Year  5 = 1970
Year  6 = 1971
Year  7 = 1972
Year  8 = 1973
Year  9 = 1974
Year 10 = 1975
Year 11 = 1976
Year 12 = 1977
Year 13 = 1978
Year 14 = 1979
Year 15 = 1980
Year 16 = 1981
Year 17 = 1982
Year 18 = 1983
Year 19 = 1984
Year 20 = 1985
Year 21 = 1986
Year 22 = 1987
Year 23 = 1988
```

Seasonal Analysis

From Julian day no. 213 to day no. 243

Discharge (cms)	Frequency (%)
0.702	100.000
0.781	99.018
0.869	97.475
0.967	95.933
1.076	93.969
1.198	92.006
1.333	89.481
1.483	85.273
1.650	80.645
1.836	75.456
2.043	71.389
2.274	66.620
2.530	60.729
2.816	55.540
3.133	48.247
3.486	43.338
3.879	38.569
4.317	33.520
4.804	30.154
5.345	25.526
5.948	20.617
6.619	17.251
7.365	13.604
8.196	11.641
9.120	9.537
10.148	8.555
11.293	6.452
12.566	5.470
13.983	4.628
15.560	3.506
17.314	2.945
19.267	1.964
21.439	1.823
23.857	1.403
26.547	0.982
29.541	0.421
32.872	0.421
36.578	0.281
40.703	0.140
45.293	0.140
50.400	0.000

Number of Observations = 713

Maximum discharge = 50.400
Minimum discharge = 0.702

```
**    MAIN MENU    **

Entre type of analysis

<1> Configuration
<2> Input data
<3> Flow duration analysis
<4> Flow duration curve
<5> Quit program
```

Figure 1. Main menu of FLODUR

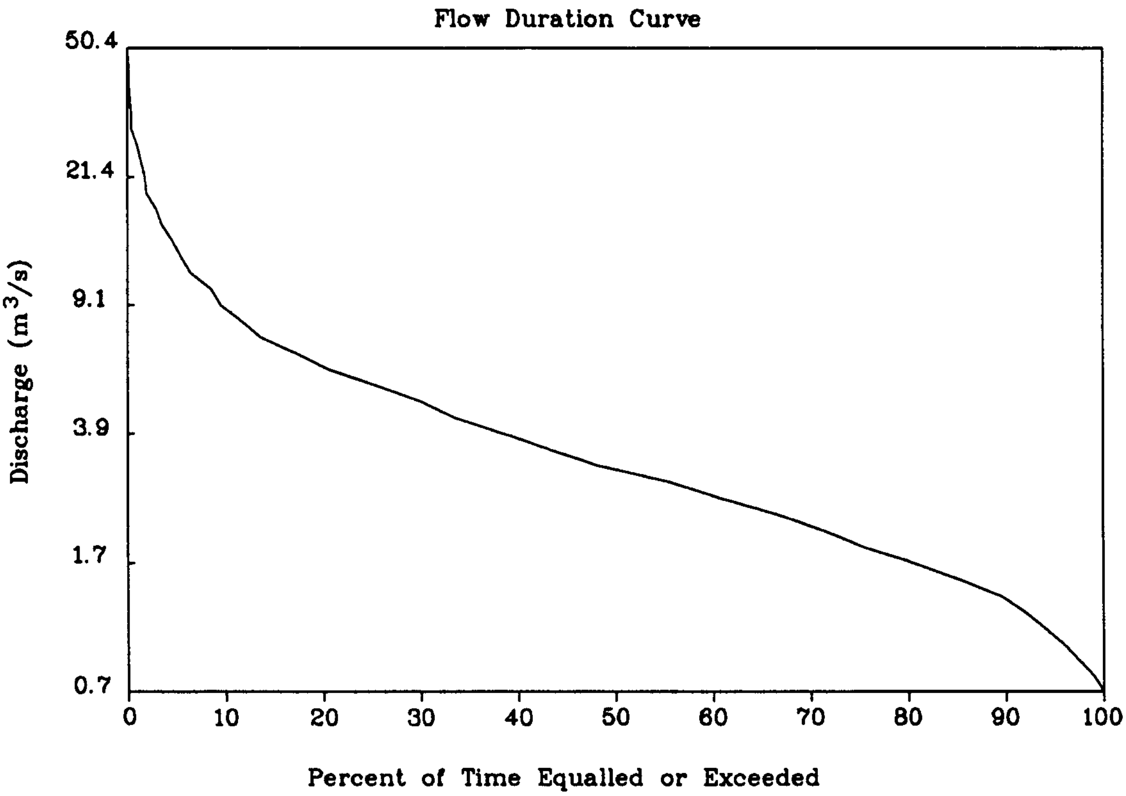

Figure 2. August flow duration curve for Renous River (NB). Station 01B0002 (1966–1988)

Appendix A

Source code listing of FLODUR

Main Program: FLODUR

