HYDROLOGICAL DATABASE

FOR

MICRO-COMPUTERS

HYDROLOGICAL DATABASE FOR MICRO-COMPUTERS

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December 1985

CONTENTS

Introduction

This note describes the design philosophy and implementation of the Hydrological Database system developed at the Institute of Hydrology primarily for use on micro-computers.

The system is designed for use either in developing countries or for project use where low cost and ease of use are of particular importance. Micro-computers offer a means of satisfying these goals by providing a cheaper, more robust, reliable and easy to use alternative than mainframe machines. Furthermore the quantities of data involved often do not require mainframe mass storage.

One of the most important design criteria for the system has been ease of use for operators. This is particularly important for staff with limited or no experience of computers. This challenge has been met by extensive use of screen menus, adopting an interactive approach throughout and with error checking of each operator response. In order to allow staff to concentrate on the scientific aspects of operation, the systems have been designed to be self contained and to require minimum knowledge of the computer operating system and datafile structure. Both on screen and plotter graphics aid data interpretation.

The database manager, which is transparent to the user, consists of a set of storage and retrieval routines which were originally developed at the Institute of Hydrology for mainframe storage of hydrological data. Under this database manager, data is owned by stations. Among other applications, these routines are used in the U.K. Surface Water Archive system. They have since been successfully transferred for micro-computer application.

The system is written in FORTRAN which aids portability and provides relatively fast execution speeds. A FORTRAN library is available to enable users to abstract data directly for use in their own analysis or modelling programs. CPM/86 and MS-DOS versions cover a wide range of 16 bit micro-computers.

The system currently supports six types of stations:

(1) River stage or lake level data (maximum 100 readings/day/station)
(2) Rating data (maximum 333 gaugings, 20 rating equations/station)
(3) Flow data (stored on a daily basis)
(4) Rainfall data (stored on a daily basis)
(5) General daily data (eg catchment rainfall)
(6) Storage data (reservoir storage on a daily basis).

Gauging information comprises date, water level, cross sectional area and estimated discharge. Rating equations are stored as three parameter and up to three segment logarithmic relationships. Interactive graphical techniques are used to develop rating equations from discharge measurements.

Associations may be set up linking river stage stations through rating stations to enable direct computations of mean daily flows or reservoir storage.

One important aspect of any hydrological database is the validation of data. This is particularly important in developing countries. Four methods are used in this system:

(1) Dual source entry on stage data. Primary source solid state loggers, for example, may be checked against observer staff readings or bridge dips.

(2) Simple numeric check against station maximum, minimum and change since last reading before acceptance.

(3) Immediate access to screen graph for visual checking.

(4) Statistical checks against similar stations. This is at present done outside the system using a commercial statistical package (eg. MINITAB). Future development will include some in-built analysis programs.

A recognition of the quality of source of the data is important when data are to be used for analysis. This is allowed for by the ability of the system to flag individual daily values as good (original data) or poor (estimated data). Thus 'holes' in the original data may be filled by modelling, whilst retaining the ability to abstract on original data at a later date.

At present there is a limit of 1000 stations on the system and data is required to come from this century. Data may be stored in calendar or hydrological years. The choice of start month is made during the installation of the system.

A primary requirement of any hydrological database system is to produce 'yearbook' type summaries of daily data for publication. In addition to this the system produces monthly summaries, graphical summaries and data in ASCII text form for transfer on floppy disc to other machines. The later form of data availability is of benefit to consultants involved in design projects who require data in a convenient computer compatible form for analysis.

The system has been used in consultancy studies in Thailand and is currently in operation in Somalia where it is used to maintain the national surface water archive. The system is also used by the Institute of Hydrology for in-house studies.

General Operation

Entry to the system is protected by password to help safeguard data. Passwords can have one of three levels of authority. The lowest level permits interrogation of data, printing, plotting and transfer to text file. The next password levels allows data to be modified and the results saved. The highest level allows all operations including addition of new stations and deletion of data.

The system is operated by a system of screen menus giving the options available at any particular point in the system. For example the plotting menu for daily flow data is as follows:

```
[1]  Quit
[2]  Start date     [Jan 1]
[3]  End date       [Dec 31
[4]  Max value      [200.0]
[5]  Min value      [0.0]
```

[6] Colour [Yes]
[7] A3/A4 [A4]
[8] Plot edits [No]
[9] Draw grid [Yes]
[10] Key position [2]
[11] Histogram [No]
[12] Change more
[13] Paper plot
[14] Screen plot

If a plot of data was required for the month of January only, the operator would first select [3] and enter Jan 31 followed by either option [13] or [14] depending on whether the plot was required on the screen or the pen plotter. At every stage the operator response is checked and an informative error message given if a mistake is made. In the above example if option [5] was selected and a minimum value of 300.0 entered the following error message would appear:

ERROR Maximum must be greater than minimum.

Any of three special characters may be entered at any point while the system is waiting for operator response. Firstly '*' instructs the system to abort the current operation or menu. This is useful if the wrong menu option is selected inadvertently. Secondly '!' closes all files and terminates database activities and finally '@' switches all input from the screen to an input file.

The '@' option provides an easy means of entering data from an external source onto the database. The operator simply prepares a text file of data, enters the database system and types '@' at the correct point and data are read in with all quality checks being applied. A second use of the '@' command is in multiple operations. Here a text file is prepared containing the appropriate menu selections on the computer editor or word processor. The data base is then entered and '@' typed at the correct point. Commands from the datafile are then processed in the same way as if they had been entered by the operator.

