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HYDROLOGY

YEMEN ARAB REPUBLIC

VISIT REPORT

(NOVEMBER 1981 AND

OCTOBER 1982)

Yemen Arab Republic Visit Report

(November 1981 and October 1982)

by

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Contents

1. Introduction
2. Flood warning - further notes
3. Mishrafah gauging station
4. Assistance proposals
5. Institute of Hydrology raingauge
6. Data processing

   6.1 Introduction
   6.2 Rating curves
   6.3 Flood volumes
   6.4 The Sharp PC 1500 computer
   6.5 Using the PC 1500
   6.6 Loading programs from cassettes
   6.7 Monthly flow programs "KOLAFLOW" and "MISHFLOW"
   6.8 Individual flood program "FLOODS"
   6.9 Writing your own programs - an example
   6.10 Equipment list.

7. Itinerary
8. List of people met
9. Acknowledgements
10. References.

1. Introduction

This report details the work carried out during two advisory visits on behalf of ODA to the Hydrology Section of the Tihama Development Authority (TDA) in the Yemen Arab Republic. The main purpose of the first visit (November 1981) was the development of a flood warning procedure for Wadi Zabid. This has been reported upon separately (Reference 1) in April 1982. The second advisory visit (October 1982) was primarily concerned with one aspect of data processing - the processing of gauging station charts and this is considered in the report as section 6. Other topics were covered during the two visits and form the remainder of this report.

2. Flood warning - further notes

During the 1981 visit a considerable amount of time was spent in collecting data to develop a flood warning procedure for the Wadi Zabid irrigation scheme. This work has been completed and reported on separately (Reference 1). The purpose of the flood warning procedure is to give advance warning of the size and time of arrival of flood peaks at the irrigation head works to enable a more efficient operation of the system.

At the time of the 1982 visit the flood warning procedure had not been implemented because the radios which were intended for the scheme were found to be defective and unrepairable. TDA is, however, actively pursuing the possibility of using radio telephones instead of the original radios and hopefully these will be installed in time for the next flood season.

Local people and TDA staff at Al-Gerba claim that they can 'sense' when a flood is likely on Wadi Zabid. Apparently a cool wind blowing down from the mountains indicates heavy rain (and hence a possible later flood) in the catchment. It is recommended that this not unreasonable hypothesis be tested by instructing the observers at Kolah to record air temperature every half hour subsequent to their arrival on site. Plots of air temperature against time may then be drawn up and comparisons made between days of flood and days of no flood.

The Wadi Zabid project was the first major irrigation improvement scheme to come into operation in the Tihama. The second scheme, on Wadi Rima, is now well into the construction stage and will, like Wadi Zabid, have greater operational efficiency if used with a flood warning scheme. The principles of the method devised for Wadi Zabid (Reference 1) may be applied to any wadi, provided an upstream advance warning station is available. In Wadi Zabid the Kolah gauging station fulfils this requirement. Located 10 km upstream of the first irrigation structure it is far enough to give a reasonable advance warning time but is before any major tributaries.

During the 1982 visit an attempt was made to locate a suitable site for an upstream flood warning station on Wadi Rima.

Several special criteria operate when selecting a wadi gauging station location:-

(1) The river channel and downstream control should be stable. This implies no movement of the wadi bed or sides with time. In Yemeni wadis this condition can rarely, if ever, be satisfied. The best that can be achieved is a narrow gorge section with stable rocky sides.

(2) Satisfactory anchoring point for stilling well and chart recorder. Again a gorge section is ideal here where near vertical sides permit good suport for the stilling well structure.

(3) Protection against flood damage. During floods, stones, boulders, trees etc are moved by high water velocities. This debris can easily damage or destroy an unprotected structure. Protection is best achieved by natural means such as a recess in the bank away from the main flow of the stream.

(4) If possible the base of stilling well should rest in a natural pool so that the station is operational throughout the full range of flows. Realignment of the baseflow channel subsequent to a flood may make this condition

difficult to satisfy but sometimes the wadi has a preferred positioning of the low flow channel.

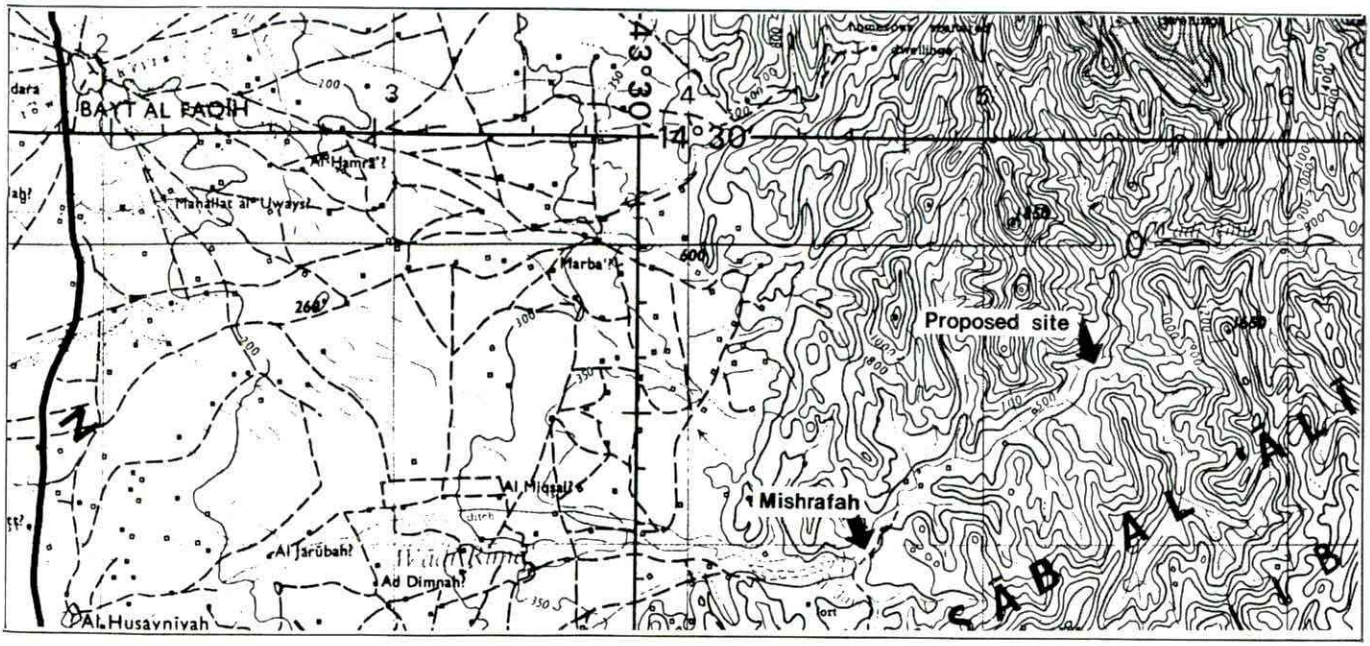
(5) Access to the site for maintenance and chart changing and availability of competent local observers (numerate and able to operate radios). If the station is to be used for flood warning access may be required on a daily basis.

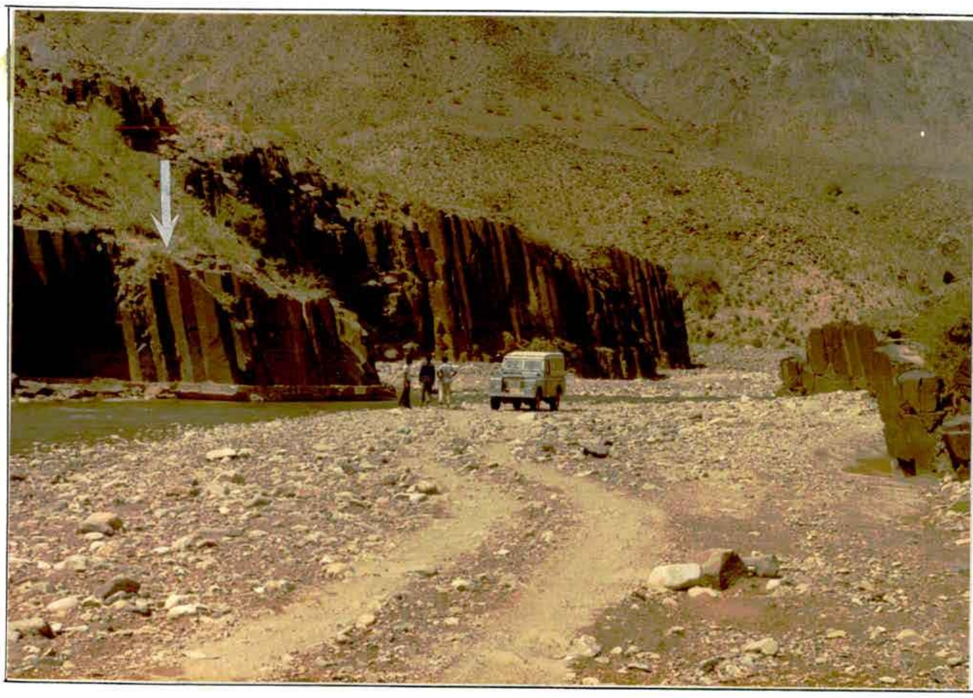
With these points in mind and the Land Rover odometer set to zero at the Mishrafah gauging station, a journey was undertaken up the wadi into the mountain catchment (Figure 1). Driving upstream, there was a poor track on the right hand side out of the wadi bed for about 2 km. Thereafter the track continued in the wadi bed. At 10.8 km, where the wadi enters a rocky gorge, a suitable site was found. This is shown in figure 1 where a rocky recess in the bank, suitable for location of a stilling well and chart recorder, is indicated. This recess offers protection from floods and a pool below should ensure water level measurements in low flows. Although the best site upstream from the hydrometric point of view and an ideal distance upstream for flood warning purposes, there may be difficulties in finding suitable attendants from the local village. Access will also be a problem, particularly in the wet season, when the possibility of floods would make the journey in the wadi bed very dangerous. There was evidence of a track in the mountains on the left hand side of the wadi which went some way towards the proposed site; however local people said it was now impassable due to damage in the preceeding flood season. If this road is improved it might prove a safer method of access.