```
DECLARE SUB CONFIG ()
DECLARE SUB FLOWA (Q!(), NYR!, YR!(), FLA1, MAX, MIN, QI(), FREQ())
DECLARE SUB IWDD (Q!(), NYR!, YR!())
DECLARE SUB TRANS (A!(), B!(), C1!(), TQ!())
DECLARE SUB GRAF1 (MAX!, MIN!, SN!(), SFRE!())
'=========================================================================
'
'                          Program: FLODUR
'
'       This software performs a flow duration analysis using daily
'       streamflow records.  A flow duration curve is also presented
'       on the computer screen and the results are put into a file
'       for printing or further analysis.  The present software package
'       was developed for research purposes.  Users are responsible for
'       the decisions on application of the results obtained.
'
'       Program   VER 1.0                    Date: January 1991
'
'       By:   Daniel Caissie
'             Fisheries and Oceans Canada
'             Habitat Ecology Section
'             P.O. Box 5030
'             Moncton, NB
'             Canada, E1C 9B6
'
'=========================================================================
'
'                          Local variables:
'
'  Q     : daily discharge.
'  NYR   : years of record.
'  YR    : actual year (ex: 1978).
'  QI    : discharge for a given exceedance probability.
'  FREQ  : exceedance probability.
'  CH1   : choice on the type of analysis from the main menu.
'  FLA1  : flag set at 0 for first flow duration analysis and 1
'          for other analysis.
'  MAX   : maximum discharge of the studied season.
'  MIN   : minimum discharge of the studied season.
'
'  ......................................................................
'
'                          Program limitations:
'
'  Years of record are limited to                          : 100
'  Number of points on flow duration curve are limited to  :  41
'
'=========================================================================
' $DYNAMIC
       DIM Q(100, 372), YR(100), QI(41), FREQ(41)
'
'  ------------------------------------
'  1. General software presentation menu.
'  ------------------------------------
'
     CLS 0
     X = 7: Y = 15
     LOCATE X, Y: PRINT CHR$(213) + STRING$(45, 205) + CHR$(184)
     LOCATE X + 1, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
     LOCATE X + 2, Y: PRINT CHR$(179) + "          Flow Duration Analysis          " + CHR$(179)
     LOCATE X + 3, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
     LOCATE X + 4, Y: PRINT CHR$(179) + "                    By                    " + CHR$(179)
     LOCATE X + 5, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
     LOCATE X + 6, Y: PRINT CHR$(179) + "              Daniel Caissie              " + CHR$(179)
     LOCATE X + 7, Y: PRINT CHR$(179) + "           Fisheries and Oceans           " + CHR$(179)
     LOCATE X + 8, Y: PRINT CHR$(179) + "   Fish Habitat and Enhancement Division   " + CHR$(179)
     LOCATE X + 9, Y: PRINT CHR$(179) + " P.O. Box 5030, Moncton, NB, Canada, E1C 9B6 " + CHR$(179)
     LOCATE X + 10, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
     LOCATE X + 11, Y: PRINT CHR$(212) + STRING$(45, 205) + CHR$(190)
     LOCATE X + 12, Y: PRINT
     INPUT "                              Press (ENTER) to continue "; ENTER$
'
'
        DO UNTIL CH1 = 5
'
'
```

```
'   -----------------------------------
'   2. Main menu
'   -----------------------------------
'
      CLS 0
      X = 7: Y = 15
      LOCATE X, Y: PRINT CHR$(213) + STRING$(45, 205) + CHR$(184)
      LOCATE X + 1, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
      LOCATE X + 2, Y: PRINT CHR$(179) + "         **   MAIN MENU   **                   " + CHR$(179)
      LOCATE X + 3, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
      LOCATE X + 4, Y: PRINT CHR$(179) + "        Entre type of analysis                 " + CHR$(179)
      LOCATE X + 5, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
      LOCATE X + 6, Y: PRINT CHR$(179) + "        <1> Configuration                      " + CHR$(179)
      LOCATE X + 7, Y: PRINT CHR$(179) + "        <2> Input data                         " + CHR$(179)
      LOCATE X + 8, Y: PRINT CHR$(179) + "        <3> Flow duration analysis             " + CHR$(179)
      LOCATE X + 9, Y: PRINT CHR$(179) + "        <4> Flow duration curve                " + CHR$(179)
      LOCATE X + 10, Y: PRINT CHR$(179) + "        <5> Quit program                      " + CHR$(179)
      LOCATE X + 11, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
      LOCATE X + 12, Y: PRINT CHR$(212) + STRING$(45, 205) + CHR$(190)
      LOCATE X + 13, Y: PRINT
      INPUT "                                    Enter selection "; CH1
'
         IF CH1 = 1 THEN CALL CONFIG
'
          IF CH1 = 2 THEN
           CALL IWDD(Q(), NYR, YR())
           SUBR2 = 1
          END IF
'
          IF CH1 = 3 THEN
           IF SUBR2 = 1 THEN
            CALL FLOWA(Q(), NYR, YR(), FLA1, MAX, MIN, QI(), FREQ())
            SUBR3 = 1
           ELSE
            CLS 0
            BEEP
            LOCATE 12, 25: PRINT "Error: No data available": PRINT
            INPUT "                         Press (Enter) to continue"; CH$
           END IF
          END IF
'
         IF CH1 = 4 THEN
           IF SUBR3 = 1 THEN
            CALL GRAF1(MAX, MIN, QI(), FREQ())
           ELSE
            CLS 0
            BEEP
            LOCATE 12, 25: PRINT "Error: No flow duration analysis to graph": PRINT
            INPUT "                         Press (Enter) to continue"; CH$
           END IF
         END IF
         LOOP
'
'   -----------------------------------
'   3. End of program
'   -----------------------------------
'
         END
```

Subroutine CONFIG

