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DUPLICATE ALSO

A comparison between the forms of Penman potential evaporation input used in the Meteorological Office Soil Moisture Bulletin (1976) and in MORECS(X).

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Summary

Simple comparisons are made between the use of long-period monthly average p.e. for the half-year October to March and p.e. based on the departure of monthly average daily duration of bright sunshine from long period average for the half-year April to September, on the one hand and monthly p.e. calculated by Penman's formula on the other. The implications of systematic under-estimation of potential evaporation in terms of actual and potential soil moisture deficit are examined.



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### 1. Calculation of Penman p.e. and of approximations thereto.

Monthly Penman p.e. totals were calculated for 5 stations (Finningley, Elmdon, Plymouth, Squires Gate and Shoburyness for the years 1971-1975 using the formula as given by Penman (1948) with the minor modification introduced, in the Meteorological Office, by Grindley (1970); these totals are given in Table 1. Approximations to the above were obtained using monthly average values from October to March and values based on sunshine duration only, from April to October following Smith (1967); these totals are given in Table 2. Similar monthly p.e. calculations for Kew and Eskdalemuir observatories for the period 1964-70 are set out in Table 3. Locations and heights above mean sea level of the 7 stations are given in Fig.1. The Penman formula (see above) is used in MORECS(X) (the Meteorological Office Rainfall and Evaporation Calculation System - Experimental Version); height-adjusted, county average p.e. for October to March and approximations to Penman p.e. based on the departure of sunshine duration from average from April to September form the p.e. input for the soil moisture deficit maps and catchment tables as published in 1976. (A table of Penman formula p.e. estimates, some 2 months in arrears, is currently published for some 80 stations.) The approximate methods involve the implicit assumption that wind speeds, air temperatures and vapour pressures never depart from station average values for the time of year.

### 2. Comparisons of approximate and calculated Penman p.e. estimates.

The approximate p.e. values (Table 2) are expressed as % of the Penman formula values (Table 1) in Table 4. The 7-year average values are treated in the same way in Table 3. Due to the occurrence of zeros for the approximate averages for two stations in December only 58 1-station, 5-year percentages could be worked; of these 39 were below 100%, 2 were 100% and 17 were above 100%. 25 station-year average percentages are all below 100% except that for March. 7-year percentages for Kew were below 100% except for September, whereas at Eskdalemuir, one of the very few high-ground stations for which reliable



Perman estimates can be made, summer half-year (7-year) percentages were at or above 100% except in August although below 100% except for October, in the winter half-year. The results are summarised in Table 5 which shows Kew in good agreement with the other 5 English stations but Eskdalemuir having marked deviations from the general pattern of the low ground stations' results. Monthly errors of approximate p.e. used as an estimate of Penman formula p.e. are plotted in Fig.2. The plotted points are 5-year and 7-year monthly average errors and the points joined by the thick lines are 25-station year average errors.

Interesting features are:-

- (a) Eskdalemuir 7-year average errors are positive except in March.
- (b) The 25 station-year graph has winter and summer "peaks" and spring and autumn "troughs".
- (c) 5-year points for Blackpool and Shoeburyness (both coastal stations) are close together in 11 out of 12 months.
- (d) The Kew 7-year points have a broadly similar pattern to the 25 station-year graph.
- (e) The Plymouth 5-year points are all above the 25 station-year graph (large-ve errors).

#### Implications of using approx.p.e. in lieu of Penman formula p.e.

The 5-station, 5-year (1971-75) averages of p.e. by the approximate and Penman formula methods are compared with 5-station, 1916-50 monthly average rainfalls in Fig.3. Approximate values of month-end potential soil moisture deficit (smd) and of actual soil moisture deficit for 3 inch root constant following Penman (1949) and Grindley (1969) are shown in Fig.4. It can be seen that there would have been, on average, an under-estimation of potential and actual smd for the 5 stations, over the period 1971-75, if the approximation to Penman p.e. had been used in lieu of Penman formula p.e.



References

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Table 1. Penman p.e. (mm) at 5 meteorological stations 1971-1975