3. Mishrafah gauging station

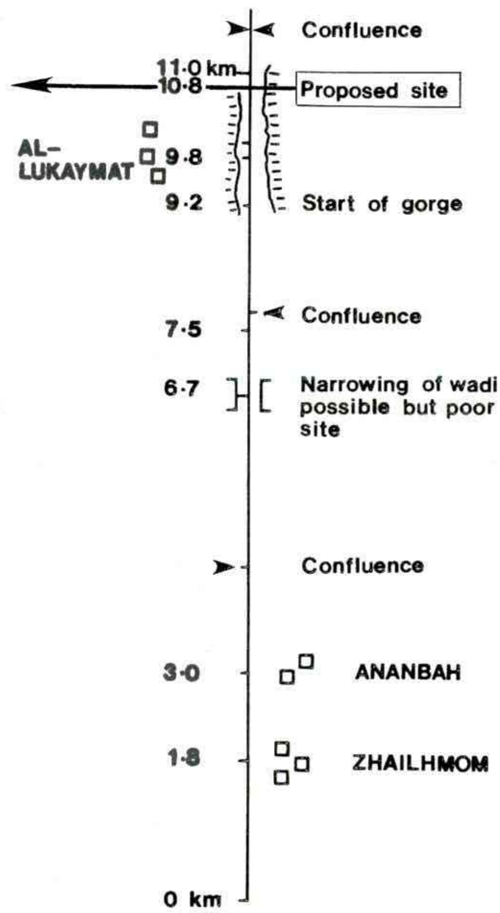
The photograph of Mishrafah gauging station taken on 21st October 1982 (figure 1) shows the earth embankment under construction downstream. This embankment was diverting wadi flow around the irrigation construction located just downstream. At the time this photograph was taken, backwater from this embankment was drowning out the gauging station and thereby affecting the data being recorded. At the time of the visit it was unclear whether, after the removal of this temporary embankment, the new weir downstream will itself cause backwater problems at the gauging station. If this is the case and

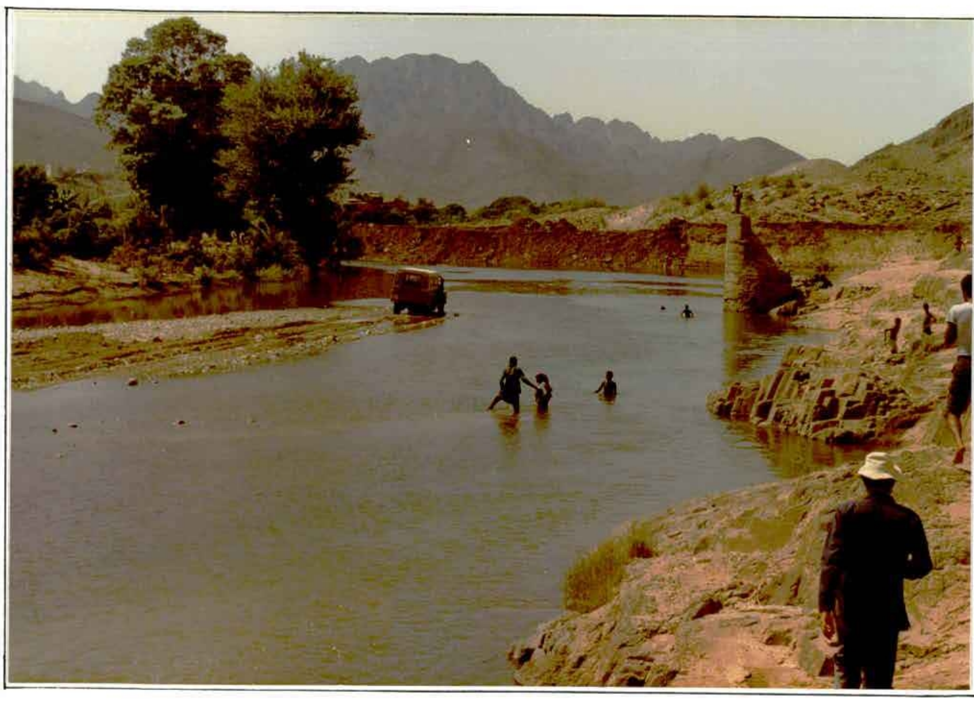
Wadi Rima-Mishrafah and proposed gauging stations





UPSTREAM VIEW OF PROPOSED GAUGING STATION
[Arrow indicates stilling well location]





MISHRAFAH GAUGING STATION

Figure 1

the station continues to be drowned out it would be advisable to relocate the station. Depending on the design of the new weir, one possible site would be at the new weir crest where flood flows could be estimated using a theoretical or model rating.

It is recommended, for the present, to wait until construction is complete and then decide upon the necessity for relocation. Existing baseflow measurements should continue, but far enough upstream to avoid the backwater zone. Charts collected from Mishrafah since the construction of the earth embankment should not be used to calculate flows using the old flood rating curve as this is now invalid.

4. Assistance proposals

Discussions during the 1981 visit revealed that the Hydrology Section staff were finding it difficult to implement advice given by IH staff during previous advisory visits. Shortages of staff, transport, money and equipment were evident. As a result a proposal entitled 'Hydrological Assistance for the Tihama Development Authority' was submitted to ODA for funding. Unfortunately this project was not backed. TDA, however, were keen for co-operation with IH to continue and as a result of discussions during the 1982 visit a project proposal 'Water Resources Assessment on the Tihama Plain' was prepared for submission to the World Bank.

Irrespective of the outcome of this proposal it is recommended that annual short term visits by IH staff to TDA should continue. It is proposed that the next visit be by Dr Bathurst in the summer of 1983 who will continue work on indirect methods of flow gauging.

5. Institute of Hydrology Simple Raingauge

The Institute of Hydrology is developing a simple, cheap electronic raingauge which will record up to 3 months of daily rainfall data in its solid state memory. The simplicity is evident in its construction which comprises one moving part (the tipping bucket) and a single sealed electronics unit. The raingauge itself is made from moulded plastic which keeps the cost to a minimum.

In countries such as the Yemen, where access to remote areas is difficult, a raingauge such as this has an obvious application. One of these simple raingauges was installed in the meteorological site at Al Gerba in 1980 (Reference 3) and has been under test since then. The biggest problem has been the effect of extreme heat on the battery power supply. Originally rechargeable batteries were installed but proved unreliable as they were unable to retain charge in conditions of prolonged high temperatures. These batteries were then replaced by sealed lead acid batteries which were more successful and supported the electronics for 1 to 2 months.

During the 1981 visit a maximum-minimum thermometer was installed inside the raingauge on 6th December. The maximum temperature recorded of $50^{\circ}C$ may have been exceeded as this was the highest value that the thermometer could record. In the summertime, temperature inside the gauge must be still higher.

During the same visit the electronics board was removed for testing at Wallingford and replaced with a new board. An experimental battery pack was installed consisting of 'Duracell' batteries.

Almost one year later, in the 1982 visit, the raingauge was re-visited and the same experimental batteries were still powering the electronics. It is encouraging to note that the electronics were able to withstand the high temperatures throughout the summer. The batteries must also be regarded as a success. Unfortunately the meteorological station observer did not understand the procedure for reading the gauge and so a comparison between daily totals recorded on the electronic gauge and manual gauge was not possible.

On 25th October 1982 the experimental battery and electronics board were removed for checking in the UK. A new board and experimental lithium battery were installed on the same date. It is hoped that this lithium battery will have a life of up to 5 years and should be left in place indefinitely.

In order that we can check measurements made by this gauge it is recommended that it be read once a month (on the first day of each month) by an experienced member of the Hydrology Section. The procedure is outlined below:

IH RAINGAUGE OPERATION

1. On the first day of the month attend the raingauge.
2. Refer to 'Operating Instructions' Fig.4 and Fig.5.
3. Activate reed switch C (to enable reading of memory from day 1).
4. Activate reed switch D to display daily totals for each day of the previous month.
5. Note daily totals on sheets provided.
6. Activate reed switch A (to reset memory).
7. Leave raingauge unattended until the first day of the next month.

Note:

1. Do not reset clock (Switch B).
2. Do not remove battery - leave connected indefinitely.
3. The raingauge clock was set at 7:00 am on 26/10/82.

6. Data processing

6.1 Introduction

During the 1982 visit several days were spent advising the Hydrology Section on the processing of wadi flow data. The techniques being used to calculate flood volumes were shown to lead to underestimation of 20% or more.

