MCB

 Evap. Memo. Number 7

THE RADIATION TERM IN THE PENMAN FORMULA – USE OF SUNSHINE OR INCOMING RADIATION AS APPROXIMATIONS

by P. B. WRIGHT

1. UNITS used in this memo, and in all future memos unless otherwise stated, will be:

Vapour pressures in mb
Wind speeds in kts
Sunshine in hours per day
Temperature in °C
Evaporation in mm per day
Radiation in mm per day

2. THE PENMAN FORMULA may be written

$$E = \frac{\Delta H + E_a'}{\Delta + 0.65}$$

where $E_a' = 0.65\ E_a$

and E_a is the Aerodynamic Term discussed in Memo 6.

3. DATA

We have calculated E for each day during the period 1 March 1968 to 28 February 1969 (numbered consecutively from 1 to 365). The aerodynamic term was calculated using Penman's approximation ((7) in Memo 6). This approximation was shown in Memo 6 to be highly dubious, but it will not affect the rest of the work described in this memo.

The radiation H was produced in three different ways:

(1) Observed net radiation. Daily values were obtained from Met 0 14 in units mWh/cm^2. These were converted to mm/day by multiplying by 10/685 and then stored as Block 55 of Magtape MEPW0001. These values N were used as H in calculating E_1.

(2) Observed incoming radiation. Values of I in mm/day were similarly produced as Block 56. These were then converted to Net radiation N_2 by the formula (produced empirically from an examination of scatter diagrams of net against incoming for each day during June to November 1968):

$$N_2 = (I - \frac{4500}{3672})\ 0.54$$

N_2 was then used to calculate E_2.

(3) Sunshine. Hours of sunshine were used to calculate incoming radiation I_3, outgoing radiation O_3 (a negative quantity) thence net radiation N_3 ($= I_3 + O_3$) using the formulae detailed in Memo 3, taking the albedo factor A = 0.75, and the black body factor B = 0.95, these values being appropriate for grass. It was necessary to use values for grass in order to be able to compare with the true radiation values which were obtained from instruments situated over grass. N_3 was then used to calculate E_3.

FH2

Daily values of all these quantities are given in Table 1 (available on request).

The purpose of this Memo is to discuss comparisons of the three estimates E_1, E_2, E_3 of Potential Evaporation. We shall assume that E_1 (using observed net radiation) is correct.

4. MONTHLY MEANS

Figure 1 shows monthly and annual mean values of E_1, E_2 and E_3.

The annual means seem acceptably close.

The Incoming radiation method shows values which were too low in summer months and too high in winter months. The Sunshine method was somewhat too high throughout the year. March seems rather anomalous.

Figure 2 shows for each month the standard deviations within the month of E_1, E_2 and E_3. The value of the standard deviation of E should be a function of the variability of the weather during the month, and should be the same for all three methods. The graph shows that for the Incoming radiation method the value is satisfactory throughout the year. For the Sunshine method the value is satisfactory in winter, but too low during most of the year. This means that the sunshine formula is not sensitive enough to day-to-day changes.

These results suggest that some changes in the arbitrary constants, perhaps involving seasonal factors, could be made in order to improve the formulae.

We cannot discuss the standard error of monthly means until several years' data have been analysed.

5. ERRORS OF DAILY VALUES

Figure 3 shows the standard error of the daily values of E_2 and E_3 each month.

The Incoming radiation method produced a standard error which was fairly constant through the year at around 0.3 mm/day (left graph). This is equivalent to a percentage standard error (right graph) of about 11% during March to August. The winter values of percentage error have little meaning. These errors would probably not be reduced by the alterations in the arbitrary constants already discussed.

The Sunshine method produced a standard error which ranged from 0.6 mm/day in summer to 0.2 in winter. This was about double the error of the Incoming radiation method in summer, and about the same in winter. The percentage standard error was around 20% during March to September. These errors would be somewhat reduced in the summer half-year by the modifications already suggested to deal with the standard deviation of daily values.

6. INDIVIDUAL DAYS

A detailed study could be made of the weather types on days when either of the approximations gave markedly different results. For this purpose Table 2 (available on request) shows the daily differences E_1-E_2 and E_1-E_3.