```
REM $STATIC
         SUB CONFIG
'=======================================================================
'
'                           subroutine: CONFIG
'
'         This subroutine reads the information for the type of graphic card
'         and prints it into a data file name SET.PC
'
'=======================================================================
'                            Local variables:
'
'   CH1   : choice for the type of graphic card.
'   ECRAN : actual screen number in QuickBASIC.
'
'=======================================================================
'
'
```

```
'  ------------------------------------
'  1. Configuration menu
'  ------------------------------------
'
      CLS 0
      X = 7: Y = 15
      LOCATE X, Y: PRINT CHR$(213) + STRING$(45, 205) + CHR$(184)
      LOCATE X + 1, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
      LOCATE X + 2, Y: PRINT CHR$(179) + "      Entre type of screen                 " + CHR$(179)
      LOCATE X + 3, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
      LOCATE X + 4, Y: PRINT CHR$(179) + "     <1> 640 X 200 (CGA,EGA,MCGA,VGA)      " + CHR$(179)
      LOCATE X + 5, Y: PRINT CHR$(179) + "      <2> 720 X 348 (HERC.)                " + CHR$(179)
      LOCATE X + 6, Y: PRINT CHR$(179) + "     <3> 640 X 350 (EGA,VGA) MULTISYNC II  " + CHR$(179)
      LOCATE X + 7, Y: PRINT CHR$(179) + "      <4> 640 X 480 (VGA)                  " + CHR$(179)
      LOCATE X + 8, Y: PRINT CHR$(179) + STRING$(45, 32) + CHR$(179)
      LOCATE X + 9, Y: PRINT CHR$(212) + STRING$(45, 205) + CHR$(190)
      LOCATE X + 10, Y: PRINT
      INPUT "                                Enter selection "; CH1
         IF CH1 = 1 THEN ECRAN = 2
         IF CH1 = 2 THEN ECRAN = 3
         IF CH1 = 3 THEN ECRAN = 9
         IF CH1 = 4 THEN ECRAN = 12
'
'  ------------------------------------
'  2. Open SET.PC file to store screen type information.
'  ------------------------------------
'
         OPEN "O", #4, "SET.PC"
         PRINT #4, ECRAN
         CLOSE (4)
END SUB
```

Subroutine FLOWA

```
SUB FLOWA (Q(), NYR, YR(), FLA1, MAX, MIN, QI(), FREQ())
' ==========================================================================
'
'                          Subroutine: FLOWA
'
'              This subroutine performs a flow duration analysis
'
' ==========================================================================
'
'   NDAY   : number of days for each year (365 or 366).
'   ANYR   : contains a value of 1 for specific years analyzed.
'   CNT    : counter for the number of observations for every QI.
'   CH1$   : choice for specific years or all years.
'   CH2$   : choice for specific seasons or annual analysis.
'   CH3$   : choice for specific years to analyzed.
'   CH4$   : choice to calculate discharges for given frequencies.
'   ISTART : day of the year for the beginning of season (1 for annual)
'   IEND   : day of the year for the end of season (365 for annual)
'   CSTART : corrected ISTART for leap years.
'   CEND   : corrected IEND for leap years.
'   INC    : increment of discharge between each exceedance prob.
'   SCOUNT : decreasing number indicating number of years analyzed to date.
'   INUMD  : counter for the total number of days.
'   NOMF1$ : name of output file.
'   P$     : exceedance probability.
'   P1     : numerical value of P$.
'   DIFF1  : increments involved in interpolations (also DIFF2 and DIFF3).
'
'===========================================================================
'
    DIM ANYR(100), NDAY(100), BMTH(12), EMTH(12), CNT(41)
'
'  ---------------------
'  1. Elimination of -1111.
'  ---------------------
'
      IF FLA1 = 0 THEN
      FOR N = 1 TO NYR
       KL1 = 0
        FOR J = 1 TO 372
         IF Q(N, J) = -1111 THEN
         ELSE
          KL1 = KL1 + 1
          Q(N, KL1) = Q(N, J)
'*          PRINT N, KL1, Q(N, KL1)
```