To calculate volumes correctly is a time consuming and repetitive task. For that reason a pocket computer (Sharp PC 1500) was taken to the Yemen to assist the Hydrology Section in this work. Unfortunately the non arrival of an add on 8K memory meant the programs written during this visit were restricted in capability. However, using the minimum 1.85K available memory, several programs were developed which should help in assessing flood and baseflow volumes more accurately and quickly.

The computer is on loan to TDA and hopefully should be replaced by a bigger machine if the Water Resources Assessment Study, mentioned in Section 4, comes to fruition.

6.2 Rating curves

The establishment of rating curves relating water level to flow at a gauging station is particularly difficult in countries such as the Yemen. The unstable boulder and gravel wadi beds are subject to realignment after the passage of each flood. The change in datum (level of zero flow) and bed profile means that it is impossible to establish one permanent rating curve. The effect of these bed changes is much more noticeable on the low flow rating than high because the proportional change in stage due to this shift is greater at low stages.

Rating curves are normally constructed by making discharge measurements with a current meter at various water levels and plotting these data on graph paper. However the use of a current meter in wadis during medium and high flows when stones, boulders and other debris are being moved in the channel, is impractible and possibly highly dangerous for the operators. Indirect methods of relating flow to stage, using physical properties of the wadi channel (cross sectional area, slope and roughness) are less accurate, but are the only feasible approach.

Bathurst (Reference 2) has reported on these methods for TDA, which should lead to an acceptable rating at medium and high flows. For low flows the only real solution is to continue as at present and make baseflow discharge measurements as frequently as possible on each of the major wadis. In assessing daily, monthly and annual volumetric discharges from the wadis 'average' rating curves should be used in assessing flood volumes and the bi-weekly (hopefully) low flow measurements used to estimate baseflow volumes.

Unfortunately, due principally to the lack of resources, the Hydrology Section has, to the present, been unable to establish rating curves using the indirect methods outlined above. In the absence of these, very approximate rating curves based on Manning's equation, will have to be used with the assumption that the water surface slope is constant through the whole stage range

There seemed to be some confusion at TDA concerning the rating for the Kolah gauging station. This is an important station as it is in the first wadi to be developed and has a relatively long record. To resolve this, a survey of the section at Kolah was made during the 1981 visit for an approximate rating based on Manning's equation.

This rating was subsequently used in the Flood Warning Manual for Wadi Zabid (Reference 1). For convenience of use, a rating table has been prepared from this curve and is given here as Table 1. It should be noted that the datum (zero stage reading) used in the derivation of this rating was the weld line above the damping cone at the base of the stilling well. This is not entirely satisfactory on a long term basis as it is possible that the stilling well may move. It is recommended that this level be related to a temporary bench mark somewhere on the rocky gorge side at Kolah.

Future users of data will benefit from a knowledge of the rating curve used in data processing. For this reason each rating curve should be given a number and this number appear on the processed data. The rating curve number should be revised after any modification to the curve has taken place.

Rating tables for Structure 1 (Tipton and Kalmbach) on Wadi Zabid and Mishrafah (LRDC) on Wadi Rima have also been prepared from rating curves given in the consultant's reports indicated; they are shown here as Tables 2 and 3 respectively. The Mishrafah curve should only be used on data prior to the drowning out noted in Section 3. Furthermore, the tabulated values less than 1 m stage should be regarded as very approximate.

The three ratings given in this section (Tables 1, 2 and 3) are used by the data processing computer programs described subsequently.

6.3 Flood volumes

This section considers the merits of different methods of estimating flood volumes. Consider the example shown in figure 2 of a flood at Kolah. Although a fictitious example, it is representative

TABLE 1 Rating table for Wadi Zabid at Kolah u/s

Source : Rating number 1

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	4.80	5.15	5.50	5.87	6.25	6.63	7.03	7.44	7.86	8.29
.1	8.73	9.18	9.64	10.11	10.60	11.09	11.59	12.10	12.62	13.16
.2	13.70	14.25	14.81	15.39	15.97	16.56	17.16	17.77	18.40	19.03
.3	19.67	20.32	20.98	21.65	22.33	23.02	23.72	24.43	25.14	25.87
.4	26.61	27.35	28.11	28.87	29.65	30.43	31.23	32.03	32.84	33.66
.5	34.48	35.23	35.98	36.74	37.50	38.27	39.04	39.83	40.61	41.41
.6	42.21	43.01	43.82	44.64	45.46	46.29	47.12	47.96	48.81	49.66
.7	50.52	51.38	52.25	53.13	54.01	54.89	55.78	56.68	57.58	58.49
.8	59.40	60.32	61.25	62.18	63.11	64.05	65.00	65.95	66.91	67.87
.9	68.84	69.81	70.79	71.77	72.76	73.75	74.75	75.76	76.77	77.78
1.0	78.80	79.99	81.21	82.43	83.67	84.91	86.16	87.42	88.69	89.96
1.1	91.25	92.54	93.85	95.16	96.48	97.81	99.15	100.50	101.85	103.22
1.2	104.59	105.97	107.36	108.76	110.17	111.59	113.01	114.45	115.89	117.34
1.3	118.80	120.27	121.75	123.23	124.73	126.23	127.74	129.27	130.79	132.33
1.4	133.88	135.44	137.00	138.57	140.15	141.74	143.34	144.95	146.56	148.19
1.5	149.82	151.46	153.11	154.77	156.44	158.12	159.80	161.49	163.19	164.90
1.6	166.62	168.35	170.09	171.83	173.58	175.34	177.11	178.89	180.68	182.48
1.7	184.28	186.09	187.91	189.74	191.58	193.43	195.28	197.15	199.02	200.90
1.8	202.79	204.69	206.59	208.51	210.43	212.36	214.30	216.25	218.21	220.17
1.9	222.15	224.13	226.12	228.12	230.13	232.14	234.17	236.20	238.24	240.29

Flows in cubic metres per second

TABLE 1
continued

Rating table for Wadi Zabid at Kolah u/s

Source : Rating number 1

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.0	242.35	244.42	246.49	248.58	250.67	252.77	254.88	257.00	259.12	261.26
2.1	263.40	265.55	267.71	269.88	272.06	274.24	276.43	278.63	280.84	283.06
2.2	285.29	287.52	289.77	292.02	294.28	296.55	298.83	301.11	303.40	305.71
2.3	308.02	310.34	312.66	315.00	317.34	319.69	322.05	324.42	326.80	329.19
2.4	331.58	333.98	336.39	338.81	341.24	343.67	346.12	348.57	351.03	353.50
2.5	355.97	358.46	360.95	363.46	365.97	368.48	371.01	373.55	376.09	378.64
2.6	381.20	383.77	386.35	388.93	391.52	394.12	396.73	399.35	401.98	404.61
2.7	407.26	409.91	412.56	415.23	417.91	420.59	423.29	425.99	428.69	431.41
2.8	434.14	436.87	439.61	442.36	445.12	447.89	450.66	453.44	456.23	459.04
2.9	461.84	464.66	467.48	470.31	473.15	476.00	478.86	481.72	484.60	487.48
3.0	490.37	493.27	496.17	499.09	502.01	504.94	507.88	510.83	513.78	516.75
3.1	519.72	522.70	525.69	528.68	531.69	534.70	537.72	540.75	543.78	546.83
3.2	549.88	552.94	556.02	559.09	562.18	565.27	568.37	571.49	574.60	577.73
3.3	580.86	584.01	587.16	590.32	593.49	596.66	599.85	603.04	606.24	609.45
3.4	612.66	615.89	619.12	622.36	625.61	628.87	632.13	635.41	638.69	641.98
3.5	645.28	648.58	651.90	655.21	658.54	661.88	665.23	668.58	671.95	675.32
3.6	678.69	682.08	685.48	688.88	692.29	695.71	699.14	702.58	706.02	709.47
3.7	712.93	716.40	719.87	723.36	726.84	730.34	733.85	737.37	740.89	744.42
3.8	747.97	751.51	755.07	758.63	762.21	765.79	769.38	772.97	776.58	780.19
3.9	783.81	787.44	791.08	794.72	798.38	802.04	805.71	809.38	813.07	816.76