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Firmingley 1971	0	10	28	45	83	77	102	71	47	23	8	5	
1972	1	9	27	57	80	82	82	79	41	23	3	2	
1973	0	11	35	61	79	109	80	78	46	16	7	4	
1974	12	17	29	50	93	95	99	84	48	27	9	21	
1975	17	8	31	55	83	126	105	105	60	23	8	3	
	(6)	(11)	(30)	(54)	(84)	(98)	(94)	(83)	(48)	(22)	(7)	(7)	
Elmdon 1971	2	14	33	50	85	83	107	72	44	21	4	8	
1972	4	12	34	62	76	84	88	75	41	23	7	4	
1973	4	15	32	60	84	108	89	87	55	19	9	5	
1974	15	18	31	54	91	99	113	81	47	27	12	23	
1975	18	9	31	48	81	123	114	100	57	23	7	6	
	(9)	(14)	(32)	(55)	(83)	(99)	(102)	(83)	(49)	(23)	(8)	(9)	
Plymouth 1971	6	12	31	58	89	91	119	77	53	25	4	11	
1972	7	20	41	75	81	77	89	90	60	33	13	12	
1973	11	17	39	63	80	105	91	85	57	29	14	11	
1974	30	25	36	73	89	100	85	79	56	31	17	23	
1975	20	16	40	57	94	133	114	87	65	30	15	11	
	(15)	(18)	(37)	(65)	(87)	(101)	(100)	(84)	(58)	(30)	(13)	(14)	
Sq. Gates 1971	1	10	24	50	90	79	99	70	46	25	9	5	
1972	4	12	29	57	79	85	88	72	45	23	10	5	
1973	3	10	32	59	88	98	93	83	47	22	12	1	
1974	17	16	35	62	93	109	92	80	53	31	10	14	
1975	14	6	33	48	89	120	99	93	59	22	8	4	
	(8)	(11)	(31)	(55)	(88)	(98)	(94)	(80)	(50)	(25)	(10)	(6)	
Shro'bress 1971	2	11	30	49	84	92	100	83	52	29	3	6	
1972	4	11	35	64	89	96	89	88	48	33	9	4	
1973	7	15	30	55	82	112	103	90	55	19	6	3	
1974	13	19	24	52	92	98	107	90	56	25	14	15	
1975	16	9	25	47	74	110	112	95	58	23	7	2	
	(8)	(13)	(29)	(53)	(84)	(102)	(102)	(89)	(54)	(26)	(8)	(6)	
Mean ..	9	13	32	56	85	100	98	84	52	25	9	8.	



Table 2 Approximations to Penman p.e. at 5 met. stations 1971-1975

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
<b>Finningley</b>													
1971	1	10	31	50	93	72	106	67	52	22	5	0	
1972				51	78	81	89	85	37				
1973				58	82	106	83	75	49				
1974				56	91	84	90	84	50				
1975				54	90	107	97	100	50				
	(1)	(10)	(31)	(54)	(87)	(90)	(93)	(82)	(48)	(22)	(5)	(0)	
<b>Elmdon</b>													
1971	1	10	31	45	89	72	107	64	52	19	4	0	
1972				48	69	81	92	72	38				
1973				56	76	101	90	81	48				
1974				54	82	90	92	84	46				
1975				47	76	112	102	86	47				
	(1)	(10)	(31)	(50)	(78)	(91)	(97)	(77)	(46)	(19)	(4)	(0)	
<b>Plymouth</b>													
1971	5	14	34	53	88	84	116	67	56	24	10	5	
1972				60	69	71	91	86	55				
1973				54	66	93	87	77	48				
1974				61	81	89	76	75	43				
1975				55	80	119	98	74	49				
	(5)	(14)	(34)	(57)	(77)	(91)	(94)	(76)	(50)	(24)	(10)	(5)	
<b>Sq. Gate</b>													
1971	5	13	34	53	94	73	103	65	51	25	9	4	
1972				54	72	79	92	71	49				
1973				58	80	94	94	76	49				
1974				60	83	102	83	72	45				
1975				52	94	121	88	91	51				
	(5)	(13)	(34)	(55)	(85)	(94)	(92)	(75)	(49)	(25)	(9)	(4)	
<b>Shoe'b'ness</b>													
1971	5	13	33	51	89	85	101	73	55	25	9	4	
1972				54	81	93	88	83	47				
1973				51	80	110	93	83	56				
1974				56	85	92	97	85	54				
1975				53	72	113	102	94	53				
	(5)	(13)	(33)	(53)	(81)	(99)	(96)	(84)	(53)	(25)	(9)	(4)	
<b>Mean</b>	3	12	33	53	81	93	94	79	49	23	7	2	



Table 3. Approx. and calculated Penman p.e. for Kew and Eskdalemuir 1964-70.

