Hydrological Research
Progress Report No 7

A System for the Storage and Retrieval of Hydrological Data

by R.P. Ibbitt

A SYSTEM FOR THE STORAGE AND RETRIEVAL OF HYDROLOGICAL DATA

By R. P. IBBITT

1972

PREFACE

This paper is a simplified account of a system for processing time series data, developed by Dr S. A. Thompson and his colleagues in the Computer Systems Laboratory of the Ministry of Works. The system, introduced by Dr R. P. Ibbitt of the Water and Soil Division, Ministry of Works, is currently used for the storage and retrieval of hydrological data, and for the use of hydrological data in research and design work.

Copies of a comprehensive Users Manual are available through the Central Library, Ministry of Works, Wellington. This paper should be adequate for those who are not users but who may have some contact with the system.

Some of the facilities more frequently used by the Water and Soil Division are discussed here and examples of the types of output from the programs are given with explanatory notes. This account of the system is neither comprehensive nor detailed and anyone requiring more information should obtain a copy of the Users Manual.

C. Toebes
Chief Scientific Hydrologist

CONTENTS

INTRODUCTION

Much of the data collected in the field is in the form of time series, i.e. strings of values ordered in time. Because the order in which the data values occur is important it has been necessary to develop new methods to utilise data in design work.

Since data are not collected for their own sake, a description of how they are stored cannot be divorced from how the data are to be used. One of the more practical approaches to the use of data in time-series form is simulation. Simulation is the process by which an input data series, e.g. rainfall or inflow to a channel reach, is converted into an output data series, e.g. discharge at a downstream gauging station.

Any technique that converts an input series into an output series by the use of mathematics is called a mathematical model. The mathematical techniques employed may range from the abstract or statistical to systems of equations that purport to describe the physics of the conversion process. Models of the latter type are usually referred to as conceptual models and have the advantage that when a simulation fails the reasons for failure can be sought in the physics embodied in the model. When simulations using conceptual models are successful, changes can confidently be made to the model. Thus the simulation of prototype behaviour can be accomplished with a high degree of reliability.

Therefore, before discussing the data handling system, a brief description is given of the simulation package maintained by the Systems Laboratory.

THE CONTINUOUS SYSTEM MODELLING PROGRAM

The continuous system modelling program (C.S.M.P. in IBM terminology) is the officially supported means for conducting simulations. Basically, C.S.M.P. provides the means for simulating any system whose physics can be described by a system of ordinary differential equations. Systems whose descriptions do not involve ordinary differential equations can also be easily handled by C.S.M.P. Since C.S.M.P. is geared to solve sets of differential equations, it can carry out numerical integration efficiently.

In the Water and Soil Division C.S.M.P. has a wide potential. Two types of use are the simulation of river mechanics, e.g. flood routing down a channel, and the manipulation of basic field data into a form suitable for simulation purposes or statistical analysis.

To present the results of a simulation, the C.S.M.P. package contains several printing facilities that can give the output great clarity. One of the most popular of these allows the output to be roughly plotted on to standard computer output (Fig. 1).

THE TIME DEPENDENT DATA PROCESSING PROGRAM

At the present time, the only time-dependent data being stored for the Water and Soil Division by the Time Dependent Data Processing Program (TIDEDA) are stage values and the time at which the stage occurred. As data handling expands, rainfall depths, temperature values, etc., can be stored in the same way. Each value is known as a TIDEDA item and an item (or items) with its time of occurrence forms a TIDEDA element. For efficient use of the computer facilities, elements are grouped into records.