Flows in cubic metres per second

TABLE 1
continued

Rating table for Wadi Zabid at Kolah u/s

Source : Rating number 1

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
4.0	820.46	823.97	827.29	830.61	833.94	837.27	840.61	843.96	847.31	850.67
4.1	854.03	857.40	860.77	864.15	867.54	870.93	874.33	877.73	881.13	884.55
4.2	887.97	891.39	894.82	898.25	901.69	905.14	908.59	912.05	915.51	918.97
4.3	922.45	925.93	929.41	932.90	936.40	939.90	943.40	946.91	950.43	953.95
4.4	957.48	961.01	964.55	968.10	971.65	975.20	978.76	982.33	985.90	989.47
4.5	993.06	996.64	1000.24	1003.84	1007.44	1011.05	1014.66	1018.28	1021.91	1025.54
4.6	1029.17	1032.81	1036.46	1040.11	1043.77	1047.43	1051.10	1054.78	1058.46	1062.14
4.7	1065.83	1069.52	1073.22	1076.93	1080.64	1084.36	1088.08	1091.81	1095.54	1099.28
4.8	1103.02	1106.77	1110.52	1114.28	1118.04	1121.81	1125.59	1129.37	1133.15	1136.94
4.9	1140.74	1144.54	1148.35	1152.16	1155.98	1159.80	1163.63	1167.46	1171.30	1175.14
5.0	1178.99	1182.84	1186.70	1190.57	1194.44	1198.31	1202.19	1206.08	1209.97	1213.87
5.1	1217.77	1221.67	1225.58	1229.50	1233.42	1237.35	1241.28	1245.22	1249.16	1253.11
5.2	1257.07	1261.02	1264.99	1268.96	1272.93	1276.91	1280.90	1284.89	1288.88	1292.88
5.3	1296.88	1300.90	1304.91	1308.93	1312.96	1316.99	1321.03	1325.07	1329.12	1333.17
5.4	1337.22	1341.29	1345.35	1349.43	1353.50	1357.58	1361.67	1365.77	1369.87	1373.97
5.5	1378.08	1382.19	1386.31	1390.43	1394.56	1398.70	1402.84	1406.98	1411.13	1415.29
5.6	1419.44	1423.61	1427.78	1431.95	1436.13	1440.32	1444.51	1448.70	1452.91	1457.11
5.7	1461.32	1465.54	1469.75	1473.98	1478.21	1482.45	1486.69	1490.94	1495.19	1499.44
5.8	1503.71	1507.97	1512.24	1516.52	1520.80	1525.09	1529.38	1533.68	1537.98	1542.29
5.9	1546.59	1550.91	1555.23	1559.56	1563.89	1568.23	1572.57	1576.92	1581.27	1585.63

Flows in cubic metres per second

TABLE 1
continued

Rating table for Wadi Zabid at Kolah u/s

Source : Rating number 1

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
6.0	1589.99	1594.35	1598.73	1603.10	1607.49	1611.88	1616.26	1620.66	1625.06	1629.47
6.1	1633.88	1638.30	1642.72	1647.14	1651.58	1656.02	1660.46	1664.90	1669.36	1673.82
6.2	1678.28	1682.74	1687.21	1691.69	1696.17	1700.66	1705.15	1709.65	1714.15	1718.65
6.3	1723.17	1727.68	1732.20	1736.73	1741.26	1745.79	1750.33	1754.88	1759.43	1763.98
6.4	1768.55	1773.11	1777.69	1782.26	1786.84	1791.43	1796.02	1800.61	1805.21	1809.82

Flows in cubic metres per second

TABLE 2

Rating table for Wadi Zabid at Structure 1

Source : Tipton & Kalmbach

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0			1.12	2.05	3.16	4.42	5.81	7.32	8.95	10.67
.1	12.50	14.42	16.44	18.53	20.71	22.97	25.30	27.71	30.19	32.74
.2	35.36	38.05	40.80	43.61	46.49	49.42	52.42	55.47	58.58	61.74
.3	64.97	68.24	71.57	74.95	78.38	81.87	85.40	88.98	92.61	96.29
.4	100.02	103.79	107.62	111.48	115.39	119.35	123.35	127.39	131.48	135.61
.5	139.78	144.00	148.25	152.55	156.89	161.27	165.68	170.14	174.64	179.18
.6	183.75	188.36	193.01	197.70	202.43	207.19	211.99	216.83	221.70	226.61
.7	231.55	236.53	241.55	246.60	251.68	256.80	261.95	267.14	272.36	277.61
.8	282.90	288.22	293.58	298.96	304.38	309.83	315.32	320.83	326.38	331.96
.9	337.57	343.21	348.88	354.59	360.32	366.09	371.88	377.71	383.57	389.45
1.0	395.37	401.32	407.30	413.31	419.35	425.42	431.52	437.65	443.80	449.99
1.1	456.20	462.44	468.71	475.01	481.34	487.69	494.08	500.49	506.92	513.39
1.2	519.88	526.40	532.95	539.52	546.12	552.75	559.40	566.08	572.79	579.52
1.3	586.28	593.06	599.88	606.71	613.58	620.47	627.38	634.32	641.29	648.28
1.4	655.29	662.33	669.40	676.49	683.61	690.75	697.92	705.11	712.32	719.56
1.5	726.82	734.11	741.43	748.76	756.12	763.51	770.92	778.35	785.81	793.29
1.6	800.79	808.32	815.87	823.45	831.04	838.66	846.31	853.98	861.67	869.38
1.7	877.12	884.87	892.66	900.46	908.29	916.14	924.01	931.91	939.83	947.76
1.8	955.73	963.71	971.71	979.75	987.80	995.87	1003.96	1012.08	1020.22	1028.38
1.9	1036.56	1044.76	1052.99	1061.23	1069.50	1077.79	1086.10	1094.44	1102.78	1111.16

Flows in cubic metres per second

TABLE 2
continued

Rating table for Wadi Zabid at Structure 1

Source : Tipton & Kalmbach

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.0	1119.56	1127.96	1136.39	1144.84	1153.31	1161.80	1170.31	1178.84	1187.39	1195.97
2.1	1204.56	1213.17	1221.81	1230.46	1239.14	1247.84	1256.55	1265.29	1274.04	1282.82
2.2	1291.62	1300.43	1309.27	1318.13	1327.00	1335.90	1344.81	1353.75	1362.71	1371.68
2.3	1380.68	1389.69	1398.72	1407.78	1416.85	1425.94	1435.05	1444.18	1453.33	1462.50
2.4	1471.69	1480.90	1490.13	1499.37	1508.64	1517.92	1527.22	1536.55	1545.89	1555.25
2.5	1564.62									

Flows in cubic metres per second

TABLE 3 Rating table for Wadi Rima at Mishrafah

Source : Rating curve 1

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	3.73	3.88	4.04	4.20	4.36	4.52	4.68	4.84	5.01	5.17
.1	5.34	5.51	5.68	5.85	6.02	6.19	6.36	6.53	6.71	6.88
.2	7.06	7.24	7.41	7.59	7.77	7.95	8.13	8.31	8.50	8.68
.3	8.87	9.05	9.24	9.42	9.61	9.80	9.99	10.18	10.37	10.56
.4	10.75	10.94	11.13	11.33	11.52	11.72	11.91	12.11	12.31	12.50
.5	12.70	12.90	13.10	13.30	13.50	13.70	13.90	14.11	14.31	14.51
.6	14.72	14.92	15.13	15.33	15.54	15.75	15.95	16.16	16.37	16.58
.7	16.79	17.00	17.21	17.42	17.63	17.91	18.34	18.78	19.23	19.69
.8	20.15	20.62	21.09	21.57	22.06	22.55	23.05	23.56	24.07	24.60
.9	25.12	25.66	26.20	26.75	27.30	27.86	28.43	29.01	29.59	30.18
1.0	30.78	31.38	31.99	32.61	33.23	33.87	34.51	35.15	35.81	36.47
1.1	37.14	37.81	38.50	39.19	39.89	40.59	41.31	42.03	42.76	43.49
1.2	44.24	44.99	45.75	46.52	47.29	48.07	48.86	49.66	50.47	51.28
1.3	52.10	52.93	53.77	54.62	55.47	56.33	57.20	58.08	58.97	59.86
1.4	60.76	61.67	62.59	63.52	64.45	65.40	66.35	67.31	68.28	69.26
1.5	70.24	71.23	72.24	73.25	74.27	75.29	76.33	77.37	78.43	79.49
1.6	80.56	81.64	82.73	83.83	84.93	86.05	87.17	88.30	89.44	90.59
1.7	91.78	93.00	94.23	95.47	96.72	97.98	99.25	100.54	101.83	103.13
1.8	104.44	105.77	107.10	108.44	109.80	111.16	112.54	113.92	115.32	116.73
1.9	118.15	119.57	121.01	122.46	123.92	125.40	126.88	128.37	129.88	131.39

Flows in cubic metres per second

TABLE 3
continued

Rating table for Wadi Rima at Mishrafah

Source : Rating curve 1

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.0	132.92	134.45	136.00	137.56	139.13	140.71	142.30	143.91	145.52	147.15
2.1	148.79	150.43	152.09	153.76	155.45	157.14	158.85	160.56	162.29	164.03
2.2	165.78	167.55	169.32	171.11	172.91	174.72	176.54	178.37	180.22	182.07
2.3	183.94	185.82	187.71	189.62	191.54	193.46	195.41	197.36	199.32	201.30
2.4	203.29	205.29	207.30	209.33	211.37	213.42	215.48	217.56	219.64	221.74
2.5	223.86	225.98	228.12	230.27	232.43	234.61	236.79	238.99	241.21	243.43
2.6	245.67	247.92	250.19	252.46	254.75	257.06	259.37	261.70	264.04	266.40
2.7	268.76	271.14	273.54	275.95	278.37	280.80	283.25	285.70	288.18	290.66
2.8	293.16	295.68	298.20	300.74	303.29	305.86	308.44	311.03	313.64	316.26
2.9	318.90	321.54	324.21	326.88	329.57	332.27	334.99	337.72	340.46	343.22
3.0	345.99	348.78	351.57	354.39	357.22	360.06	362.91	365.78	368.66	371.56
3.1	374.47	377.40	380.34	383.29	386.26	389.24	392.24	395.25	398.28	401.32
3.2	404.37	407.44	410.52	413.62	416.73	419.86	423.00	426.16	429.33	432.52
3.3	435.72	438.93	442.16	445.40	448.66	451.94	455.23	458.53	461.85	465.18
3.4	468.53	471.89	475.27	478.66	482.07	485.49	488.93	492.39	495.86	499.34
3.5	502.84	506.35	509.88	513.42	516.99	520.56	524.15	527.76	531.38	535.02
3.6	538.67	542.34	546.02	549.72	553.44	557.17	560.91	564.67	568.45	571.94
3.7	575.41	578.89	582.39	585.90	589.41	592.95	596.49	600.05	603.62	607.20
3.8	610.79	614.40	618.02	621.65	625.29	628.95	632.62	636.30	639.99	643.70
3.9	647.42	651.15	654.89	658.65	662.42	666.20	670.00	673.80	677.62	681.46