```
         END IF
        NEXT J
        NDAY(N) = KL1
'*        PRINT "N AND NDAY  "; N; NDAY(N)
        NEXT N
        END IF
        FLA1 = 1
'
'   ---------------------
'   2. Selection of specific years for the flow duration analysis (or all years).
'   ---------------------
'
        CLS 0:
        LOCATE 10, 10: PRINT "   Select specific years for the analysis (S)"
        LOCATE 11, 10: INPUT "   or select all years of record (A) "; CH1$
        PRINT
        IF CH1$ = "s" THEN CH1$ = "S"
        IF CH1$ = "a" THEN CH1$ = "A"
'
          FOR N = 1 TO NYR
          IF CH1$ = "S" THEN
            PRINT USING "            Do you want to analyze year #### "; YR(N)
            IF (ANYR(N - 1) = 0 AND N <> 1) THEN
             INPUT "             Default value = [N] "; CH3$
             IF CH3$ = "n" THEN CH3$ = "N"
             IF CH3$ = "" OR CH3$ = "N" THEN
             ANYR(N) = 0
             ELSE
             ANYR(N) = 1
             END IF
            ELSE
             INPUT "             Default value = [Y] "; CH3$
             IF CH3$ = "y" THEN CH3$ = "Y"
             IF CH3$ = "" OR CH3$ = "Y" THEN
             ANYR(N) = 1
             ELSE
             ANYR(N) = 0
             END IF
            END IF
          ELSE
           ANYR(N) = 1
          END IF
          NEXT N
'
'   ---------------------
'   3. Selection of specific season for the analysis (or annual).
'   ---------------------
'
         CLS
         LOCATE 10, 10: PRINT "Carry out flow duration analysis for a selected month or season (S)"
         LOCATE 11, 10: INPUT "or carry out the analysis for the whole year (A) "; CH2$
         IF CH2$ = "s" THEN CH2$ = "S"
         IF CH2$ = "a" THEN CH2$ = "A"
         IF CH2$ = "S" THEN
          CLS : LOCATE 10, 10: PRINT "Enter the day for the beginning of season and the end": PRINT
'
         PRINT USING "                January   ### - ###"; 1; 31
         PRINT USING "                February  ### - ###"; 32; 59
         PRINT USING "                March     ### - ###"; 60; 90
         PRINT USING "                April     ### - ###"; 91; 120
         PRINT USING "                May       ### - ###"; 121; 151
         PRINT USING "                June      ### - ###"; 152; 181
         PRINT USING "                July      ### - ###"; 182; 212
         PRINT USING "                August    ### - ###"; 213; 243
         PRINT USING "                September ### - ###"; 244; 273
         PRINT USING "                October   ### - ###"; 274; 304
         PRINT USING "                November  ### - ###"; 305; 334
         PRINT USING "                December  ### - ###"; 335; 365
         PRINT : PRINT
               INPUT "          Beginning of season "; ISTART
               INPUT "                End of season "; IEND
         ELSE
          ISTART = 1
          IEND = 365
         END IF
'
'
        MAX = 0
```

```
MIN = 9999
'
 FOR N = 1 TO NYR
 IF ANYR(N) = 1 THEN
   IF NDAY(N) = 366 THEN
    IF ISTART >= 60 THEN CSTART = ISTART + 1
    IF IEND >= 59 THEN CEND = IEND + 1
   ELSE
    CSTART = ISTART
    CEND = IEND
   END IF
  FOR J = CSTART TO CEND
    IF (Q(N, J) > MAX) AND (Q(N, J) <> -9999) THEN
   MAX = Q(N, J)
  END IF
  IF (Q(N, J) < MIN) AND (Q(N, J) <> -9999) THEN
   MIN = Q(N, J)
  END IF
  NEXT J
 END IF
 NEXT N
'
INC = (LOG(MAX) - LOG(MIN)) / 40!
 FOR I = 1 TO 41
  QI(I) = EXP((I - 1) * INC + LOG(MIN))
 NEXT I
'
 INUMD = 0
  FOR I = 1 TO 41
   CNT(I) = 0
  NEXT I
'
 FOR N = 1 TO NYR
  CLS 0: PRINT : PRINT : PRINT
  SCOUNT = NYR - N + 1
  LOCATE 12, 25: PRINT USING "Please Wait ... ###"; SCOUNT
  IF ANYR(N) = 1 THEN
     IF NDAY(N) = 366 THEN
      IF ISTART >= 60 THEN CSTART = CSTART + 1
      IF IEND >= 59 THEN CEND = CEND + 1
     ELSE
      CSTART = ISTART
      CEND = IEND
     END IF
   FOR J = CSTART TO CEND
    IF Q(N, J) <> -9999 THEN INUMD = INUMD + 1
    FOR L = 1 TO 41
     IF (Q(N, J) >= QI(L)) AND (Q(N, J) <> -9999) THEN CNT(L) = CNT(L) + 1
    NEXT L
   NEXT J
  END IF
 NEXT N
'
 CLS 0: LOCATE 10, 10: PRINT "   Enter name of output file (e.g. C:\station.FDA) ": PRINT
 INPUT "            ", NOMF1$
'
 OPEN "O", #2, NOMF1$
 PRINT #2, "          ***********************************"
 PRINT #2, "          *                                 *"
 PRINT #2, "          *      Flow Duration Anaysis      *"
 PRINT #2, "          *                                 *"
 PRINT #2, "          *      FLODUR : Version 1.0       *"
 PRINT #2, "          *                                 *"
 PRINT #2, "          ***********************************"
 PRINT #2,
 PRINT #2, USING "             Results data file = & "; NOMF1$
 PRINT #2,
 PRINT #2, USING "     Analysis carried out & at &"; DATE$; TIME$
 PRINT #2,
'
 PRINT #2, "   The following years of records were used in the analysis"
 PRINT #2,
 FOR N = 1 TO NYR
   IF ANYR(N) = 1 THEN
    SCNT = SCNT + 1
    PRINT #2, USING "                      Year ### = #### "; SCNT; YR(N)
   END IF
 NEXT N
```