A preliminary look at these has suggested one result. On July 10 (day 132) the sunshine method gave a much too high estimate of evaporation ($E_3 = 1.45$, $E_1 = 0.37$). This was an overcast day with very low cloud and no sunshine. Hence the sunshine method could not have given any lower value on that particular date in the year. Nearly all sunless days appear to have resulted in overestimates of evaporation (Table 3, available on request). The errors in the sunshine formula already discussed could have arisen in this way. The suggested modification would be to reduce the constant term in the conversion from sunshine to net radiation and make some increase in the multiplying factor.

Further studies on these lines could prove rewarding.

7. CONCLUSIONS

1. Some modifications seem desirable to the arbitrary constants in the two formulae used to estimate Net Radiation.

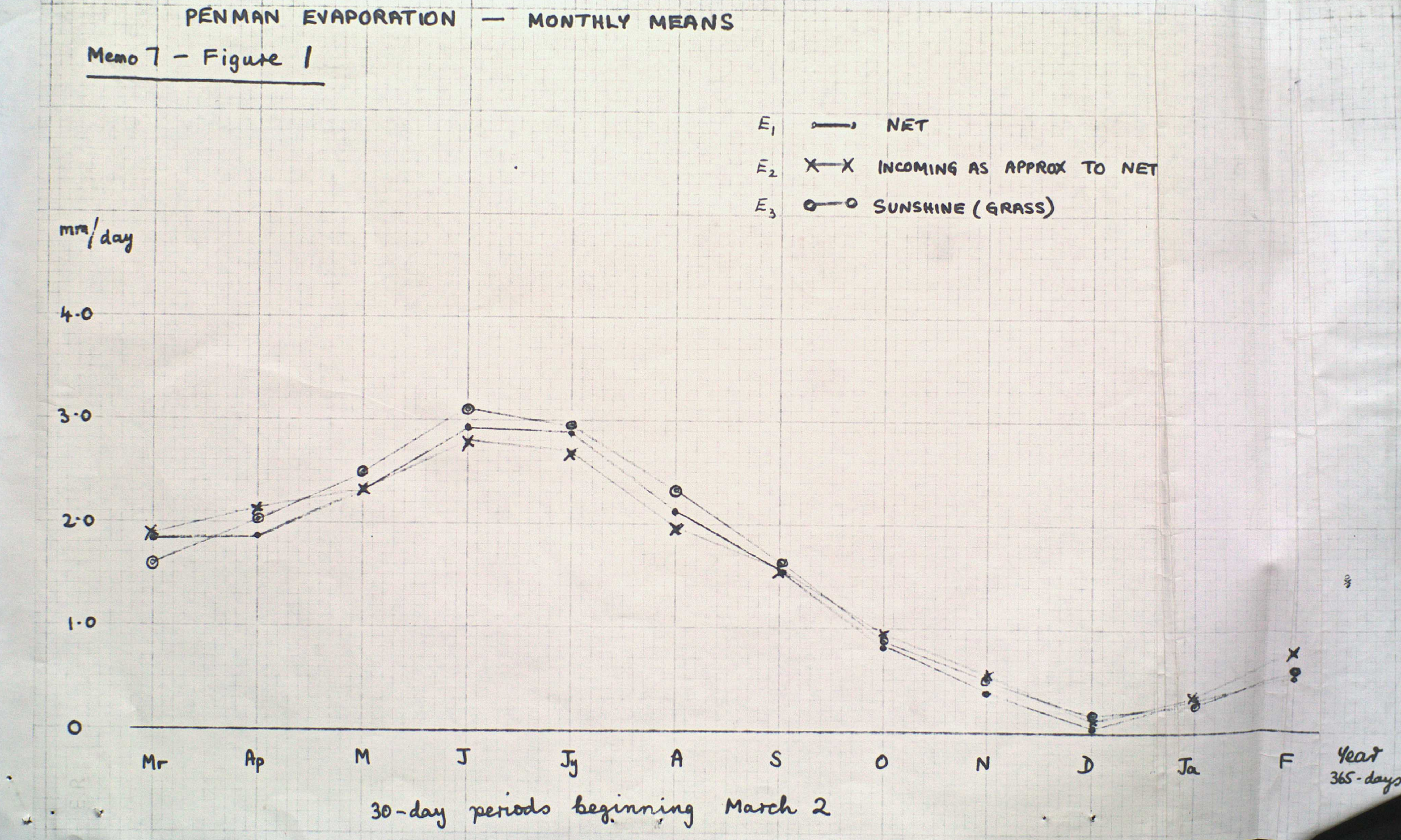
2. With these modifications, good estimates of the monthly mean Potential Evaporation can be obtained using either approximation and evaluating daily.