Flows in cubic metres per second

TABLE 3
continued

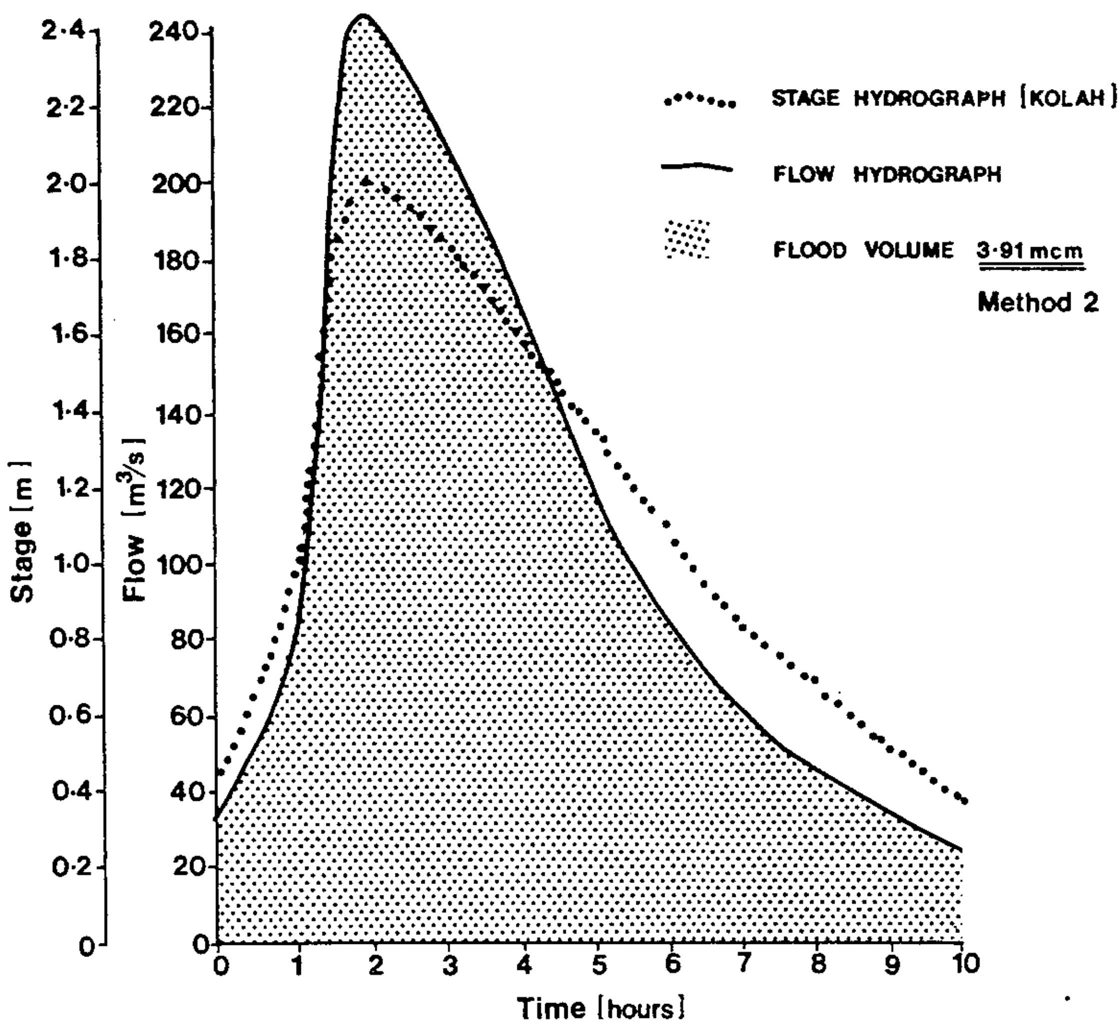
Rating table for Wadi Rima at Mishrafah

Source : Rating curve 1

Stage (m)	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
4.0	685.30	689.16	693.03	696.91	700.81	704.72	708.64	712.57	716.52	720.48
4.1	724.45	728.44	732.44	736.45	740.47	744.51	748.56	752.62	756.70	760.79
4.2	764.89	769.00	773.13	777.27	781.42	785.59				

Flows in cubic metres per second

Flood volume calculation example



(1) TIME hour	(2) STAGE m	(3) FLOW m^3/s	(4) SIMPSON MULTIPLIER	(5) SIMPSON TOTAL
0	0.45	30	1/3	10
1	1.00	79	4/3	105
2	2.00	242	2/3	161
3	1.85	212	4/3	283
4	1.62	179	2/3	119
5	1.34	125	4/3	167
6	1.10	93	2/3	62
7	0.82	61	4/3	81
8	0.64	45	2/3	30
9	0.50	34	4/3	45
10	0.39	26	1/3	89

AVERAGE STAGE 1.065
AVERAGE FLOW 87 m^3/s
VOLUME = 3.13 MCM
METHOD 1

TOTAL $\frac{1072 \times 3600}{10^6}$ = 3.86 MCM
METHOD 3

of a fairly large flood on Wadi Zabid at Kolah. The stage hydrograph shown in figure 2 represents the flood as recorded on the chart at Kolah. Three methods of assessing the flood volume are considered below.

(i) Average stage

Water levels are abstracted from the chart (figure 2) at a suitable time interval (1 hour here), the mean stage obtained and converted to flow by the rating table (Table 1). This flow rate (m^3/s) is then converted to volumes (million cubic metres - MCM) by multiplying by the duration of the flood (10 hours). Columns 1 and 2 of figure 2 show this calculation. The flood volume by this method is 3.13 MCM.

(ii) Graphical Integration

The stage hydrograph in figure 2 is converted to flow using the rating table (Table 1). The area under the discharge-time graph represents the volume of flood water. This area may be estimated by planimeter or counting squares on millimetre graph paper. The latter method was used in this case and the volume estimated as 3.91 MCM.

(iii) Numerical Integration

The estimation of flood volumes is a case of integration of discharge with time. In our example discharge has been evaluated at a constant time interval (1 hour in our example). Simpson's Rule is a simple and accurate method of obtaining this integral:

$$V = \frac{T}{3}(q_o + 4q_T + 2q_{2T} + 4q_{3T} + 2q_{4T} + \ldots\ldots 4q_{(n-1)T} + q_{nT})$$

where:

V = Volume of flood m^3

T = Time interval (3600 seconds)

q_o = Discharge at time zero

q_T = Discharge at time T

q_{2T} = Discharge at time 2T

q_{nT} = Discharge at last time interval

The calculation of flood volume by this method is shown in figure 2 for our example flood. The answer obtained was 3.86 MCM.

Of the three methods considered above, the numerical integration and graphical integration techniques are acceptable for calculating flood volumes. In the example considered the flood volumes by these two methods agreed to within 2%. The average stage technique, however, yields a flood volume some 20% below the other two. This method is not satisfactory and should not be used because it assumes a linear relationship between stage and discharge which is untrue. As stage increases there is a proportionally higher increase in discharge. Estimation of flood volumes based on average stage will therefore always be too low.

The graphical integration technique is tedious when many floods have to be analysed and cannot easily be automated. Although the numerical integration method takes considerably more time to evaluate than the average stage method, it is readily adaptable to computer analysis. In fact the data analysis computer programs described in subsequent sections use the Simpson method of numerical integration.

6.4 The Sharp PC1500 computer

A Sharp PC 1500 computer with printer and cassette interface was made available to the Hydrology Section during the October 1982 visit.

Programs were written at that time to assist with the processing of hydrological data. It is hoped that use of this computer will enable more accurate estimation of flood flows from the wadis and reduce some of the tedium of data processing. Furthermore it should give Hydrology Section staff an opportunity to familiarise themselves with the use of a computer and give them a chance to start some elementary programming. The computer is on loan to the Hydrology Section from the Institute of Hydrology and hopefully will be replaced by a larger machine if the proposal for a water resources assessment project comes to fruition.

The following sections consider the use of ther PC1500 and the programs written during October 1982.

6.5 Using the Sharp PC1500 computer

(1) Keep and use in a relatively clean and cool room. Do not leave in direct sunlight.

(2) Remove pens after use (to stop them drying up). Instructions for this can be found on page 15 of the small booklet in the computer case.

(3) Hint for installing pens:
Keep pressing the key on the printer until the bar magnet is in the correct position. (See page 15 of the printer booklet). Install the black pen first.

(4) Charge overnight once a week. Even when the computer is not being used.

(5) Use with mains adaptor connected.

(6) If the display says:

CHECK 6 or

ERROR 80 or

ERROR 78

the batteries are low and must be recharged. (See page 18 of the printer booklet).