In addition the database system may be called from an external FORTRAN program. This facility is useful when data are transferred from an external source. For example a FORTRAN program concerned with the retrieval of data from electronic loggers or digitisation of charts can prepare data for transfer and start execution of the database system and control its operation by commands and data stored in the '@' file.

If the data entry requirement is greater than possible on a single machine the '@' facility provides a method of linking computers. The main database is held on a master machine with adequate storage for the whole system. The database programs are also installed on any number of compatible computers (maybe in regional offices). Data may then be transferred on floppy discs to the master machine. This transfer is straightforward since the database system writes data to text files in exactly the same format as it would be entered by the operator or read in using the '@' command.

Security and integrity of data are important considerations of any system. The system provides a menu operated facility for data backup onto floppy discs and also a data restore facility should it be necessary to return to an earlier copy of the data. For large amounts of data it is possible that some database files would be greater that the maximum capacity of a floppy disc. The backup system has the ability to split files over any number of backup discs and join them together again during data restore.

A system summary may be requested at any time to provide a list of stations on the system, the station details such as name, latitude and longitude and period of data on the system.

Station numbers may be from one to eight digits (1 - 99999999). It is possible to have the same station number for different types of station; for example stage station 100, rating station 100 and daily flow 100 are allowed. Characters, however, are not permitted in this station number. Station numbers may be changed later if required.

3. Edit display facilities

Editors are provided for all types of data stored on the system. The appropriate editor for a particular station type is selected by menu operation as described above in Section 2. Editors cover a wide range of functions:

(a) Entry and quality control of data.

(b) Printouts of data.

(c) Plotting of data.

(d) Conversion of storage to flow (or storage volume) (Storage data editor only).

(e) Writing of data to text-files.

(f) Changing station details such a number, name, altitude etc.

For all but rating data, the operator selects data to be edited by station year. Immediate access is then provided to 12 months of data. Since plotting is available within the editor it is possible to check data entered by plotting a graph before 'saving' the results onto disc. Quality control checks are applied on data as they are entered. Checks are made against preset station maxima and minima and against unatural jumps between readings. The staff gauge editor also permits conversion of storage to flow (or volume) either as data are entered or at a later date. In addition, if an independent graphics screen is fitted to the system, the stage editor is able to plot data as they are entered in the form of a scrolling hydrograph.

Comments of up to 32 characters in length may be stored with each month of data (stage, flow, rainfall, storage or general). This facility may be removed for any or all station types to save disc space.

The rating data editor has access to all discharge measurements and rating equations for the station and has the ability to develop 3 segment, 3 parameter rating equations for any sub set of the discharge measurements. The rating equations are of the form:

$$Q = a_1(h + c)^{b_1} \quad h < h_1$$
$$a_2(h + c)^{b_2} \quad h_2 > h > h_1$$
$$a_3(h + c)^{b_3} \quad h_3 > h > h_2$$

where Q = discharge $m^3 s^{-1}$

h = stage m

$a_1, a_2, a_3, b_1, b_2, b_3, c$ = parameters

One or two segment curves may be fitted if more appropriate.

There may be up to 332 discharge measurements and 20 rating equations for each station. Rating equations are date marked. When calculating daily mean flow, the stage data editor automatically selects the correct rating equation for each station and day. Rating tables may be produced from the rating data editor.

Example printout and plots are given in Section 5.

4. System requirements

A sixteen bit micro-computer is required with at least 256 k bytes memory. If more than 24 stage readings/day are being stored, 512 k bytes memory is needed. The programs themselves occupy approximately 1M byte but are split into a number of modules which allow them to run under the smaller memory requirements given above. (Switching between modules is transparent to the user). The computer should run under CPM86, MS-DOS or PC-DOS operating systems.

A hard disc is recommended for all applications because this allows all program modules to be present and available to the user, provides larger amounts of storage space for data, and provides considerably faster execution. The only possible application for a floppy-disc machine would be as a second data entry station (see Section 2.).

The disc storage requirements may be calculated from the following figures. It should be noted that space is allocated in yearly blocks.

Each station	500 bytes
One stage reading	2 bytes
One flow reading	4 bytes
One rainfall reading	2 bytes
One general reading	4 bytes
One storage reading	4 bytes
Gauging and rating data	1302 bytes
One year of comments	97 bytes

Records need not be continuous. If, for example, a station was not operational for 10 years, disc space could be saved by avoiding allocating space for those 10 years.

As an example assume it is required to store data from 100 stations recording 4 stage readings per day for 20 years. There are rating equations at each station and daily mean flows are also to be stored. Comments are to be stored on stage but not flow data.

	Bytes
300 stations (100 stage, 100 ratings, 100 flow) at 500 bytes	150,000
2000 station years of stage data. 4 readings/day = 8 bytes/day 366 day/year = 2928 bytes/year	5,856,000
100 sets of discharge measurements and ratings at 1302 bytes	130,200
2000 station years of daily flow data 4 bytes/day = 1464 bytes/year	2,928,000
2000 station years of comment on stage data 97 bytes/year	194,000
Total	9,258,200

In the above example over 9 M bytes are required for data storage and 1 M byte to store programs. A suitable hard disc unit would be 15 M byte to 20 M byte unit depending on requirements for other work on the computer.

The system uses direct screen addressing to control the computer display. It is important that the computer or terminal is able to support this facility. However, only the following features of screen control are required.