3. The standard error of daily estimates in summer is about 0.3 mm/day using the Incoming radiation method, and could be reduced to around 0.4 mm/day using the Sunshine method; the percentage standard errors are 11% and about 15-18% respectively. The standard error in winter is about 0.3 mm/day using either method.

NOTE

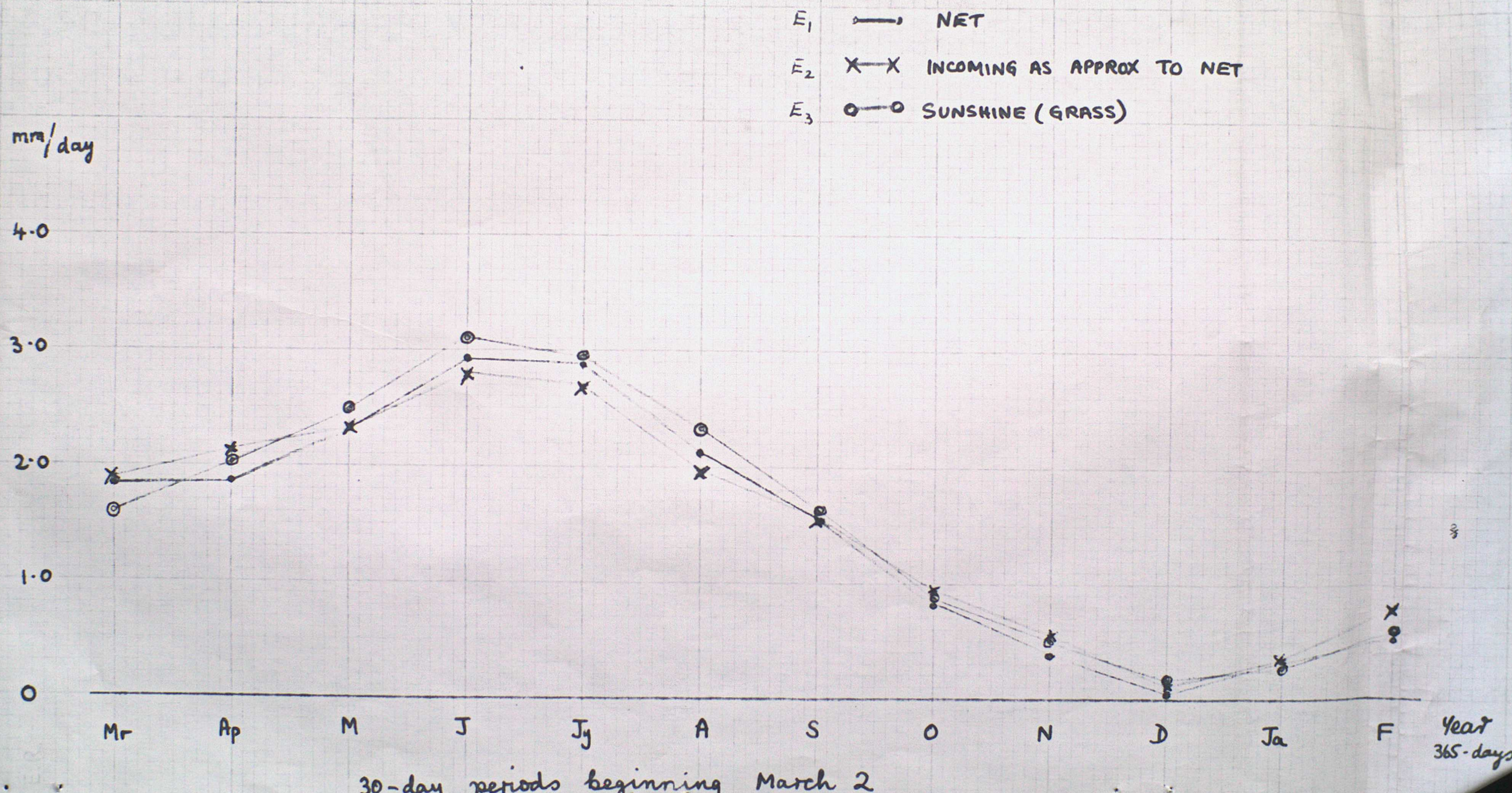
This Memo is circulated for discussion purposes only. Any comments and suggestions should be sent to the author.