PAGE 1

FLOW VERSUS TIME

MINIMUM 7.3000E 01 — MAXIMUM 4.0494E 02

TIME	FLOW	CUM
0.0	7.3000E 01	0.0
1.0000E 00	7.9938E 01	7.3000E 01
2.0000E 00	1.0688E 02	1.5294E 02
3.0000E 00	1.9019E 02	2.5981E 02
4.0000E 00	3.1900E 02	4.5000E 02
5.0000E 00	3.6631E 02	7.6900E 02
6.0000E 00	3.5306E 02	1.1353E 03
7.0000E 00	4.0494E 02	1.4884E 03
8.0000E 00	3.7365E 02	1.8933E 03
9.0000E 00	3.3563E 02	2.2670E 03
1.0000E 01	3.1494E 02	2.6026E 03
1.1000E 01	3.0106E 02	2.9176E 03
1.2000E 01	2.8269E 02	3.2186E 03
1.3000E 01	2.6556E 02	3.5013E 03
1.4000E 01	2.5263E 02	3.7669E 03
1.5000E 01	2.4269E 02	4.0195E 03
1.6000E 01	2.3406E 02	4.2622E 03
1.7000E 01	2.2694E 02	4.4963E 03
1.8000E 01	2.2194E 02	4.7232E 03
1.9000E 01	2.1600E 02	4.9451E 03
2.0000E 01	2.1000E 02	5.1611E 03
2.1000E 01	2.0400E 02	5.3711E 03
2.2000E 01	2.0006E 02	5.5751E 03
2.3000E 01	1.9500E 02	5.7752E 03
2.4000E 01	1.9031E 02	5.9702E 03
2.5000E 01	1.8694E 02	6.1605E 03
2.6000E 01	1.8337E 02	6.3474E 03
2.7000E 01	1.7981E 02	6.5308E 03
2.8000E 01	1.7700E 02	6.7106E 03
2.9000E 01	1.7456E 02	6.8876E 03
3.0000E 01	1.7269E 02	7.0622E 03
3.1000E 01	1.7044E 02	7.2348E 03
3.2000E 01	1.6800E 02	7.4053E 03
3.3000E 01	1.6594E 02	7.5733E 03
3.4000E 01	1.6194E 02	7.7392E 03
3.5000E 01	1.5850E 02	7.9011E 03
3.6000E 01	1.5744E 02	8.0596E 03
3.7000E 01	1.5500E 02	8.2171E 03
3.8000E 01	1.5294E 02	8.3721E 03
3.9000E 01	1.5144E 02	8.5250E 03
4.0000E 01	1.4900E 02	8.6764E 03
4.1000E 01	1.4769E 02	8.8254E 03
4.2000E 01	1.4600E 02	8.9731E 03
4.3000E 01	1.4394E 02	9.1191E 03
4.4000E 01	1.4244E 02	9.2630E 03
4.5000E 01	1.4000E 02	9.4055E 03
4.6000E 01	1.3869E 02	9.5455E 03
4.7000E 01	1.3700E 02	9.6842E 03
4.8000E 01	1.3700E 02	9.8212E 03
4.9000E 01	1.3419E 02	9.9582E 03
5.0000E 01	1.3400E 02	1.0092E 04

FIG. 1: Example of C.S.M.P. output

INPUT FACILITIES UNDER TIDEDA

Although the basic storage medium is magnetic tape, advantage is taken, in the processing of data, of the more advanced facilities available for use with temporary storage magnetic disks. Once the field data has been converted into cards, these are fed through translation programs that produce strings of corrected stage values and their associated time of occurrence. These strings are split into records or part records that are then written on to the magnetic disk. When a sufficient number of data have been assembled on the magnetic disks to justify the cost overheads involved in running the magnetic tapes, an UPDATE job is run. In the UPDATE program the material on the disks is merged with the data on tape in such a way that the ordering structure of the tape is maintained.

On the magnetic tape, data are stored in sequential blocks. Data pertaining to the site with the lowest site number are located at the start of the tape, whilst data pertaining to high site numbers are well down the tape. Within the block of data associated with a site number, all the elements are arranged in advancing time order. This is illustrated in Fig. 2:

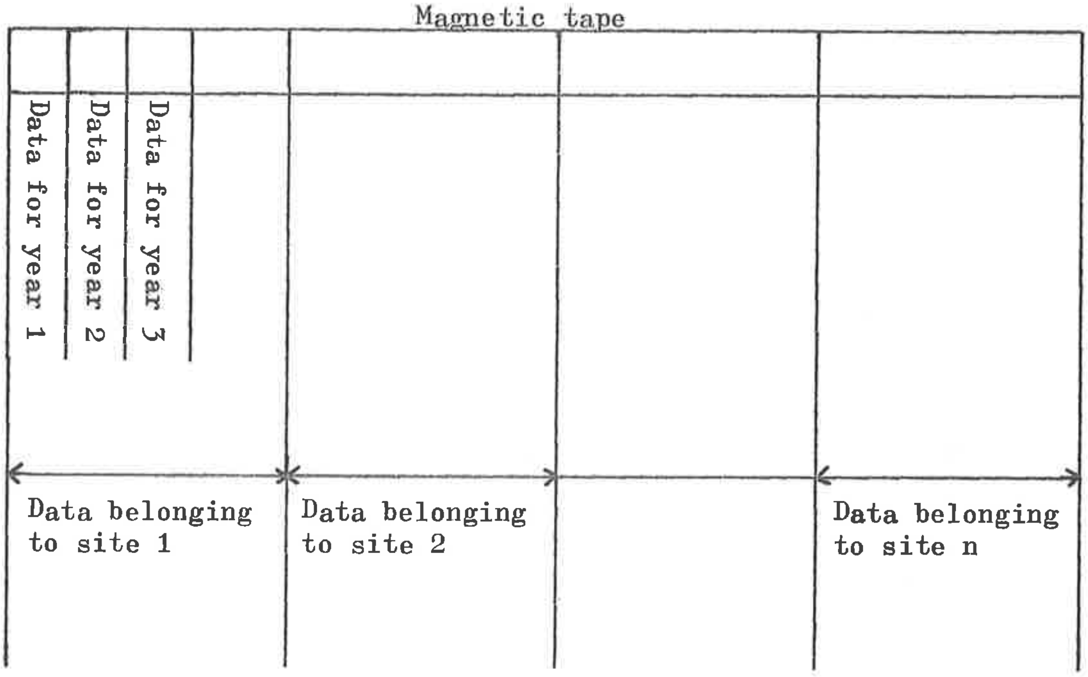

FIG. 2: Arrangement of data on magnetic tape

The data that are initially assembled on the magnetic disks come from a variety of programs (TFISCH, TEVENT, TCHART, TMANL) that convert the basic field data into TIDEDA elements. Within each program there are checks on the consistency of the data, and where the item values in successive elements do not change, storage efficiency is improved by compression of the data. Compression is applied only to data from the Fischer and Porter translation programs (TFISCH and TEVENT) and manual records (TMANL).

Fischer and Porter tapes in particular have the tendency during periods of low stage to return paper tapes that have long strings of identical stage values. It is not economical to store these long strings of identical values, especially when by storing the beginning and end values of the strings and assuming that the storage varies linearly between these points all the information in the record is preserved. This is shown in Fig. 3:

Original paper tape values (23)points

Values stored on magnetic tape (5 points)

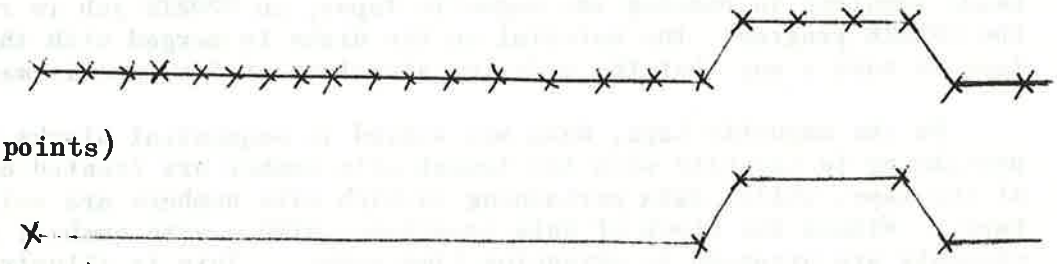

FIG. 3

This illustration serves to introduce a very important concept that is embodied in the TIDEDA system. Between two adjacent elements of data the phenomena being observed is assumed to vary linearly.

The assumption of linearity applies not only to the elements of time series such as the strings of stage-time values, but also applies to relevant site data that are not time series, e.g. rating tables.

For most sites there are data measured at an instant in time which are applicable for a considerable time thereafter. Particular examples are rating tables and cross-section data. Also, to document a site fully, information by comment as well as indications of irrevocably lost data are needed. This information can all be inserted into the data associated with a particular site, its point of insertion being the time at which the comment, etc., becomes relevant.