```
        PRINT #2,
        PRINT #2,
'
       IF CH2$ = "A" THEN
         PRINT #2, "                    Annual Analysis"
         PRINT #2,
       ELSE
        IF CH2$ = "S" THEN
         PRINT #2, "                   Seasonal Analysis"
         PRINT #2,
         PRINT #2, USING "       From Julian day no. ### to day no. ###"; ISTART; IEND
         PRINT #2,
        END IF
       END IF
'
'
       CLS 0
       PRINT #2, "        ----------------------------------------"
       PRINT #2, "             Discharge            Frequency"
       PRINT #2, "        ----------------------------------------"
       PRINT #2,
'
       FOR L = 1 TO 41
        FREQ(L) = CNT(L) / (INUMD * 1!)
        IF L = 41 THEN FREQ(L) = 0
         PRINT #2, USING "           #####.###            ###.### "; QI(L); 100 * FREQ(L)
       NEXT L
'
'
              PRINT "         Discharge  Frequency    Discharge  Frequency": PRINT
       FOR L = 1 TO 20
        PRINT USING "         #####.###   ###.###     #####.###   ###.###"; QI(L); 100 * FREQ(L);
&QI(L + 20); 100 * FREQ(L + 20)
       NEXT L
        PRINT USING "                              #####.###   ###.###"; QI(41); 100 * FREQ(41)
          INPUT "     Press (Enter) to Continue"; CH$
          CLS 0
'
       PRINT #2,
       LOCATE 12, 20: PRINT USING "Number of Observations =######"; INUMD
       PRINT #2, "          -----------------------------------"
       PRINT #2, USING "           Number of Observations =######"; INUMD
       PRINT #2,
       PRINT USING "                  Maximum discharge = ####.###"; MAX
       PRINT USING "                  Minimum discharge = ####.###"; MIN
       PRINT #2, USING "           Maximum discharge = ####.###"; MAX
       PRINT #2, USING "           Minimum discharge = ####.###"; MIN
             PRINT #2, "         -----------------------------------"
       PRINT : PRINT : INPUT "                              Press (Enter) to Continue "; CH$
'
       CLS 0
       LOCATE 10, 6: INPUT "Do you wish to calculate discharges of given frequencies <Y or N>";
&CH4$
       PRINT
'
      IF CH4$ = "y" THEN CH4$ = "Y"
      IF CH4$ = "Y" THEN
       WHILE P$ <> "EX"
        INPUT "         Enter frequency in percentage (ex: 50 for 50%) or EX to exit"; P$
         IF P$ = "ex" THEN P$ = "EX"
        IF P$ <> "EX" THEN
         P1 = VAL(P$)
         P1 = P1 / 100
         IF P1 = 1 OR P1 = 0 THEN
          IF P1 = 0 THEN X = QI(41)
          IF P1 = 1 THEN X = QI(1)
          PRINT USING "          The flow for ### percent is ####.###"; P1 * 100; X
         ELSE
          FOR L = 1 TO 40
           IF FREQ(L) > P1 AND FREQ(L + 1) < P1 THEN
            DIFF1 = FREQ(L) - FREQ(L + 1)
            DIFF2 = QI(L + 1) - QI(L)
            DIFF3 = FREQ(L) - P1
            X = DIFF2 * (DIFF3 / DIFF1) + QI(L)
            PRINT USING "          The flow for ### percent is ####.###"; P1 * 100; X
           END IF
          NEXT L
         END IF
```

```
         END IF
        WEND
       END IF
        CLOSE (2)
END SUB
```

Subroutine GRAF1