Met O 8
Met Office
Bracknell
September 1969


PENMAN EVAPORATION — MONTHLY MEANS
Memo 7 - Figure 1
E1 NET
E2 INCOMING AS APPROX TO NET
E3 SUNSHINE (GRASS)
mm/day
4.0
3.0
2.0
1.0
0
Mr
Ap
M
J
Jy
A
S
O
N
D
Ja
F
Year 365-days
30-day periods beginning March 2

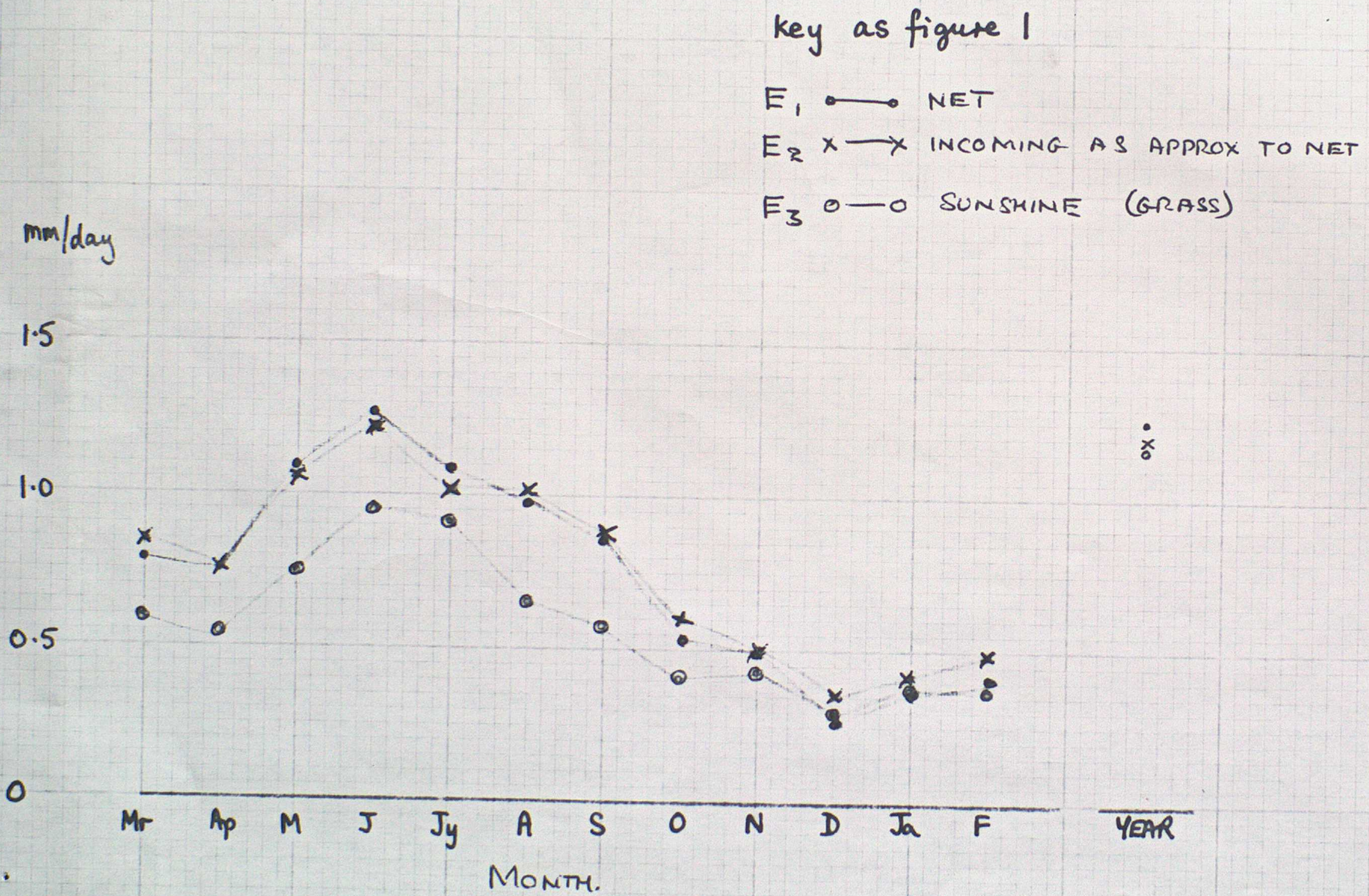
PENMAN EVAPORATION — MONTHLY MEANS

Memo 7 – Figure 1



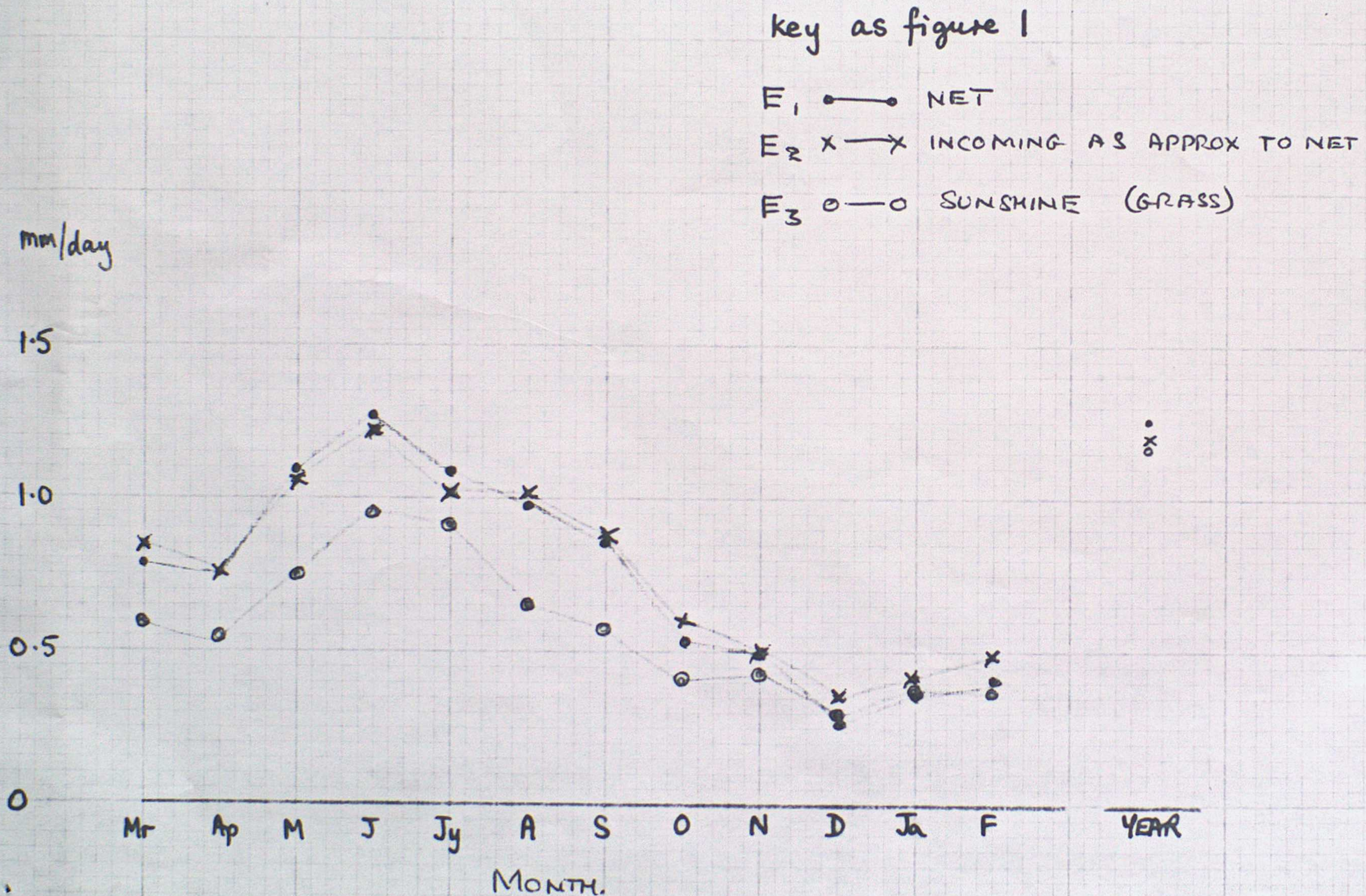
PENMAN EVAPORATION — Standard deviations of daily values