Each type of data for a site is given two indication parameters, NUMB and KIND. Values of NUMB and KIND and their associated type of data are given in Appendix 1. Whenever the type of data changes, the computer record writes a new record, for the reason that when the data are being retrieved it is done on a record-by-record basis. Each record is examined and, depending upon the instructions supplied and the type of data in the record, a variety of actions may follow.

For example, suppose mean daily discharges are being calculated. Obviously, a rating table must be applied to the stage values. The system retrieves the records covering the requested period. These records will be predominantly ones holding stage values. Interleaved with the stage records will be rating tables, etc. As each record is retrieved its type is examined and the appropriate action is taken. Suppose that the latest record that has been retrieved contains a new rating table. Then the system recognises this fact, ceases to use the old rating table, and begins to apply the new one.

If in the course of retrieval records containing data not required for the calculations being conducted are encountered, they are ignored and processing continues with the next record of the required type.

OUTPUT FACILITIES AVAILABLE UNDER TIDEDA

TIDEDA is a flexible system and offers a wide range of facilities. The first of these are the programs that print out in detail or in summary form the data held on the magnetic tapes. The most economical of these is PSCAN. When a PSCAN program is run the printing begins at the date of the first piece of data held for the first site on the tape, i.e. the one with the lowest site number. Then whenever the type of data for that site changes, e.g. stage-time data are followed by a rating table, the date of the change is printed along with details of the new type of record; e.g. if the new record is a rating table its date of application is given. Any comments pertinent to the site that are on the tape are also listed. An example of a PSCAN listing is shown in Fig. 4.

CHANNEL	RECORDS	VERSION	DATE	DESCRIPTION
INPUT	0	23	27/01/72	SD.WS.NAPIER.G0023V00
				B R & SOIL NAPIER DISTRICT.

RECORDS	SITE	NUMB	KIND	DATE ON	HOUR ON	DATE OFF	HOUR OFF	LABEL
1	19709	0	1	650405	134500			
206	19709	1	0	671213	143000	700505	110000	
1	19711	0	1	670203	60000			
170	19711	1	0	671212	173000	700504	143000	
12	21410	1	0	680829	112000	700305	134959	
1	21801	0	1	580201	1500			
189	21801	1	0	671220	130000	700604	91500	
23	21803	1	0	680506	143000	680622	110000	
1	21803	0	1	680622	111500			
229	21803	1	0	680622	111500	700428	113000	
125	22802	1	0	660222	180000	680731	120000	
1	22802	0	1	680731	121500			
120	22802	1	0	680731	121500	700519	91500	
1	23005	0	1	680222	0			
83	23005	1	0	690101	1500	700522	83500	
26	23103	1	0	671221	144500	680622	123000	
1	23103	0	1	680622	124500			
99	23103	1	0	680622	124500	681224	103000	
1	23103	0	1	700115	140000			
81	23104	1	0	660223	180000	670203	80000	
1	23104	0	1	670203	81500			
323	23104	1	0	670203	81500	700403	114500	
34	23106	1	0	671220	120000	700304	95959	
1	23209	0	1	660311	180000			
179	23209	1	0	660323	144500	700507	84500	
1	23210	0	1	660318	230000			
160	23210	1	0	660325	144500	700130	104500	
1	23211	0	1	671229	160000			
46	23211	1	0	681004	150000	700602	140000	
2118								

FIG. 4: PSCAN output

A more detailed summary of the data held on tape is often useful in checking for unprocessed charts or paper tapes. The PREC program prints out one set of information for each record. The information contains the site number, the type of data held, the data associated with the value in the first element, and finally the number of days of the record covered by the time-series data within the record. For non-time-series data, e.g. rating tables, the days of record covered by the data within the record are given the value zero.