(7) When paper has to be replaced refer to page 12 of the printer booklet.

(8) The computer has been left with the "MODE" switch locked in the "RUN" position. This is the mode for running programs. If you

wish to experiment with your own programs type:

UNLOCK

The mode switch now works. Pressing "MODE" alternatively switches from "RUN" to "PROGRAM" mode. The current mode is indicated at the top of the display.

When you have finished experimenting make sure the computer is left in "RUN" mode and type

LOCK

(9) If you want to enter a new program, first type NEW in program mode to clear the existing program.

6.6 Loading programs from cassettes

(1) Connect the computer to the cassette recorder using the triple lead in the computer case:
GREY lead (EAR socket computer - EAR socket recorder).
RED lead (MIC socket computer - MIC socket cassette).
BLACK lead (REM 0 socket computer - REM socket cassette).

(N.B. The REM 1 socket on the computer is not used.
Ensure you are using REM 0 and not REM 1).

(2) The "REMOTE" switch on the computer should now be off.
(3) Rewind tape to start.
(4) Set counter to zero.
(5) If the required program is not the first on the tape, advance the tape to start position number as indicated on cassette label.
(6) Turn "REMOTE" switch on computer to ON
(7) Press "PLAY" on the cassette recorder.
(8) Type CLOAD "PROG" (where "PROG" is the appropriate program name - don't forget the quotes")
(9) The tape should now move and after a while you should hear a whistling noise.
(10) If the computer finds the program you want, the program name appears on the display. If not refer to the paragraph immediately following these instructions.

(11) After the program has been read in the tape will stop automatically. Press the stop button on the cassette recorder.

(12) Turn the remote switch on the cassette recorder off.

(13) Rewind the cassette and disconnect leads.

(15) You are now ready to run the program.

If you are having problems first check that you have spelt the program name correctly (in capitals). The program name must be in quotes. Check you have the right tape. Check the leads to the cassette recorder are the correct way round. If the batteries are low in the cassette recorder replace or use mains adaptor.

6.7 Monthly flow programs "KOLAFLOW" and "MISHFLOW"

Programs "KOLAFLOW" and "MISHFLOW" assist in the calculation of monthly flood and baseflow volumes for the Kolah and Mishrafah stations respectively. The programs are identical in method of operation and computation and differ only in the rating curve held with the program.

Some preparatory work on the data is necessary before running the program and this is achieved by completing the form given in figure 3. All baseflow discharge measurements (defined as 8 m/s or less at Kolah) during the month in question are entered in section (1) of the form. Any flood discharge measurements are placed in section 2.

To complete section (3) of the form it is necessary to consult the gauging station charts for the month in question. Firstly count the number of days on which a flood occurred and then write in pencil the hourly flood stages on the chart. With each flood ensure that there is at least one value before the peak. If the peak value does not fall exactly on the hour omit the nearest hourly reading and substitute with the peak. Continue reading from the chart on the hydrograph's recession for a reasonable distance (use your judgement). Readings should not be taken from the chart when the trace becomes horizontal; this implies that the float is sticking and readings are invalid. If a flood is flat topped, this again is due to a sticking float and the flood peak should be estimated by comparison with similar floods elsewhere in the record.

Monthly Flow record

STATION: YEAR: MONTH:

YOUR NAME: TODAY'S DATE:

(I) BASEFLOW MEASUREMENTS (8 m^3/s or less at KOLAH)

DATE	TIME	STAGE	DISCHARGE	DATE	TIME	STAGE	DISCHARGE
		m	m^3/s			m	m^3/s

(2) FLOOD DISCHARGE MEASUREMENTS (8 m^3/s or more at KOLAH)

DATE	TIME	STAGE	DISCHARGE	DATE	TIME	STAGE	DISCHARGE
		m	m^3/s			m	m^3/s

(3) RECORDED FLOODS

NUMBER OF DAYS WITH FLOODS:

DATE	TIME	HOUR	STAGE	DATE	TIME	HOUR	STAGE	DATE	TIME	HOUR	STAGE	DATE	TIME	HOUR	STAGE
		NO.	m			NO.	m			NO.	m			NO.	m

REMARKS:

Figure 3

Having marked the hourly stages for periods of flood on the charts, these should then be transcribed to section (3) of the Monthly Flow record form. The example Monthly Flow record form shown in figure 4 shows how this is done. Here three floods have been entered in section (3) for April 1979. The first flood, commencing on April 1st at 19:00 hours with a stage of 0.15 m, is entered as shown. This flood has a duration of 12 hours. Data from subsequent floods are then appended to the table. Note the hour number is not reset at the beginning of each flood, but increases throughout the month.

Data stored in sections (1) and (3) of the completed Monthly Flow record form (figure 4) are used by the data processing computer programs.

The following instructions relate to running the computer program "KOLAFLOW". To run "MISHFLOW" the procedures are identical. Figure 5 is a listing of "KOLAFLOW" together with an example output.

(1) Load "KOLAFLOW" from cassette (see section 6.6)

(2) Type RUN

(3) The computer replies:

    Hydrology Section - TDA -
    Wadi Flow - KOLA
    Enter year

(4) Enter year as requested eg. 1979

(5) Enter your name eg. MOHAMMED ANWAR

(6) Enter month number (1 = JAN, 2 = FEB etc) eg. 4 for APRIL

(7) The computer then prints the information you have told it plus today's date and the number of the rating curve being used (figure 5).

(8) The display now says:

    Apr 1979 Number d m's?

    Enter the number of discharge measurements made during the months (eg. 5). Note that there must be at least one discharge measurement. If there are none find a suitable substitute value from adjacent months. Note also that these must be baseflow discharge measurements; at Kolah this is 8 m^3/s or less.

(9) Now enter the discharge measurements, one by one, in m^3/s until

Monthly Flow record

STATION: KOLAH YEAR: 1979 MONTH: APRIL

YOUR NAME: C.S. GREEN TODAY'S DATE: 5.1.83.

(1) BASEFLOW MEASUREMENTS (8 m^3/s or less at KOLAH)

DATE	TIME	STAGE	DISCHARGE	DATE	TIME	STAGE	DISCHARGE
		m	m^3/s			m	m^3/s
2	8:30		2.94				
5	9:45		1:87				
9	9:05		1:21				
15	9:30		5:63				
25	9:00		0:54				

(2) FLOOD DISCHARGE MEASUREMENTS (8 m^3/s or more at KOLAH)

DATE	TIME	STAGE	DISCHARGE	DATE	TIME	STAGE	DISCHARGE
		m	m^3/s			m	m^3/s

(3) RECORDED FLOWS

NUMBER OF DAYS WITH FLOODS: 3

DATE	TIME	HOUR	STAGE	DATE	TIME	HOUR	STAGE	DATE	TIME	HOUR	STAGE	DATE	TIME	HOUR	STAGE
		NO.	m			NO.	m			NO.	m			NO.	m
1	19:00	1	0.15			16	0.33								
		2	0.54			17	0.30								
		3	0.40			18	0.28								
		4	0.32			19	0.26								
		5	0.23			20	0.25								
		6	0.28	15	1:00	21	0.22								
		7	0.40			22	0.28								
		8	0.36			23	0.33								
		9	0.35			24	0.28								
		10	0.29			25	0.24								
		11	0.26												
		12	0.23												
13	5:30	13	0.12												
		14	0.38												
		15	0.36												