```
SUB GRAF1 (MAX, MIN, SN(), SFRE()) STATIC
'============================================================================
'
'                            Subroutine: GRAF1
'
'            This subroutine graphs a flow duration curve following a
'            flow duration analysis.
'
'============================================================================
'
'                        Local variables:
'
'  MIN    : minimum discharge as calculated by FLOWA.
'  MAX    : maximum discharge as calculated by FLOWA.
'  SMIN   : selected minimum discharge.
'  SMAX   : selected maximum discharge.
'  AXE    : label for the y axis.
'  CH1$   : choice of new minimum or new maximum discharge.
'  ECRAN  : type of computer screen or graphics card.
'  SFRE   : equivalent to FREQ in main program.
'  SN     : equivalent to QI in main program.
'
'============================================================================
'
   DEFINT I
   DEFSNG S
   DEFSTR C
   DIM AXE(6)
'
'  ------------------------------------
'  1. Input maximum and/or minimum of Y axis or use existing values.
'  ------------------------------------
'
   SMAX = MAX
   SMIN = MIN
   CLS 0
   LOCATE 12, 15: PRINT "These are the maximum and minimum values for the Y axis": PRINT
   PRINT "                                 Maximum Discharge = "; SMAX
   PRINT "                                 Minimum Discharge = "; SMIN: PRINT
   INPUT "                          Do you want to keep these values <Y or N>"; CH1$
   IF CH1$ = "y" THEN CH1$ = "Y"
   IF CH1$ = "n" THEN CH1$ = "N"
'
     IF CH1$ = "N" THEN
      PRINT
      INPUT "                                 Enter new maximum :"; SMAX
      INPUT "                                 Enter new minimum :"; SMIN
      IF SMIN = 0 THEN
      CLS 0
      LOCATE 12, 23: PRINT "Error: new minimum value can not be 0": PRINT
      INPUT "                            Enter new minimum greater than 0 :"; SMIN
      END IF
     END IF
'
      SMIN = LOG(SMIN)
      SMAX = LOG(SMAX)
'
'  ------------------------------------
'  2. Get type of screen from SET.PC data file.
'  ------------------------------------
'
    OPEN "I", #4, "SET.PC"
    INPUT #4, ECRAN
    CLOSE (4)
    SCREEN ECRAN
'
'  ------------------------------------
'  3. Set X and Y factors depending on the type of screen
'  ------------------------------------
'
    X = 1
```

```
    Y = 1
'
     IF ECRAN = 3 THEN
     X = 1.125
     Y = 1.74
     END IF
     IF ECRAN = 12 THEN
     X = 1
     Y = 2
     END IF
     IF ECRAN = 9 THEN
     X = 1
     Y = 1.65
     END IF
'
'   ------------------------------------
'   4. Calculate labels for X and Y axes.
'   ------------------------------------
'
     CLS 0
     SINC = (SMAX - SMIN) / 5
     SFAC = 100 / (SMAX - SMIN)
      FOR L = 1 TO 6
       AXE(L) = SMAX - ((L - 1) * SINC)
      NEXT L
'
'   ------------------------------------
'   5. Draw border and print axes title.
'   ------------------------------------
'
     CLS 0
     LOCATE 7, 1: PRINT "D"
     LOCATE 8, 1: PRINT "I"
     LOCATE 9, 1: PRINT "S"
     LOCATE 10, 1: PRINT "C"
     LOCATE 11, 1: PRINT "H"
     LOCATE 12, 1: PRINT "A"
     LOCATE 13, 1: PRINT "R"
     LOCATE 14, 1: PRINT "G"
     LOCATE 15, 1: PRINT "E"
'
     LOCATE 2, 2: PRINT USING "###.#"; EXP(AXE(1))
     LOCATE 5, 2: PRINT USING "###.#"; EXP(AXE(2))
     LOCATE 9, 2: PRINT USING "###.#"; EXP(AXE(3))
     LOCATE 13, 2: PRINT USING "###.#"; EXP(AXE(4))
     LOCATE 17, 2: PRINT USING "###.#"; EXP(AXE(5))
     LOCATE 21, 2: PRINT USING "###.#"; EXP(AXE(6))
     LOCATE 22, 8: PRINT "0    10     20     30     40      50     60     70     80     90    100"
     IF ECRAN = 9 THEN
     LOCATE 3, 6: PRINT "                         Flow Duration Curve"
     ELSE
     LOCATE 1, 6: PRINT "                         Flow Duration Curve"
     END IF
     LOCATE 23, 2: PRINT "                        Percent of Time Equalled or Exceeded"
'
      IF ECRAN = 9 THEN
       LINE (50 * X, 1 * Y)-(611 * X, 164 * Y), , B          'BORDER
       VIEW (50 * X, 1 * Y)-(611 * X, 164 * Y)
       WINDOW (0, 0)-(100, 100)
      ELSE
       LINE (50 * X, 8 * Y)-(611 * X, 164 * Y), , B          'BORDER
       VIEW (50 * X, 8 * Y)-(611 * X, 164 * Y)
       WINDOW (0, 0)-(100, 100)
      END IF
'
'   ------------------------------------
'   6. Draws ticks for X and Y axes.
'   ------------------------------------
'
   FOR K = 1 TO 10
    X1 = (K - 1) * (100 / 10)
    LINE (X1, 0)-(X1, 2)
   NEXT K
    FOR K = 1 TO 5
     Y1 = (K - 1) * (100 / 5)
     LINE (0, Y1)-(2, Y1)
    NEXT K
'
```