Besides programs that retrieve the basic data on the file there are others that calculate mean values of the basic data over specified time intervals. The one most often used is the PDAILY program by which mean daily discharges are calculated. An example of PDAILY output is shown in Fig. 5. Considerable thought has gone into the form of the tables. The size of the table makes it suitable for reproduction on A4-size paper. In deciding how the figures should be set out, the basic purpose of these tables was carefully considered. With the potential of the computer available it is clearly pointless to use the data in the tables for anything other than trivial calculations. Therefore the main purpose of the tables is to catalogue the data for each site. For example, in the table shown in Fig. 5, the periods of high flow are obvious at a glance. To achieve this graphic quality the variable part of the mean daily discharge values is "distilled" from the constant part. This is done by subtracting a constant and scaling the result so that the maximum value has four significant figures. For checking purposes and for spot calculations, there are sufficient data to reconstruct the absolute flow value.

The values in the table are in litres per second unless a comment to the contrary is explicitly included in the output for each site. Asterisks in the table indicate the limits of the data and irrevocably missing data. Where a data batch within the limits of the processed data has not yet been put on the magnetic tape, the program linearly interpolates across the interval.

Associated with each table are two (or three) lines of title and the rating table used to derive the flow values. Note that the rating table(s) with associated cross-section data, if any, are printed on the page of output immediately preceding the year in which they became applicable . See Fig. 6 for an example.

The first line of the title is optional and will frequently be blank; the title then starts with the word SITE followed by the number of the site for which the table is being printed. If the site number begins with a letter of the alphabet, then its numerical equivalent within the computer is printed, e.g. A ≡ 10, B ≡ 11, etc. to Z ≡ 36. Thus A13367 is represented as 1013367. The use of numbers instead of letters affects only the output side of the TIDEDA system. For the input to the chart and to the Fischer and Porter tape processing programs, etc., the letter remains.

If averages over periods other than one day are required these can be calculated on a non-calendar basis using program PAVER, shown in Fig. 7.

DAILY MEANS YEAR=1970 SITE= 15410 ITEM= 1 RATING APPLIED
MULT. BY 10 TO POWER 2

DAY	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	
1	105	70	58	73	54	77	137	201	318	1171	465	115	
2	104	68	57	112	58	79	131	197	306	991	546	112	
3	115	67	53	89	56	181	129	200	297	841	463	113	
4	132	66	52	105	55	784	172	195	279	715	447	108	
5	104	65	51	165	55	598	192	205	265	589	409	102	
6	102	65	51	127	59	589	155	185	254	512	371	99	
7	100	64	51	105	54	461	152	182	250	439	342	96	
8	99	64	51	93	77	360	195	180	233	396	316	94	
9	98	63	74	84	106	296	168	178	220	362	294	91	
10	97	63	74	79	84	250	160	175	208	326	275	87	
11	95	62	65	75	84	220	181	172	241	298	258	86	
12	94	62	81	72	69	199	221	169	356	279	242	83	
13	93	61	71	69	64	181	299	187	305	261	227	83	
14	92	60	76	67	62	169	291	2192	275	249	220	92	
15	91	59	73	65	60	191	273	1771	260	245	204	123	
16	89	59	61	64	59	179	256	1013	269	235	191	161	
17	88	58	57	63	59	176	240	726	403	217	181	122	
18	87	57	73	62	58	302	229	573	532	206	173	96	
19	86	56	93	61	59	251	216	461	439	191	173	88	
20	84	56	73	60	87	230	221	397	395	180	235	87	
21	83	56	65	59	90	214	256	366	349	171	175	109	
22	82	56	62	58	145	202	228	386	316	163	161	86	
23	81	55	59	57	154	190	224	354	291	156	152	80	
24	79	55	57	57	126	180	223	313	289	150	149	76	
25	78	54	57	56	116	173	221	282	385	145	141	78	
26	77	54	67	56	103	165	220	262	587	137	154	125	
27	76	56	88	57	98	153	222	248	601	133	142	89	
28	74	54	70	60	90	149	217	247	534	128	135	81	
29	73		62	56	84	149	213	358	465	129	126	76	
30	72		59	55	82	145	209	344	552	378	120	73	
31	71		58		79		205	328		367		78	
MIN	71	54	51	55	54	77	129	169	208	128	120	73	51
MEAN	90	60	64	75	80	249	208	420	349	347	249	96	191
MAX	132	70	93	165	154	784	299	2192	601	1171	546	161	2192