(1) Clear entire screen
(2) Position cursor at a specified line and column number
(3) Inverse video (on/off)
(4) Bold/dim characters (on/off) (Optional).

If the screen is able to display in colour, features (3) and (4) above may be replaced with change background colour and alternate colour respectively. The sequence of characters required to operate these screen control features varies from machine to machine. The database system offers a fairly flexible means of screen addressing which may be adapted to suit many machines without the need to re-compile the programs.

Information about the method of screen addressing and the special characters sequences are held in an installation file which may be edited to suit a particular machine. The screen display must be at least 80 columns wide by at least 24 lines long.

The database system supports both screen and plotter graphics. However because of the lack of any universal standard in graphics in the computer industry, it is not possible to state whether the system will operate without a knowledge of the proposed installation. The database uses the GINO graphics language which will operate a number of screen and plotting devices, but a potential user is advised to contact the Institute of Hydrology for advice on any particular device.

Example printout and plot

Examples of the print and plot output of the hydrological database are given in this section. These do not represent the full range of output available but illustrate some of the possible options.

Printed output is designed to be copyable onto A4 or quarto sized paper. This is useful if output is required for yearbook presentation or for inclusion in reports.

Plotter output may be produced in single or multi colour. If single colour is selected dashed lines replace lines of different colour. Although all plots shown are A4 size, A3 plots can also be produced. In fact plots of almost any size up to A3 can be produced by changing overall scaling factors. This is useful if a small plot is required for inclusion with text in a report. Many of the plotting parameters such as origin position, axis length and letter size are held in the installation file which may be changed to suit the user's preferred format. Screen graphics are identical to plotter graphics except screen resolution is normally less than can be achieved on a pen plotter.

The tables following illustrate various print out options:

Table 1 List of stations and parameters
(Part of table)

Table 2 File allocation and usage for stage stations

Table 3	Summary of stage data for one year
Table 4	Annual summary of daily mean flow data
Table 5	List of discharge measurements (Part of table)
Table 6	Rating table (Part of table)

The following figures illustrate some of the plotting possibilities:

Figure 1	Annual stage hydrograph (black and white)
Figure 2	Histogram of annual daily flows (colour)
Figure 3	Four month flow hydrograph (black and white) (plotting period may be from 1 day to 1 year)

Table 1

List of stations & parameters

Type	Number	Name	Basin No.	Latitude	Longitude	Altitude	Area	Max value	Min value	Max change	Data Format	Co-Rating	Co-Flow
Stage	1	Jubba at Lugh Ganana	1	0: 0: 0 N	0: 0: 0 E	141.42	179000.	7.5	-1.0	3.0	1	1	1
Stage	2	Jubba at Bardheere	1	0: 0: 0 N	0: 0: 0 E	88.98	216730.	7.0	-1.0	2.0	1	2	2
Stage	3	Jubba at Jamame	1	0: 0: 0 N	0: 0: 0 E	0.0	268800.	7.5	-2.0	1.5	1	3	3
Stage	6	Juba at Kamsuma	1	0: 0: 0 N	0: 0: 0 E	0.0	1000.0	6.0	0.0	2.0	1	6	6
Stage	10	Shebelli at Beled Weyn	2	0: 0: 0 N	0: 0: 0 E	176.11	211800.	7.0	-1.0	2.5	1	10	10
Stage	11	Shebelli at Bulo Burti	2	0: 0: 0 N	0: 0: 0 E	133.39	231000.	10.0	-1.0	2.0	1	11	11
Stage	12	Shebelli at Mahaddey Weyn	2	0: 0: 0 N	0: 0: 0 E	104.57	255300.	7.0	-1.0	2.0	1	12	12
Stage	14	Shebelli at Afgoi	2	0: 0: 0 N	0: 0: 0 E	77.42	278000.	6.0	0.0	2.0	1	14	14
Stage	15	Shebelli at Audegle	2	0: 0: 0 N	0: 0: 0 E	70.05	280000.	6.45	-2.0	2.5	1	15	15
Stage	101	Jowhar Reservoir Level (gauge H)	2	0: 0: 0 N	0: 0: 0 E	99.5	999.0	5.0	0.0	1.0	1	0	0
Stage	102	Jowhar OSR - Shebelle d/s intake	2	0: 0: 0 N	0: 0: 0 E	103.5	255400.	6.0	0.0	2.0	1	102	102
Stage	103	Jowhar OSR supply canal/Gauge F	2	0: 0: 0 N	0: 0: 0 E	103.5	999.0	6.0	0.0	1.0	1	103	103
Stage	104	Jowhar OSR outlet canal/Gauge I	2	0: 0: 0 N	0: 0: 0 E	0.0	1000.0	6.0	0.0	0.5	1	104	104
Stage	105	Jowhar OSR - Shebelli d/s outlet	2	0: 0: 0 N	0: 0: 0 E	0.0	264000.	6.0	0.0	2.0	1	105	105
Rating	1	Jubba at Lugh Ganana	1	0: 0: 0 N	0: 0: 0 E	141.42		7.5	1.0				
Rating	2	Jubba at Bardheere	1	0: 0: 0 N	0: 0: 0 E	88.98		7.0	-1.0				
Rating	3	Jubba at Jamame	1	0: 0: 0 N	0: 0: 0 E	0.0		7.5	0.0				
Rating	6	Juba at Kamsuma	1	0: 0: 0 N	0: 0: 0 E	0.0		6.0	0.0				
Rating	10	Sebelli at Beled Weyn	2	0: 0: 0 N	0: 0: 0 E	176.11		7.0	-1.0				
Rating	11	Shebelli at Bulo Burti	2	0: 0: 0 N	0: 0: 0 E	133.39		10.0	0.0				
Rating	12	Shebelli at Mahaddey Weyn	2	0: 0: 0 N	0: 0: 0 E	104.57		7.0	0.0				
Rating	14	Shebelli at Afgoi	2	0: 0: 0 N	0: 0: 0 E	77.42		7.0	-1.0				
Rating	15	Shebelli at Audegle	2	0: 0: 0 N	0: 0: 0 E	70.05		6.5	0.0				
Rating	102	Jowhar OSR - Shebelle d/s intake	2	0: 0: 0 N	0: 0: 0 E	103.5		6.0	0.0				
Rating	103	Jowhar OSR supply canal/Gauge F	2	0: 0: 0 N	0: 0: 0 E	103.5		6.0	0.0				
Rating	104	Jowhar OSR outlet canal/Gauge I	2	0: 0: 0 N	0: 0: 0 E	0.0		6.0	0.0				
Rating	105	Jowhar OSR - Shebelli d/s outlet	2	0: 0: 0 N	0: 0: 0 E	0.0		6.0	0.0				
Flow	1	Jubba at Lugh Ganana	1	0: 0: 0 N	0: 0: 0 E	141.42	179000.	2000.0	0.0	250.0			
Flow	2	Jubba at Bardheere	1	0: 0: 0 N	0: 0: 0 E	88.98	216730.	2000.0	0.0	250.0			
Flow	3	Jubba at Jamame	1	0: 0: 0 N	0: 0: 0 E	0.0	268800.	1000.0	0.0	200.0			