Figure 4 17

```
  10:CLEAR :WAIT 10
     0:PRINT "Hydro
     logy Section -
     TDA-"
  20:PRINT "Kola fl
     ow"
  30:INPUT "Enter y
     ear ";Z:INPUT
     "Your name ?";
     N$
  32:DATA "1",.261,
     -.442,.942,-.1
     19,1.537,.101,
     1.897,.797,3.2
     02
  33:DIM LH(3),LQ(3
     ):READ R$,A:
     FOR W=0TO 3:
     READ LH(W),LQ(
     W):NEXT W
  36:INPUT "Enter m
     onth no.(1-12)
      ?";U
  40:DATA "Jan","Fe
     b","Mar","Apr"
     ,"May","Jun","
     Jul","Aug","Se
     p","Oct","Nov"
     ,"Dec"
  50:FOR L=1TO 12:
     READ @$(L):
     NEXT L
  52:I=INT (TIME /1
     E4):J=INT (
     TIME /100)-I*1
     00
  54:LPRINT TAB 3;"
     KOLA ";@$(U);Z
     :LF 1:LPRINT "
      By ";N$:
     LPRINT " On ";
     @$(I);" ";J
  56:LPRINT " Flood
      rating ";R$:
     LF -1
  60:GOSUB 2000
  65:LF 2
  70:CLS :PRINT @$(
     U);Z;:INPUT "
     Number dm^s?";
     V
  80:Y=0:FOR W=1TO
     V:CLS :WAIT 0:
     PRINT "Enter d
     m ";W;" ";:
     INPUT X:IF X<0
     GOTO 70
  85:Y=Y+X:NEXT W
  90:Y=Y/V
 110:V=0:T=0:S=0:Q=
     0:CLS :WAIT 0:
     PRINT @$(U);Z;
     :INPUT " no. o
     f floods ?";V:
     IF V<0GOTO 70
 120:IF V=0GOTO 310
 160:W=0:X=0:T=0:G=
     1/3
 170:WAIT 0:CLS :
     PRINT "Stage (
     m) hour";W+1;:
     BEEP 2,5,250:
     INPUT " ? ";O$
 175:IF VAL O$<0
     GOTO 110
 180:IF ASC O$>57OR
     ASC O$<46GOTO
     310
 182:IF VAL O$<10
     GOTO 190
 184:BEEP 15:CLS :
     WAIT 400:PRINT
     "Mistake ";O$;
     "m ? Repeat":
     GOTO 170
 190:W=W+1:X=VAL O$
     :IF X>QLET Q=X
 192:IF X<=0LET X=0
     .0001
 194:X=LOG (X+A)
 200:FOR R=1TO 3
 220:P=R-1:IF X<=LH
     (R)GOTO 240
 230:NEXT R
 240:X=LQ(P)+((LQ(P
     +1)-LQ(P))*(X-
     LH(P))/(LH(P+1
     )-LH(P)))
 250:X=10^X:IF X>S
     LET S=X
 260:T=T+G*(.0036*(
     X-Y)):G=4/3:IF
     (INT (W/2))=(W
     /2)LET G=2/3
 300:GOTO 170
 310:R=31:IF U=4OR
     U=6OR U=9OR U=
     11LET R=30
 320:IF U=2LET R=28
 330:IF U=2AND (INT
     (Z/4))=Z/4LET
     R=29
 340:Y=Y*R*0.0864
 500:LPRINT TAB 6;"
     Floods":LF 1:
     GRAPH :P$="###
     ##.##"
 510:LPRINT " Numbe
     r ";V:TEXT :LF
     1:GRAPH
 520:LPRINT USING "
     ##.##";" Max s
     tage ";Q;" m":
     TEXT :LF 1:
     GRAPH
 530:LPRINT USING P
     $;" Max flow "
     ;S
 535:GOSUB 2000
 540:TEXT :LF 2:
     LPRINT TAB 6;"
     Volumes":LF 1:
     GRAPH
 560:COLOR 3:LPRINT
     USING P$;" Flo
     od";T;" MCM":
     TEXT :LF 1:
     GRAPH :COLOR 0
 570:LPRINT USING P
     $;" Base ";Y;"
      MCM":TEXT :LF
     1:GRAPH
 580:COLOR 1:LPRINT
     USING P$;" Tot
     al";(T+Y);" MC
     M"
 590:GOSUB 2000
 600:GRAPH :SORGN
 610:FOR K=1TO 7
 620:GRAPH :LINE -(
     (5*Y),-5),,0,B
     :LINE ((5*Y),0
     )-((5*(Y+T)),-
     5),,3,B:
     GLCURSOR (0,-5
     ):SORGN :NEXT
     K
 625:LINE -(216,35)
     ,,2,B
 630:GLCURSOR (0,-2
     5):SORGN
 700:TEXT :LF 3:
     COLOR 0:BEEP 3
1000:END
2000:TEXT :GRAPH
     :GLCURSOR (0
     ,-5):SORGN
2010:LINE -(216,8
     0),,2,B:LINE
     (0,80)-(216,
     100),,,B
2020:GLCURSOR (0,
     0):COLOR 1:
     TEXT
2050:RETURN

STATUS 1
                1771
```

Output

```
    KOLA Apr 1979

By CHRIS
On Feb  1
Flood rating 1

       Floods

Number   3
Max stage   0.54 m
Max flow     37.50

      Volumes

Flood      1.56 MCM
Base       6.31 MCM
Total      7.88 MCM
```

Listing of program "KOLAFLOW" and output

Figure 5

all have been entered.

(10) The next part of the program concerns floods and the display says:

April 1979 no. of floods?

Enter the number of days with floods in the month (3 in our example of April 1979). If there are none you now pass to step 14 below.

(11) The display now says

Stage (m) hour 1?

After the beep-beep sound enter the first stage of the first flood in metres. Note that stages of 10 m or more will be considered as mistakes and you will be asked to re-enter the value.

(12) After completing the entry for the first flood continue directly with the first stage of the second flood. The program assumes, for convenience of analysis, that the floods are continuous. The hour number on the display thus corresponds with the hour number in section 3 of the monthly flow record form (figure 6).

(13) When finished entering the stage data type any letter eg. X.

(14) A monthly summary is then produced on the printer giving the total flow at Kolah in million cubic metres. This is separated into baseflow and flood runoff. The bar chart is scaled in proportion to these two quantities where baseflow is coloured black and flood flow coloured red (not visible on the black only copy in this report - figure 5). Information on the number and biggest flood in the month is also given. The maximum stage is in metres and maximum flow in m^3/s.

Notes: (1) If you make a mistake while entering a discharge measurement or flood stage, type -1 to the next prompt. You will then move one step back in the program without having to restart from the beginning.

(2) Somebody else should run the program as a check. If the two outputs agree then all is well.

The program works by calculating baseflow from the average of the discharge measurements made during the month. Flood stages are converted to flows inside the program using the appropriate rating curve and flood volumes calculated using Simpson's rule. Finally baseflows are subtracted from flood flows. The program knows how many days there are in each month - even in leap years.

6.8 Individual flood program "FLOODS"

This program computes individual flood volumes recorded at Kolah, Mishrafah and Structure 1. Simpson's rule is again used to calculate flood volume. The time interval of the data is not fixed to one hour as it is in "KOLAFLOW" and "MISHFLOW", but is specified during program execution. Rating curves for all three sites are stored within the program so the same program may be used for any station. Total volume of water passing the gauging station during the flood is calculated; there is no subtraction of baseflow.

"FLOODS" is listed in figure 6 and executed as described below:

(1) Load program "FLOODS" from cassette

(2) Type RUN

(3) The computer replies:

> Hydrology Section - TDA -
> Flood volumes
> Your name?

Enter your name

(4) Enter date of the flood eg. 10/10/79.

(5) You are then given a choice of Kolah, Mishrafah or Structure 1. Answer Y (for Yes) to the one you want. Answer N (for No) to the others.

(6) Now enter the number of points on the flood hydrograph. There must be an odd number (eg. 7, 11 or 13).

(7) Enter the time interval of the data. This can be 0.5 for half hour, 1 for 1 hour etc. The display then confirms (6) and (7) from above.

(8) Now input the stages one by one. The time starts at 1 x the time interval. Thus if you have a time interval of 1 hour the program assumes hour 1 is the start time. You must wait for the beep-beep before entering a number. Stages 10 m or more are considered as mistakes.

(9) On completion of entry the printer gives peak stage, peak flow and flood volume.

```
 10:CLEAR :WAIT 10
    0:PRINT "Hydro
    logy Section -
    TDA-"
 20:PRINT "Flood v
    olumes"
 30:INPUT "Your na
    me ? ";X$
 35:INPUT "Date of
     flood ?";U$
 40:DIM LH(3),LQ(3
    )
 50:DATA "KOLA","1
    ",.261,-.442,.
    942,-.119,1.53
    7,.101,1.897,.
    797,3.202
 52:DATA "STRUCT.
    1","1",0.0,-3.
    ,-1.903,-1.,1.
    097,0.,2.597,.
    301,3.049
 54:DATA "MISHRAFA
    H","1",.3,-.3,
    .85,0.02,1.25,
    .3,1.96,.6,2.7
    55
 80:FOR Y=1TO 3
 90:READ Z$,Y$,W:
    FOR V=0TO 3:
    READ LH(V),LQ(
    V):NEXT V
100:CLS :WAIT 0:
    PRINT Z$;:
    INPUT " Y/N ?"
    ;W$:IF W$="Y"
    GOTO 150
110:NEXT Y
120:CLS :WAIT 200:
    PRINT "You hav
    e said NO to a
    ll":GOTO 1000
150:CLS :INPUT "Ho
    w many points?
     ODD no.";U
160:IF (INT (U/2))
    =U/2GOTO 150
170:CLS :INPUT "Ti
    me interval (h
    ours) ?";T
180:CLS :WAIT 400:
    PRINT U;" poin
    ts-Time int";T
    ;"hr"
190:O=T
200:FOR Y=1TO U
210:S=2:IF (INT (Y
    /2))=(Y/2)LET
    S=4
220:IF Y=1OR Y=U
    LET S=1
230:S=S*T*0.0036/3
240:CLS :WAIT 0:
    PRINT "Hour";O
    ;:BEEP 2:INPUT
    " Stage (m) ?
    ";X:M=X
242:IF X<10GOTO 25
    0
244:CLS :WAIT 300:
    BEEP 7,5,100:
    PRINT "Mistake
    ";X;" m ? Repe
    at":GOTO 240
250:IF X<=(-W)LET
    X=0.001+W
260:X=LOG (X+W)
270:FOR R=1TO 3
280:P=R-1:IF X<LH(
    R)GOTO 300
290:NEXT R
300:X=LQ(P)+((LQ(P
    +1)-LQ(P))*(X-
    LH(P))/(LH(P+1
    )-LH(P)))
310:Q=10^X:X=Q*S:N
    =N+X
320:IF Q>KLET K=Q
330:IF M>LLET L=M
500:O=O+T
550:NEXT Y
560:COLOR 1:LPRINT
    "Station ";Z$
570:LPRINT "Flood
    on ";U$
580:LPRINT "By ";X
    $
590:LPRINT "Rating
     no. ";Y$:LF 1
610:CLS :WAIT 100:
    PRINT "Peak st
    age ";L;" m"
620:PRINT USING "#
    ###.####";"Pea
    k flow ";K;" c
    umecs"
630:PRINT "Volume
    ";N;" MCM"
640:GRAPH :LPRINT
    USING "##.##";
    "Peak stage (m
    )";L:TEXT :LF
    1:GRAPH
650:GRAPH :LPRINT
    USING "####.##
    ";"Peak flow "
    ;K:TEXT :LF 1:
    GRAPH
660:LPRINT USING "
    ###.####";"Vol
    ume";N;" MCM":
    TEXT
670:LF 4:COLOR 0
990:BEEP 1
 1000:END


STATUS 1
                1357
```

Listing of program "FLOODS"

Figure 6

6.9 Writing your own programs - an example

The instruction manual with the PC1500 is intended as a beginners guide to programming. It is written in an easy to understand manner and should make a good starting point. This section explains a simple example program which is designed to analyse monthly rainfall data giving totals, maxima and number of rainy days.