FIG. 5: PDAILY output

FIG. 6: Rating tables and cross sections

15410 0 1	660124	0									
0 5947	30 6756	61 7787	122 10053	152 11327	213 14158	244 15716	305 19114	335 20955	396 24919	457 29450	549 37095
610 42759	701 52103	792 62297	884 73341	975 85234	1097 102224	1189 115816	1311 135072	1402 150363	1524 171884	1646 194538	1768 218324
1890 243243	2012 269295	2134 296479	2195 310637								
15410 0 1	670203	121500									
122 2407	152 2690	183 3115	213 3681	274 4955	335 6513	396 8495	457 11044	518 14158	579 17840	640 22087	701 26901
762 32281	823 38228	884 44741	914 48422	945 52386	975 56634	1006 61165	1036 65979	1097 75890	1158 86367	1219 97410	1250 103357
1280 109587	1311 116100	1341 122896	1372 129975	1402 137337	1433 145266	1463 153478	1494 161973	1524 171035	1554 180379	1585 190007	1615 200201
1676 220872	1707 231633	1737 242677	1768 254287	1798 266180	1829 278356	1859 291099	1890 304124	1920 317433	1951 331309	2012 359343	2042 373784
2073 388792	2103 404083	2134 419658	2164 435798	2195 452505	2225 469496	2256 487052	2286 504892	2316 523298	2347 541987	2377 561243	2408 581065
2438 601170	2469 621841	2499 642796									
15410 0 15	670203	121500									
5486 202661	6553 202692	6706 201960	8077 201015	9296 200985	9449 200894	9906 200985	10668 200985	11278 200924	11735 200680	12802 200863	13106 199309
13716 199552	15545 199034	15545 199004	17374 198851	18898 198851	20422 198790	21946 198821	23470 198912	24994 198882	26518 198790	28042 198668	29566 198608
31090 198486	32614 198364	34138 198272	35662 198089	37186 198089	38710 198059	40234 198120	41758 198181	43282 198211	43739 199278	45415 199888	46939 200650
52426 200985	54864 200924	62484 200863	65532 200954	70409 200833	73762 200894	76200 200802	77724 201076	79248 201595	80772 201808	85649 201991	86258 202661
15410 0 1	700814	141500									
427 4248	549 11044	610 15008	671 19539	701 22087	884 39077	975 48422	1128 65412	1250 81270	1341 94862	1494 120347	1585 137337
1676 156876	1707 164239	1768 181229	1890 219740	2195 327344							

SITE 230C5 FROM 690505 0 TO 690510 0 ITEM 1 INTERVAL 3600 CYCLE 12

INTERVAL MEANS

75	75	75	75	75	75	75	75	75	75	75	75
75	75	75	75	74	72	72	72	72	72	72	72
72	72	72	72	72	72	72	72	72	72	72	72
72	72	72	71	69	69	69	69	69	69	69	71
76	83	95	118	156	223	307	330	359	373	361	345
391	418	387	360	342	329	318	311	304	297	288	277
265	262	256	249	244	240	236	232	227	225	223	220
217	214	211	208	204	203	200	199	195	194	191	189
187	185	184	182	180	178	176	176	175	173	173	171
170	169	167	167	166	164	162	161	159	157	157	156

COLUMN MEANS (CYCLE)

160	162	159	157	158	162	168	169	170	170	168	164

ROW MEANS (TREND)

75	73	72	70	235	335	240	202	178	162

*****

FIG. 7: PAVER output

Programs to obtain more elaborate forms of output are being produced, of which program PCOVAR is a typical example. This program prints a table and graph showing the autocovariance and power spectrum of the data. The calculation is based on averages specified over a given interval. See Fig. 8.

EDITING FACILITIES AVAILABLE UNDER TIDEDA

The output programs described in the preceding section permit information to be printed only. If the data require some processing before being printed, e.g. suppose mean hourly runoff values are required instead of mean hourly discharge values, then before running the appropriate output program (PAVER for example) some form of editing program must be run.

The first operation is to copy the basic data required for the job in hand from the master magnetic tape to auxiliary disk storage. Thus the overheads associated with the master magnetic tape are incurred only once. Program SELECT performs this task.