```
'   -----------------------------------
'   7. Draws the flow duration curve.
'   -----------------------------------
'
     FOR J = 1 TO 40
       IF ECRAN = 12 OR ECRAN = 9 THEN
        LINE (SFRE(J) * 100, (LOG(SN(J)) - SMIN) * SFAC)-(SFRE(J + 1) * 100, (LOG(SN(J + 1)) - SMIN)
& * SFAC), 12
       ELSE
        LINE (SFRE(J) * 100, (LOG(SN(J)) - SMIN) * SFAC)-(SFRE(J + 1) * 100, (LOG(SN(J + 1)) - SMIN)
& * SFAC)
       END IF
      NEXT J
'
'   -----------------------------------
'   8. Reset screen to text type and exit subroutine.
'   -----------------------------------
'
     DO: LOOP WHILE INKEY$ = ""
     SCREEN 0
  END SUB
```

Subroutine IWDD

```
DEFSNG C, I
     SUB IWDD (Q(), NYR, YR())
'=========================================================================
'
'                            subroutine: IWDD
'
'    This subroutine reads daily flow records from an IWD (Inland Waters
'    Directorate) data file.  The format of the IWD data is described in
'    "Supplying Hydrometric and Sediment Data to Users" by Inland
'    Waters Directorate, Water Resources Branch, Ottawa, 1980
'
'=========================================================================
'
'                        Local variables:
'   TQ     : temporary discharge.
'   TTQ    : second temporary discharge.
'   A      : flag to identify first portion of missing month.
'   B      : flag to identify second portion of missing month.
'   C      : flag to identify third portion of missing month.
'   NANN   : year of previous line record.
'   NANN1  : year of present line record.
'   MOI1   : portion of the month of the present line record.
'
'=========================================================================
'
        DIM TQ(372), TTQ(11), A(12), B(12), C1(12)
'
'   -----------------------------------
'   1. Read station name, IWD data file, and output file name.
'   -----------------------------------
       CLS
       LOCATE 10, 18: PRINT "Enter input file name (ex:station.ENV) "
       LOCATE 12, 18: INPUT "", FILE1$
       PRINT
       OPEN "I", #1, FILE1$
'
'   -----------------------------------
'   2. Initializing variables and reading data from data file.
'   -----------------------------------
'
       FOR KM = 1 TO 12
       A(KM) = 0
       B(KM) = 0
       C1(KM) = 0
       NEXT KM
'
       NYR = 0
       NANN = 4000
'
       CLS
       LOCATE 10, 18: PRINT "Reading data file, please wait...": PRINT
       PRINT "                ";
       DO WHILE NOT EOF(1)
          IF NANN <> 4000 THEN
           PRINT ".";
```

```
    END IF
 NANN1 = NANN
 LINE INPUT #1, LINE$
 STAT$ = MID$(LINE$, 2, 7)
 NANN = VAL(MID$(LINE$, 9, 3))
 MOI1 = VAL(MID$(LINE$, 12, 3))
'
   IF NANN1 < NANN THEN
      NYR = NYR + 1
      YR(NYR) = NANN1 + 1000
      PRINT USING " Year ### = ####"; NYR; YR(NYR)
      PRINT "                  ";
    CALL TRANS(A(), B(), C1(), TQ())
'
    FOR L = 1 TO 372
    Q(NYR, L) = TQ(L)
    NEXT L
'
   END IF
'
'
  FOR L = 1 TO 11
    S = 15 + (L - 1) * 6
    TTQ(L) = VAL(MID$(LINE$, S, 5))
  NEXT L
'
'
     IF MOI1 = 11 THEN A(1) = 1
     IF MOI1 = 12 THEN B(1) = 1
     IF MOI1 = 13 THEN C1(1) = 1
     IF MOI1 = 21 THEN A(2) = 1
     IF MOI1 = 22 THEN B(2) = 1
     IF MOI1 = 23 THEN C1(2) = 1
     IF MOI1 = 31 THEN A(3) = 1
     IF MOI1 = 32 THEN B(3) = 1
     IF MOI1 = 33 THEN C1(3) = 1
     IF MOI1 = 41 THEN A(4) = 1
     IF MOI1 = 42 THEN B(4) = 1
     IF MOI1 = 43 THEN C1(4) = 1
     IF MOI1 = 51 THEN A(5) = 1
     IF MOI1 = 52 THEN B(5) = 1
     IF MOI1 = 53 THEN C1(5) = 1
     IF MOI1 = 61 THEN A(6) = 1
     IF MOI1 = 62 THEN B(6) = 1
     IF MOI1 = 63 THEN C1(6) = 1
     IF MOI1 = 71 THEN A(7) = 1
     IF MOI1 = 72 THEN B(7) = 1
     IF MOI1 = 73 THEN C1(7) = 1
     IF MOI1 = 81 THEN A(8) = 1
     IF MOI1 = 82 THEN B(8) = 1
     IF MOI1 = 83 THEN C1(8) = 1
     IF MOI1 = 91 THEN A(9) = 1
     IF MOI1 = 92 THEN B(9) = 1
     IF MOI1 = 93 THEN C1(9) = 1
     IF MOI1 = 101 THEN A(10) = 1
     IF MOI1 = 102 THEN B(10) = 1
     IF MOI1 = 103 THEN C1(10) = 1
     IF MOI1 = 111 THEN A(11) = 1
     IF MOI1 = 112 THEN B(11) = 1
     IF MOI1 = 113 THEN C1(11) = 1
     IF MOI1 = 121 THEN A(12) = 1
     IF MOI1 = 122 THEN B(12) = 1
     IF MOI1 = 123 THEN C1(12) = 1
'
  FOR K = 1 TO 11
     IF MOI1 = 11 THEN LM = K
     IF MOI1 = 12 THEN LM = K + 10
     IF MOI1 = 13 THEN LM = K + 20
     IF MOI1 = 21 THEN LM = K + 31
     IF MOI1 = 22 THEN LM = K + 41
     IF MOI1 = 23 THEN LM = K + 51
     IF MOI1 = 31 THEN LM = K + 62
     IF MOI1 = 32 THEN LM = K + 72
     IF MOI1 = 33 THEN LM = K + 82
     IF MOI1 = 41 THEN LM = K + 93
     IF MOI1 = 42 THEN LM = K + 103
     IF MOI1 = 43 THEN LM = K + 113
     IF MOI1 = 51 THEN LM = K + 124
```