Memo 7 - Figure 2



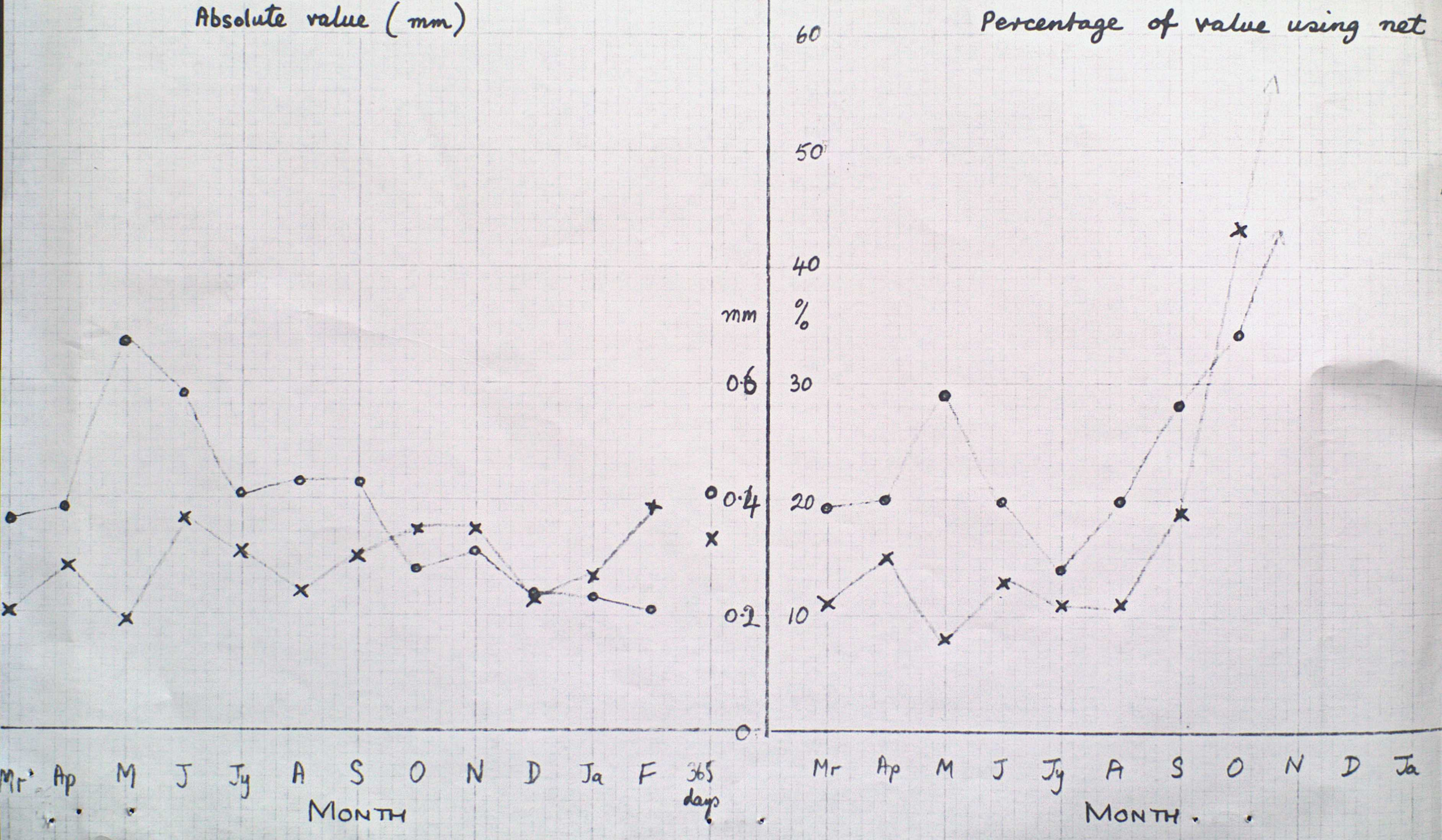
PENMAN EVAPORATION — Standard deviations of daily values