When the desired information has been selected, linear transformations can be applied by program LINEAR. The output from LINEAR can then be fed into any of the output programs already described. A typical example of the use of LINEAR would occur in the conversion of mean hourly discharge values to mean hourly runoff values using program PAVER.

AUTOCOVARIANCE AND POWER SPECTRUM
SITE 23005 FROM 690505 0 TO 690510 0 ITEM I INTERVAL 3600 MEAN= 0.1651E 03

TIMELAG HOURS	AUTO-COVAR.	AUTO-CORREL.
0	0.9084E 04	100
1	0.9108E 04	100
2	0.9008E 04	99
3	0.8838E 04	97
4	0.8603E 04	95
5	0.8313E 04	92
6	0.7993E 04	88
7	0.7629E 04	84
8	0.7218E 04	79
9	0.6795E 04	75
10	0.6386E 04	70
11	0.6002E 04	66
12	0.5645E 04	62
13	0.5307E 04	58
14	0.4986E 04	55
15	0.4684E 04	52
16	0.4398E 04	48
17	0.4125E 04	45
18	0.3865E 04	43
19	0.3629E 04	40
20	0.3402E 04	37
21	0.3186E 04	35
22	0.2980E 04	33
23	0.2782E 04	31
24	0.2589E 04	29
25	0.2402E 04	26
26	0.2217E 04	24
27	0.2035E 04	22
28	0.1857E 04	20
29	0.1678E 04	18
30	0.1498E 04	16
31	0.1319E 04	15
32	0.1142E 04	13
33	0.9646E 03	11
34	0.7877E 03	9
35	0.6125E 03	7
36	0.4381E 03	5
37	0.2638E 03	3
38	0.9105E 02	1
39	-0.7912E 02	0