File allocation & usage for Stage stations

YEAR

Station	1900-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990 - 2000	
	0123456789	0123456789	0123456789	0123456789	0123456789	0123456789	0123456789	0123456789	0123456789	0123456789	0
1	----------	----------	----------	----------	----------	-ddddddddd	dddddddddd	dddddddddd	ddddddxxxx	x---------	-
2	----------	----------	----------	----------	----------	-.........	...dddddxd	dddddxddxx	ddxxddxxxx	x---------	-
3	----------	----------	----------	----------	----------	-.........	...ddddxxx	dxdddddddd	ddxddd....	.---------	-
6	----------	----------	----------	----------	----------	-.........	....	....	xxxxx	x---------	-
10	----------	----------	----------	----------	----------	-ddxdddddd	dddddddddd	dddddddddd	ddddddxxxx	x---------	-
11	----------	----------	----------	----------	----------	-.........	...ddddddd	dddddxdddd	ddddddxxxx	x---------	-
12	----------	----------	----------	----------	----------	-.........	...ddddddd	ddxxdddddd	ddddddxxxx	x---------	-
14	----------	----------	----------	----------	----------	-.........	...ddddddd	dddddddddd	ddddddxxxx	x---------	-
15	----------	----------	----------	----------	----------	-.........	...ddddddx	xdxxxxdddd	ddddddxxxx	x---------	-
101	----------	----------	----------	----------	----------	-.........	....	....	dddddxxxxx	x---------	-
102	----------	----------	----------	----------	----------	-.........	....	....	dddxxxxxxx	x---------	-
103	----------	----------	----------	----------	----------	-.........	....	....	xxxxxxxxxx	x---------	-
104	----------	----------	----------	----------	----------	-.........	....	....	xxxxxxxxxx	x---------	-
105	----------	----------	----------	----------	----------	-.........	....	....	xxxxxxxxxx	x---------	-

Key :

- = outside project period
. = inside project period
x = space allocated - no data
d = space allocated - data on

Summary of stage data

Station number

Name : Shebelli at Beled Weyn

Basin no. : 2
Longitude : 0: 0: 0 E
Area : 211800.
Min. value : -1.0
Data format: 1
Co-flow : 10

Latitude : 0: 0: 0 N
Altitude : 176.11
Max. value : 7.0
Max. change: 2.5
Co-rating : 10

Year : 1964

2 Readings @ times :

8:00:00 18:00:00

Monthly & annual maxima & minima

Month	First maximum			First minimum			Days
	Stage	Date	Time	Stage	Date	Time	Missing
Jan	1.130	1	8:00:00	0.770	31	18:00:00	0
Feb	0.760	1	8:00:00	0.420	26	18:00:00	0
Mar	0.410	1	8:00:00	0.200	26	8:00:00	0
Apr	1.310	30	8:00:00	0.180	6	18:00:00	0
May	1.350	1	8:00:00	0.650	30	18:00:00	1
Jun	0.770	15	18:00:00	0.500	11	8:00:00	0
Jul	1.430	29	8:00:00	0.670	1	18:00:00	0
Aug	3.310	31	18:00:00	1.350	3	8:00:00	0
Sep	3.500	30	18:00:00	2.560	10	8:00:00	0
Oct	3.550	2	8:00:00	2.180	16	8:00:00	0
Nov	3.550	3	8:00:00	0.770	30	8:00:00	0
Dec	1.450	31	18:00:00	0.580	12	8:00:00	0
Annual	3.550	2 Oct	8:00:00	0.180	6 Apr	18:00:00	