The program is typed in directly as listed below except for the colon: after the statement number which will be inserted automatically by the computer after ENTER is pressed. Note you must be in PROGRAM mode to enter or modify a program (see section 6.5 notes (8) and (9)).

PROGRAM	COMMENTS
10 :CLEAR	Clear everything in computer for start of new program
20 :INPUT"HOW MANY DAYS";N	N is number of days in the month, eg 30, 31
30 : T = 0	T = Monthly total rainfall = zero
40 : M = 0	M = Monthly maximum rainfall = zero
50 : P = 0	P = Number of rainy days = zero
60 : FOR I = 1 TO N	Start of loop I = 1 ie day 1 of the month
70 : CLS	Clear screen
80 : WAIT 0	No waiting required
90 : PRINT"DAY"; I;	DAY 1 appears on screen - because I = 1
100: INPUT"RAIN?"; R	RAIN? appears on screen next to DAY 1 asking operator for the rainfall on day 1. R contains the number typed in by the operator.

110: T=T+R	The total rain T is increased by the rainfall R typed in for the current day.
120: IF R>M LET M=R	If the current day's rainfall,R, is greater than the previously recorded maximum,M, then the new maximum is R. Otherwise M remains unchanged.
130: IF R>0LET P=P+2	If the rainfall on the current day is greater than zero (ie it is raining, the number of rainy day P is increased by one.
140: NEXT I	Go back to line 60 and repeat for the next day. If I, the current day, was the last in the month (N) then continue with next line.
150: LPRINT"TOTAL"; T	Print month total, T, on printer
160: LPRINT"MAX"; M	Print monthly maximum, M, on printer
170: LPRINT"RAINY DAYS"; P	Print number of rainy days, P, on printer
180: END	End of program.

Having typed the program into the computer's memory, try and run it by typing RUN. Remember you must change from PROGRAM mode to RUN mode before this is possible. If there are mistakes you will have to refer to the instruction manual for clarification. Once the program is working try storing it on cassette tape. Modify the program, if you wish, to improve presentation of the output and to allow for missing data. This may be done by inputting -1 for a day with no rainfall then reading and counting the number of -1's in a month - but don't add these -1's into the monthly total or the monthly total will be wrong.

6.10 Equipment list

The following is an inventory of computer related equipment on loan to TDA:

1 x PC1500 Computer (+ case)
1 x Add on 8K memory
1 x CE150 Printer and cassette interface
1 x Fair Mate cassette recorder
1 x Sharp mains adaptor
1 x Fair Mate mains adaptor
1 x Set of collecting leads
1 x Sharp PC1500 Instruction Manual
1 x Sharp PC1500 Application Manual
1 x Sharp CE150 Instruction Manual.

7. Itinerary

Visit 1 20/11/1981 - 10/12/81

Friday	20 Nov		Arrive Sana'a. Local weekend
Saturday	21 Nov		Preparation for YOMINCO visit. Reading references
Sunday	22 Nov	am	Meeting British Embassy
		pm	Meeting YOMINCO
Monday	23 Nov	am	Drive to Zabid
		pm	Introductory meeting with Hydrology Section
Tuesday	24 Nov		Discussions with Hydrology Section
Wednesday	25 Nov	am	Field visit to Kolah gauging station
		pm	Study data available to establish flood warning scheme
Thursday	26 Nov		Devise flood warning scheme and outline suggested procedure to Hydrology Section.

Friday	27 Nov		Continue development and collection of data for flood warning scheme
Saturday	28 Nov		Field visit to Wadi Rasyn
Sunday	29 Nov	am	Field work for flood warning scheme
		pm	Assist field crew with current meter gauging at Kolah
Monday	30 Nov		Demonstrate the field technique of indirect flow measurement at Kolah to Hydrology Section staff
Tuesday	1 Dec	am	Attend to the IH automatic raingage at Al Gerba
		pm	Continue data collection for flood warning scheme
Wednesday	2 Dec		Visit IH automatic raingauge. Continue work on flood warning scheme
Thursday	3 Dec		Field visit to wadi Siham. Established a more suitable location for the Siham gauging station
Friday	4 Dec		Local weekend
Saturday	5 Dec		Discussions with Hydrology Section on data processing
Sunday	6 Dec		Visit IH automatic raingauge. Collect remaining data for flood warning. Final discussions with Hydrology Section
Monday	7 Dec		Drive to Sana'a via Ibb and Rihab raingauges
Tuesday	8 Dec		Visit YOMINCO and Dutch Embassy
Wednesday	9 Dec		Visit YOMINCO and British Embassy
Thursday	10 Dec		Fly home from Sana'a.

Visit 2 9/10/1982 - 29/10/1982

Saturday	9 Oct	Arrive Sana'a. Familiarisation with computer
Sunday	10 Oct	Visit British Embassy. Purchase cassette recorder for computer in Sana'a. Commence program writing for computer.
Monday	11 Oct	Continue program development on computer.

Tuesday	12 Oct	Drive to Zabid. Meeting with Hydrology Section
Wednesday	13 Oct	Attend presidential opening of Wadi Rima project
Thursday	14 Oct	National Holiday. Discussions with Hydrology Section on Water Resources Project
Friday	15 Oct	Preparation of initial project proposal for joint IH/TDA water resources project
Saturday	16 Oct	Visit Wadi Rasyn catchment climate station and chemical analysis laboratory Taiz
Sunday	17 Oct	Telephone Embassy from Zabid town to check arrival of 8K memory chip. Computer program development.
Monday	18 Oct	Discussions with Hydrology Section on the proposed water resources study
Tuesday	19 Oct	Continue program development on computer for processing wadi flow data
Wednesday	20 Oct	Visit Kolah and Structure 1 gauging stations to obtain information on 1982 big flood
Thursday	21 Oct	Field visit to Wadi Rima. Inspect Mishrafah station and drive up wadi to find a location for a suitable flood warning station
Friday	22 Oct	Continue program development on computer and write notes on computer and programs for Hydrology Section staff
Saturday	23 Oct	Introduce computer and programs to Hydrology Section staff
Sunday	24 Oct	Meeting with Director General and Chairman, TDA at Hodeidah
Monday	25 Oct	Discussions on data processing with Hydrology Section. Discuss developments in Flood Warning.
Tuesday	26 Oct am	Final discussions on use of computer
	pm	Drive to Sana'a
Thursday	28 Oct	Visit British Embassy. Confirm flight. Depart to airport for midnight flight to London.

8. List of people met

The following people were met either during one or both visits:

Mr Ahmed Ali Hummad	Chairman TDA
Mr Ibrahim El Domi	Director General TDA
Mr Mohammed Arshed	Resident Engineer
Mr Mohammed Anwar	Senior Hydrologist TDA
Mr Mohammed Ashfaq	Hydrogeologist TDA
Mr Kahlid Saeed	Hydrologist TDA
Mr Mohammed Saleh Salem	Hydrologist TDA
Mr Saleh Tahir	Hydrologist TDA
Mr Ali Hussein Swadi	Hydrologist TDA
Mr Abdo Mohammed	Head of Department of Hydrlogy YOMINCO
Mr Mohammed Ayub	Senior Hydrologist YOMINCO (SHELADIA Associates)
Dr M. Noureddine Al-Rifai	Professor and Head of Dept. of Irrigation and Hydraulics University of Damascus
Dr Gerald F.J. Jeurissen	Deputy Managing Director TNO (Groundwater Survey)
Mr P.J. Drury	Associate, Sir M. McDonald and Partners
Mr H.M. Robertson	Attache Technical Cooperation British Embassy
Mr J.T.M. Vervloed	Third Embassy Secretary - Royal Netherlands Embassy.

9. Acknowledgements

I would like to acknowledge the assistance given to me by many people during the two visits to the Yemen. In particular thanks are due to the staff of the Hydrology Section of TDA for their hospitality and also to British Embassy staff in Sana'a for their assistance and provision of transport both of which maximised the work achieved during the two short visits.

10. References

1. 'Flood Warning Manual for Wadi Zabid', C.S. Green, April 1982.

2. 'Stage and discharge measurements in steep wadis: Report on a vist to the Yemem Arab Republic', J.C. Bathurst, November 1980.

3. 'Report on a visit to the Yemen Arab Republic', C.H.R. Kidd, April 1980.

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