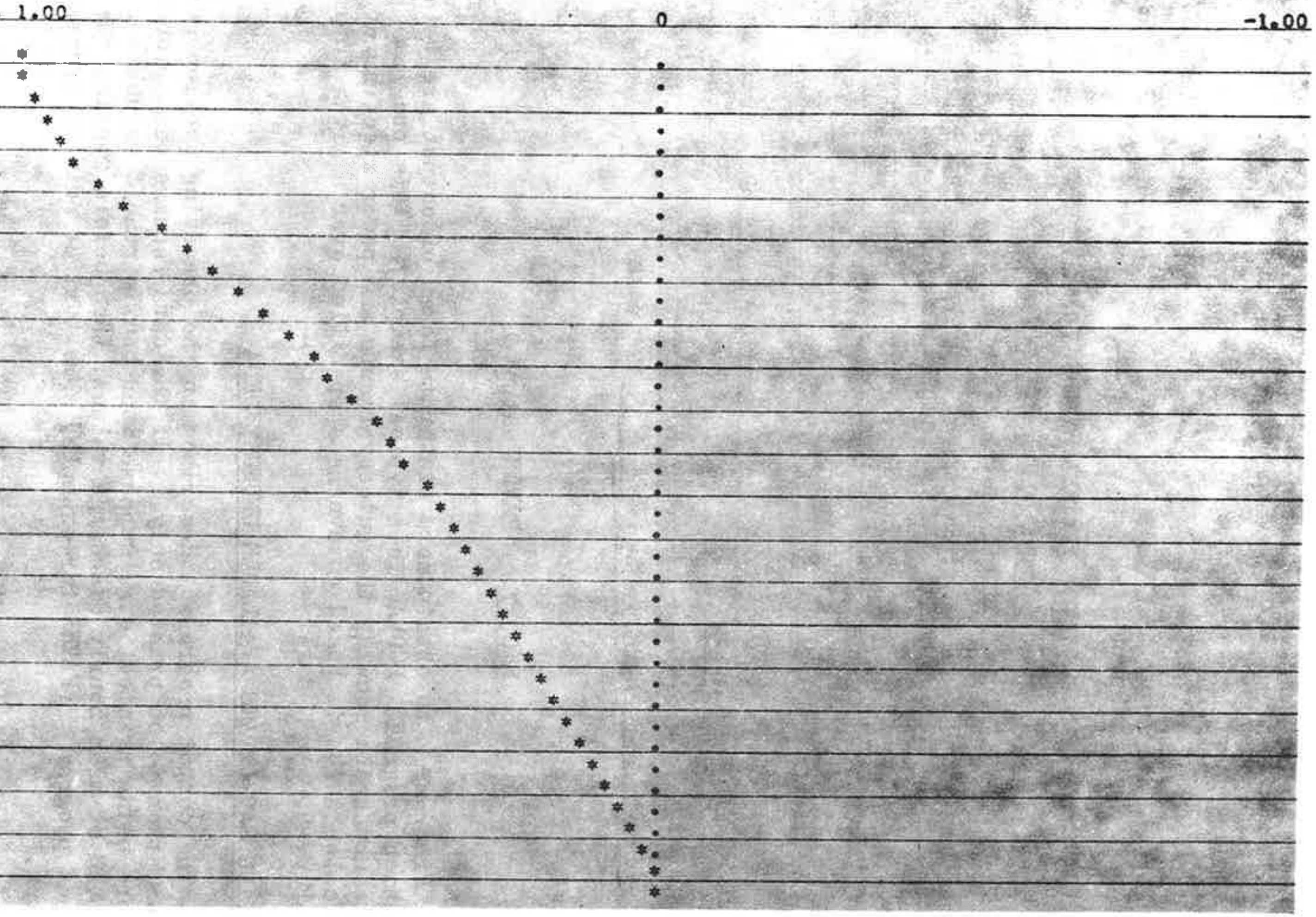

FIG. 8: PCOVAR output

The operations outlined above are trivial when they are compared with what can be done using C.S.M.P. To prepare information for C.S.M.P. jobs, program REFINE is used to turn the results of a SELECT operation into a form compatible with C.S.M.P.

Other editing programs are largely restricted in usefulness to the Data Processing Section, being used to "clean" "dirty" information from the master magnetic tapes.

CONCLUSION

This brief account covers no more than a few of the possibilities of processing and printing hydrological data by computer. Far more can be done with TIDEDA than has been given here. Even more can be done by using C.S.M.P. Further information can be found in the Users Manual, but anyone with a particular problem beyond the scope of this paper should first contact the Data Processing Section of the Water and Soil Division. In this way the type of incoming requests can be gauged, and if demand warrants it further facilities can be incorporated into the system. Matters that cannot be resolved in the data processing section will be submitted to the Systems Laboratory for attention.

BIBLIOGRAPHY

THOMPSON, S. M.; WRIGLEY, G. R. 1971:

CSMP-TIDEDA Users Manual. Systems Laboratory, Ministry of Works, Wellington.

APPENDIX I

DATA IDENTIFICATION

These will be printed out at the head of each record to identify it.

NUMB	KIND	DATA TYPE
0	0	a comment
0	1	a rating table
0	15	cross section data
1	0	stage - time data
1	13	rainfall - time data

APPENDIX II

COMPUTER PROGRAMS MENTIONED IN TEXT

C.S.M.P. — Continuous System Modelling Program

- does simulations, possibly using data from:

TIDEDA — Time Dependent Data Processing Program

- stores stage values at present, later rainfall depths, temperatures, etc.

INPUT	UPDATE	- brings temporary disk material on to tape	
	TRAIN TFISCH TEVENT	Fischer and Porter records	Convert field data into TIDEDA elements
	TCHART	charts	
	TMANL	manual records	
OUTPUT	PSCAN	- brief details of each site	
	PREC	- prints length of each record	
	PLIST	- prints data in full	
	PDAILY	- calculates mean daily discharges	
	PAVER	- calculates averages over any period of time	
EDITING	SELECT	- selects material from tape storage	
	LINEAR	- linear transformations	
	REFINE	- material prepared for C.S.M.P.	

PROGRESS REPORTS PUBLISHED PREVIOUSLY

No	
1	Some runoff results from Moutere Conservation Station by F. Scarf
2	Puketurua microclimate survey by S. Franks
3	Classification of vegetation cover in representative basins by G.J. Blake and A.D. Cook
4	Water retention properties of leaves by G.J. Blake
5	Development of a conceptual model of interception by R.P. Ibbitt
6	Evaluation of chemical gauging techniques by R.J. Bellamy