Stage readings in metres

Table 3

Annual summary of daily data - Flow

Station number : 10 Name : Shebelli at Beled Weyn

Basin no. : 2 Latitude : 0: 0: 0 N Longitude : 0: 0: 0 E Altitude : 176.11
Area : 211800. Max. value : 800.0 Min. value : 0.0 Max. change: 200.0

Year : 1964

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	40.995	24.407	11.759	6.051	51.08	20.125	21.14	57.352	212.83	227.25	221.86	24.243
2	39.626	23.577	11.73	5.921	48.321	19.581	21.538	56.464	215.6	230.61	227.55	24.422
3	38.897	22.759	11.587	5.921	48.175	18.481	23.903	54.132	215.78	230.81	230.52	25.902
4	38.194	21.952	11.402	5.921	45.628	17.392	26.952	54.098	213.67	230.81	228.22	25.8
5	37.903	21.337	11.124	5.812	44.116	16.797	28.332	57.146	204.23	230.53	218.68	24.323
6	37.474	20.763	10.819	5.577	43.901	16.457	27.618	59.414	179.7	225.72	206.0	24.141
7	37.156	20.162	10.518	5.451	40.858	16.241	26.353	62.624	164.98	222.2	177.85	23.347
8	35.03	19.621	10.22	5.451	40.166	15.588	25.037	66.22	150.09	215.73	135.25	21.995
9	35.771	19.031	9.941	5.451	39.918	15.346	24.367	70.038	142.92	203.94	103.06	21.854
10	38.226	18.279	9.78	5.622	36.094	15.033	23.267	73.915	140.36	185.43	87.734	20.506
11	41.341	17.856	9.491	7.381	36.419	14.763	22.742	78.06	141.71	166.96	76.665	19.387
12	40.692	17.229	9.32	14.061	33.775	15.892	22.752	81.158	142.62	146.09	71.718	17.822
13	39.585	16.943	8.949	33.699	31.904	19.075	25.474	84.579	142.71	132.6	66.954	18.358
14	34.236	16.598	8.643	39.463	30.063	23.262	28.607	88.29	143.37	117.79	61.599	18.232
15	36.155	16.082	8.368	41.759	26.735	24.694	29.472	91.512	142.53	111.0	57.71	18.454
16	37.334	15.729	8.22	39.817	24.071	24.978	28.79	96.292	141.1	109.36	53.088	18.449
17	37.408	15.203	8.205	37.402	23.167	24.554	28.535	101.43	141.71	109.81	49.565	18.765
18	37.803	14.4	7.961	36.909	22.56	23.016	30.034	111.89	144.34	110.23	46.452	19.071
19	37.402	14.317	7.588	36.014	22.5	21.392	33.996	120.94	149.16	120.79	43.085	18.938
20	36.684	14.012	7.421	32.386	22.157	20.609	37.911	129.48	152.01	130.92	40.502	18.192
21	35.708	13.696	7.302	30.643	22.119	20.356	42.483	141.28	158.81	137.29	38.009	19.586
22	34.473	13.513	7.161	31.924	22.721	20.188	42.973	149.9	170.11	145.65	35.55	19.969
23	32.703	13.184	7.044	24.419	24.151	20.873	43.725	158.65	177.67	153.98	33.168	19.39
24	32.117	12.858	6.892	22.837	25.499	21.304	45.421	170.11	185.49	158.14	32.116	18.505
25	30.961	12.535	6.638	22.506	25.587	22.07	47.112	177.52	192.86	170.11	30.8	19.182
26	29.663	12.216	6.212	25.345	24.049	23.033	50.711	182.12	203.0	177.52	29.458	27.027
27	28.724	12.044	6.406	33.751	22.613	22.393	53.766	187.9	211.86	182.49	28.435	35.751
28	27.838	12.044	6.406	41.112	21.875	21.574	56.358	193.64	215.86	189.0	27.246	40.204
29	26.964	12.027	6.294	48.909	21.018	21.14	58.391	196.64	220.43	197.99	26.659	47.499
30	26.1		6.162	51.381	20.394	21.107	58.56	202.14	224.38	207.94	25.118	52.521
31	25.248		6.162		20.259?		58.021	206.57		215.58		57.873
Mean	35.11	16.703	8.5718	23.63	31.029	19.91	35.301	114.89	174.73	174.01	90.354	25.152
Maximum	41.341	24.407	11.759	51.381	51.08	24.978	58.56	206.57	224.38	230.81	230.52	57.873
Minimum	25.248	12.027	6.162	5.451	20.259	14.763	21.14	54.098	140.36	109.36	25.118	17.822
R/off mm	0.444	0.19759	0.1084	0.28918	0.39239	0.24366	0.44642	1.4528	2.1383	2.2005	1.1057	0.31807

Flows in cubic metres per second

Annual statistics

Maximum 230.805 Minimum 5.451 Mean 62.538 cubic metres per second

Total 1977.604 milllion cubic metres Runoff 9.337 millimetres

Possible data flags

Data missing - flag "-" Original data - no flag set Estimated data - flag "?"