```
          IF MOI1 = 52 THEN LM = K + 134
          IF MOI1 = 53 THEN LM = K + 144
          IF MOI1 = 61 THEN LM = K + 155
          IF MOI1 = 62 THEN LM = K + 165
          IF MOI1 = 63 THEN LM = K + 175
          IF MOI1 = 71 THEN LM = K + 186
          IF MOI1 = 72 THEN LM = K + 196
          IF MOI1 = 73 THEN LM = K + 206
          IF MOI1 = 81 THEN LM = K + 217
          IF MOI1 = 82 THEN LM = K + 227
          IF MOI1 = 83 THEN LM = K + 237
          IF MOI1 = 91 THEN LM = K + 248
          IF MOI1 = 92 THEN LM = K + 258
          IF MOI1 = 93 THEN LM = K + 268
          IF MOI1 = 101 THEN LM = K + 279
          IF MOI1 = 102 THEN LM = K + 289
          IF MOI1 = 103 THEN LM = K + 299
          IF MOI1 = 111 THEN LM = K + 310
          IF MOI1 = 112 THEN LM = K + 320
          IF MOI1 = 113 THEN LM = K + 330
          IF MOI1 = 121 THEN LM = K + 341
          IF MOI1 = 122 THEN LM = K + 351
          IF MOI1 = 123 THEN LM = K + 361
'
          TQ(LM) = TTQ(K)
'
       NEXT K
'
       LOOP
          NYR = NYR + 1
          YR(NYR) = NANN1 + 1000
          PRINT ".";
          PRINT USING " Year ### = ####"; NYR; YR(NYR)
         CALL TRANS(A(), B(), C1(), TQ())
'
         FOR L = 1 TO 372
         Q(NYR, L) = TQ(L)
         NEXT L
'
         CLOSE (1)
'
END SUB
```

Subroutine TRANS

```
 SUB TRANS (A(), B(), C1(), TQ())
'=======================================================================
'
'                          Subroutine: TRANS
'
'     This portion of the program is executed only when the year changes.
'     It identifies missing months and adds -9999 for every missing day.
'
'=======================================================================
'
'                        Local variables: see IWDD
'
'=======================================================================
'
'  ------------------------------------
'  1. Adds -9999 for months of missing data.
'  ------------------------------------
'
       FOR KL = 1 TO 12
        IF A(KL) <> 1 THEN
         FOR KL1 = 1 TO 10
          JE = (KL - 1) * 31 + KL1
          TQ(JE) = -9999
         NEXT KL1
        END IF
'
         IF B(KL) <> 1 THEN
          FOR KL1 = 1 TO 10
           JE = (KL - 1) * 31 + KL1 + 10
           TQ(JE) = -9999
          NEXT KL1
         END IF
'
        IF C1(KL) <> 1 THEN
```

```
          FOR KL1 = 1 TO 11
           JE = (KL - 1) * 31 + KL1 + 20
           TQ(JE) = -9999
          NEXT KL1
         END IF
        NEXT KL
'
        FOR KM = 1 TO 12
         A(KM) = 0
         B(KM) = 0
         C1(KM) = 0
        NEXT KM
'
'  ------------------------------------
'  2.  For the months smaller than 31 days, fictive values of -1111
'      are entered to complete the 31 day month.
'  ------------------------------------
'
       FOR L = 1 TO 372
        IF L = 60 AND TQ(L) = -9999 THEN TQ(L) = -1111
        IF L = 61 AND TQ(L) = -9999 THEN TQ(L) = -1111
        IF L = 62 AND TQ(L) = -9999 THEN TQ(L) = -1111
        IF L = 124 AND TQ(L) = -9999 THEN TQ(L) = -1111
        IF L = 186 AND TQ(L) = -9999 THEN TQ(L) = -1111
        IF L = 279 AND TQ(L) = -9999 THEN TQ(L) = -1111
        IF L = 241 AND TQ(L) = -9999 THEN TQ(L) = -1111
       NEXT L
'
END SUB
```