Memo 7 - Figure 2



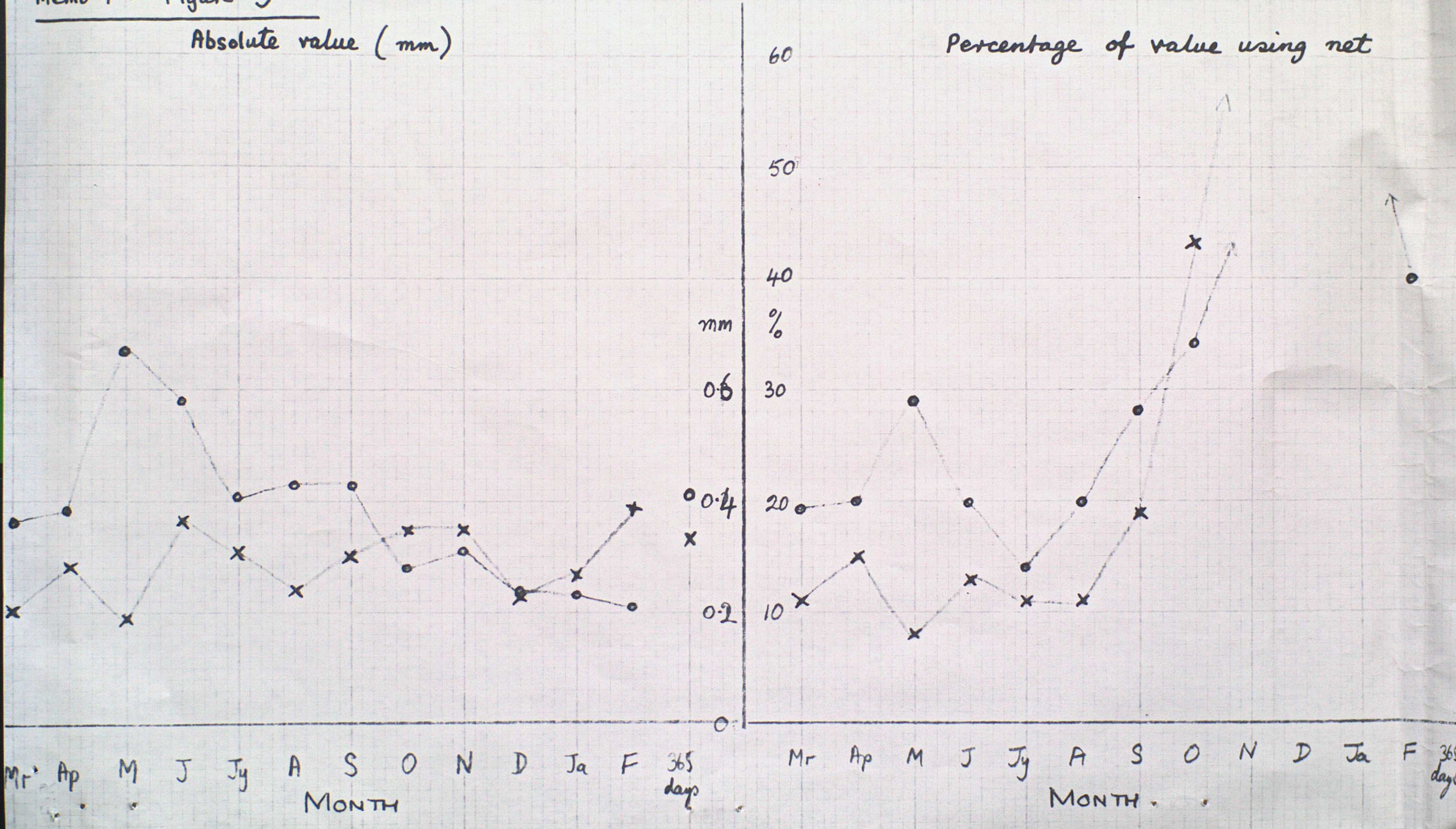
STANDARD ERROR OF DAILY VALUES OF EVAPORATION WHEN USING { INC AS APPROX TO NET x—x / SUNSHINE (GRASS) o—o }

Memo 7 – Figure 3



STANDARD ERROR OF DAILY VALUES OF EVAPORATION WHEN USING { INC AS APPROX TO NET ×—× / SUNSHINE (GRASS) o—o

Memo 7 – Figure 3



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Memo 7 – Figure 3