Discharge measurements for station 11 : Shebelli at Bulo Burti

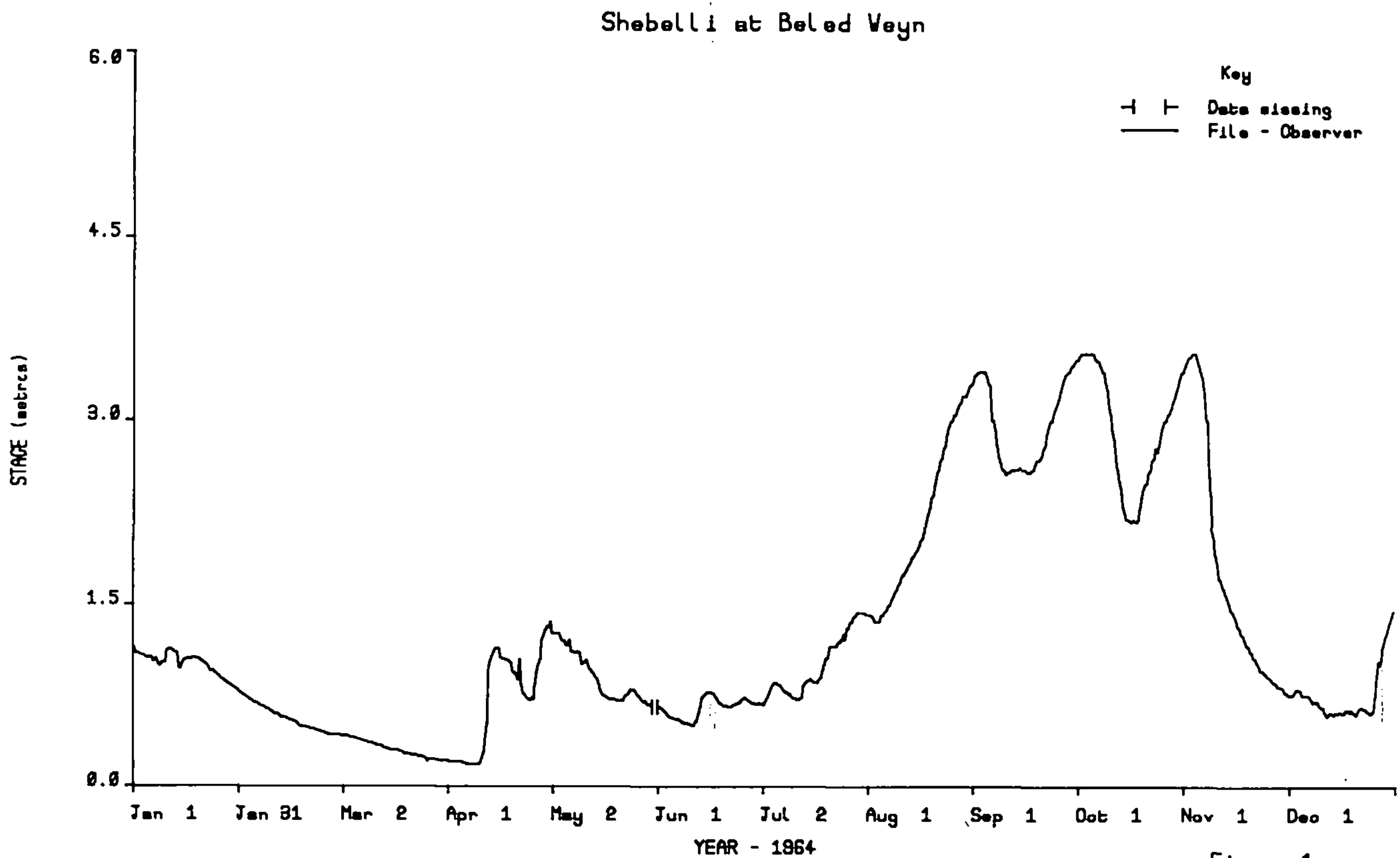
Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	10 May 1963	A	5.93	1.045	200.11	209.120
2	16 Jun 1963	A	3.16	1.191	61.12	72.790
3	7 Jul 1963	A	2.67	0.653	65.44	42.730
4	8 Aug 1963	A	3.60	0.854	99.67	85.120
5	30 Aug 1963	A	4.37	1.008	128.67	129.700
6	9 Oct 1963	A	3.69	1.024	94.53	96.800
7	12 Nov 1963	A	2.45	0.665	47.11	31.330
8	8 Dec 1963	A	3.22	0.861	100.13	86.210
9	23 Dec 1963	A	3.24	0.822	99.17	81.520
10	5 Jan 1964	A	2.40	0.758	54.25	41.120
11	23 Jan 1964	A	2.32	0.727	48.86	35.520
12	8 Feb 1964	A	1.95	0.571	27.53	15.720
13	5 Mar 1964	A	1.90	0.489	17.12	8.370
14	20 Apr 1964	A	2.48	0.706	57.97	40.930
15	27 Apr 1964	A	1.94	0.548	43.18	23.660
16	26 May 1964	A	2.04	0.705	44.85	31.620
17	17 Jun 1964	A	2.05	0.701	40.86	28.640
18	3 Aug 1964	A	3.05	0.768	81.99	62.970
19	25 Aug 1964	A	4.57	1.013	147.70	149.620
20	4 Nov 1964	A	5.23	1.103	172.98	190.800
21	9 Mar 1965	A	1.58	0.528	13.11	6.920
22	27 Sep 1965	?	2.83	0.274	73.20	20.056
23	17 Nov 1965	A	3.33	0.745	92.51	68.920
24	19 Mar 1969	A	4.14	0.848	137.44	116.550
25	2 Nov 1969	A	2.53	0.802	59.99	48.110
26	26 Nov 1969	A	1.83	0.723	35.15	25.410
27	3 Mar 1971	A	1.23	0.480	13.75	6.600
28	26 Dec 1971	A	1.69	0.613	33.61	20.600
29	24 May 1972	A	4.28	1.064	120.00	127.680
30	29 Feb 1980	B	1.00	0.375	11.55	4.330
31	8 Mar 1980	B	0.97	0.334	17.60	5.880
32	18 Apr 1980	B	0.85	0.263	6.54	1.720
33	9 May 1980	B	4.04	1.024	130.22	133.350

Rating table for station 11 : Shebelli at Bulo Burti

Rating B from 1 Jan 1976 Q = 19.450 (h - 0.620) ** 1.517 to 10.00 m

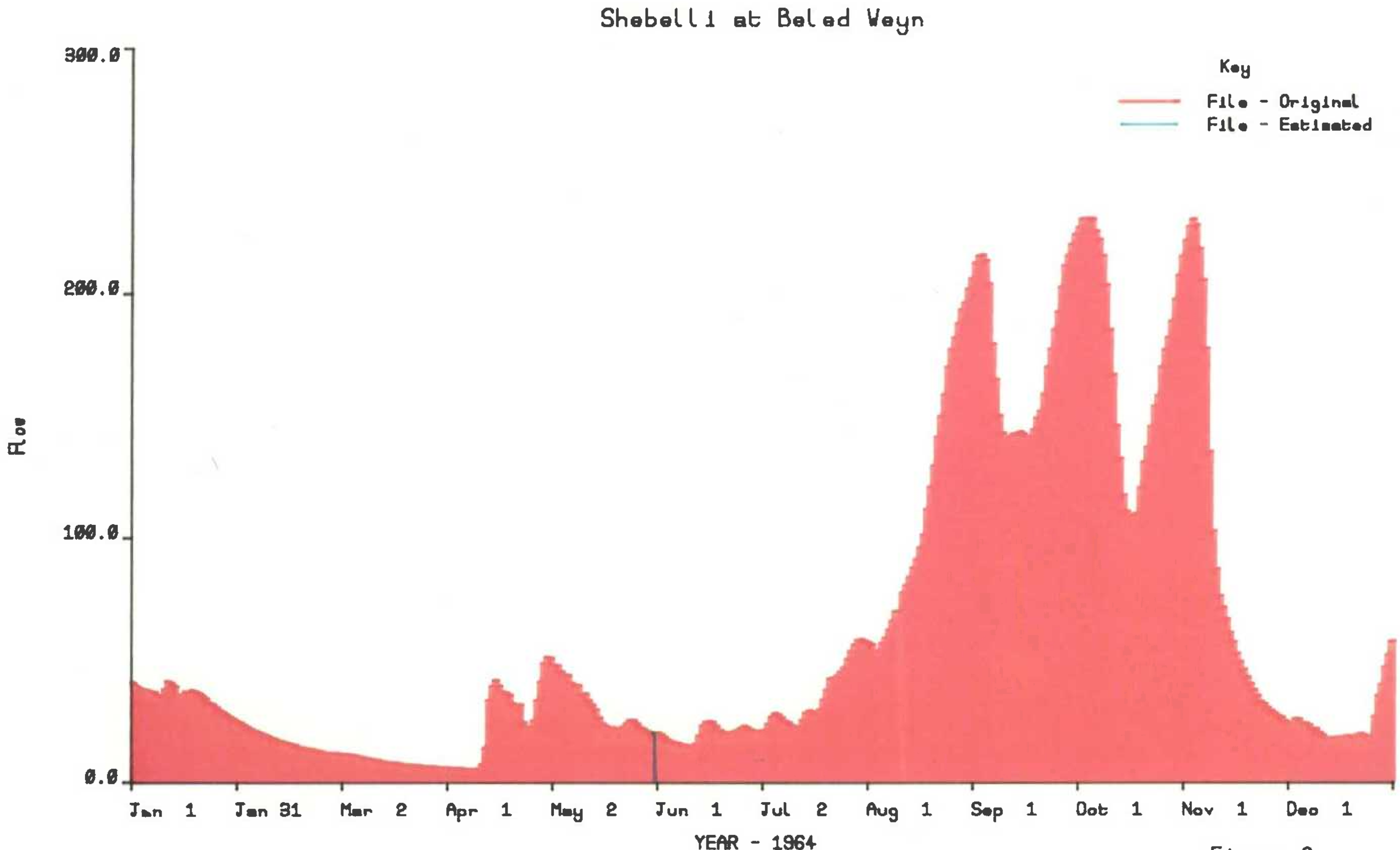
Stage (m)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0										
0.1										
0.2										
0.3										
0.4										
0.5										
0.6				0.02	0.05	0.10	0.15	0.21	0.27	0.34
0.7	0.42	0.50	0.59	0.68	0.78	0.88	0.99	1.09	1.21	1.32
0.8	1.44	1.57	1.69	1.82	1.96	2.09	2.23	2.37	2.52	2.67
0.9	2.82	2.97	3.13	3.29	3.45	3.62	3.79	3.96	4.13	4.30
1.0	4.48	4.66	4.84	5.03	5.22	5.41	5.60	5.79	5.99	6.19
1.1	6.39	6.59	6.80	7.00	7.21	7.42	7.64	7.85	8.07	8.29
1.2	8.51	8.74	8.96	9.19	9.42	9.65	9.88	10.12	10.36	10.59
1.3	10.84	11.08	11.32	11.57	11.82	12.07	12.32	12.57	12.83	13.08
1.4	13.34	13.60	13.86	14.13	14.39	14.66	14.93	15.20	15.47	15.75
1.5	16.02	16.30	16.58	16.86	17.14	17.42	17.71	17.99	18.28	18.57
1.6	18.86	19.16	19.45	19.75	20.04	20.34	20.64	20.94	21.25	21.55
1.7	21.86	22.17	22.48	22.79	23.10	23.41	23.73	24.04	24.36	24.68
1.8	25.00	25.32	25.65	25.97	26.30	26.63	26.96	27.29	27.62	27.95
1.9	28.29	28.62	28.96	29.30	29.64	29.98	30.32	30.66	31.01	31.36

Flows in cubic metres per second



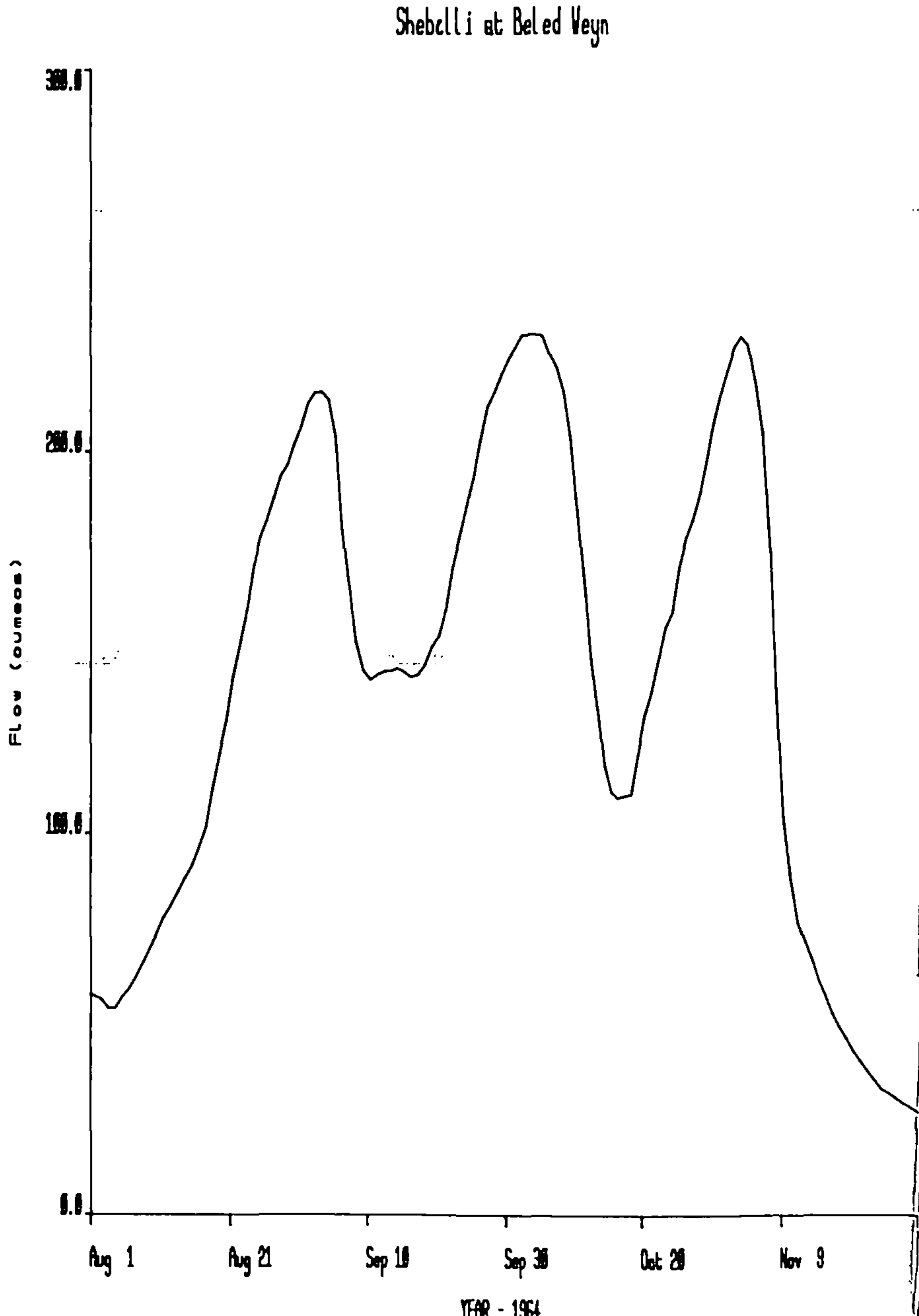
Shebelli at Beled Weyn
STAGE (metres)
6.0
4.5
3.0
1.5
0.0
Key
Data missing
File - Observer
Jan 1
Jan 31
Mar 2
Apr 1
May 2
Jun 1
Jul 2
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
YEAR - 1964

Figure 1



Shebelli at Beled Weyn
300.0
200.0
100.0
0.0
Flow
Key
File - Original
File - Estimated
Jan 1
Jan 31
Mar 2
Apr 1
May 2
Jun 1
Jul 2
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
YEAR - 1964

Figure 2



Shebelli at Beled Weyn
300.0
200.0
100.0
0.0
Flow (cumecs)
Aug 1
Aug 21
Sep 10
Sep 30
Oct 20
Nov 9
YEAR - 1964

Figure 3