Date	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
KEW														
1964	3	13	34	53	84	88	104	89	65	23	6	0		
1965				54	80	90	80	81	49					
1966				48	86	95	89	83	54					
1967				55	81	99	109	80	47					
1968				61	75	86	86	64	50					
1969				64	74	112	105	72	47					
1970				53	88	117	96	82	55					
MEAN	3	13	34	55	81	98	96	79	52	23	6	0		
p/p %	30	68	81	93	89	90	92	95	101	89	50	/		
1964	8	13	34	43	92	92	110	91	57	23	13	11		
1965	13	25	39	61	91	100	88	77	39	27	11	6		
1966	13	24	49	53	101	113	100	88	57	23	17	14		
1967	9	22	53	66	89	110	123	87	49	30	7	3		
1968	12	18	51	63	80	99	93	72	49	25	11	5		
1969	9	15	33	73	84	120	111	80	48	25	14	8		
1970	5	19	37	55	97	132	102	85	54	26	11	6		
MEAN	10	19	42	59	91	109	104	83	50	26	12	8		
ESKDALE- MUIR 1964	1	6	23	40	73	72	73	52	44	17	3	1		
1965				52	64	69	66	53	36					
1966				40	78	65	79	45	40					
1967				44	66	88	66	50	38					
1968				49	69	86	65	59	38					
1969				51	59	91	73	61	38					
1970				47	70	93	67	64	36					
MEAN	1	6	23	46	68	81	70	55	39	17	3	1		
p/p %	50	86	82	105	111	103	100	98	122	106	75	50		
1964	0	8	21	40	70	71	71	50	34	10	0	0		
1965	0	10	20	45	55	73	62	55	29	13	1	0		
1966	4	7	31	38	67	66	76	47	34	11	4	4		
1967	0	11	37	43	52	83	67	52	31	19	5	0		
1968	5	6	31	43	62	84	65	60	31	17	7	3		
1969	1	10	26	51	53	83	75	63	33	20	5	2		
1970	1	0	30	47	70	90	74	64	34	22	8	3		
MEAN	2	7	28	44	61	79	70	56	32	16	4	2		

APPROX P.E.

PENMAN P.E.

APPROX P.E.

PENMAN P.E.



Table 4: Approx p.e. as % of Penman p.e.

1971-1975

	J	F	M	A	M	J	J	A	S	O	N	D	
<b>Framlingley</b>													
1971	-	100	111	111	112	93	104	94	111	96	63 <sup>✓</sup>	-	
1972	100	111	115	89	97	99	109	108	90	96	167 <sup>✓</sup>	-	
1973	-	91	89	95	104	97	104	96	107	137	71 <sup>✓</sup>	-	
1974	8	59	107	112	98	88	91	100	104	81	55 <sup>✓</sup>	-	
1975	6	125	100	98	108	85	92	95	83	96	63 <sup>✓</sup>	-	
	(38)	(97)	(104)	(101)	(104)	(92)	(100)	(99)	(99)	(101)	(84)	(-)	
<b>Elmdon</b>													
1971	50	71	94	90	105	87	100	89	118	91	100 <sup>✓</sup>	-	
1972	25	83	91	77	91	96	105	96	93	83	57 <sup>✓</sup>	-	
1973	25	67	97	53	91	93	101	93	87	100	44 <sup>✓</sup>	-	
1974	7	55	100	100	90	91	81	104	98	70	33 <sup>✓</sup>	-	
1975	5	111	100	98	94	91	89	86	83	83	57 <sup>✓</sup>	-	
	(22)	(77)	(96)	(92)	(94)	(92)	(95)	(94)	(96)	(85)	(58)	(-)	
<b>Plymouth</b>													
1971	83	117	110	91	99	92	97	87	106	96	250	45	
1972	71	70	83	80	85	92	102	95	92	73	77	42	
1973	45	82	87	86	83	89	96	91	84	83	71	45	
1974	17	56	94	84	91	89	89	95	77	77	59 <sup>✓</sup>	22	
1975	25	87	85	97	85	89	86	85	75	80	67 <sup>✓</sup>	45	
	(48)	(82)	(92)	(88)	(89)	(90)	(94)	(91)	(87)	(82)	(105)	(40)	
<b>Sq. Gate</b>													
1971	500	130	142	106	104	92	104	93	111	100	100	80	
1972	125	108	117	95	91	93	105	99	109	109	90	80	
1973	167	130	106	98	91	96	101	92	104	114	75	400	
1974	29	81	97	97	89	94	90	90	85	81	90	29	
1975	36	217	103	108	106	101	89	98	86	114	113	100	
	(171)	(133)	(113)	(101)	(96)	(95)	(98)	(94)	(99)	(104)	(94)	(138)	
<b>Shoeburys</b>													
1971	250	118	110	104	106	92	101	88	106	86	300	67	
1972	125	118	94	84	91	97	99	94	98	76	100	100	
1973	71	87	110	93	98	98	90	92	102	132	150	133	
1974	39	68	137	108	92	94	91	94	96	100	64	27	
1975	31	144	132	113	97	103	91	99	91	109	129	200	
	(103)	(107)	(117)	(100)	(97)	(97)	(94)	(93)	(99)	(101)	(149)	(105)	
<b>Mean *</b>	33	92	103	95	95	93	96	94	94	92	78	25	

\* from means in Tables 1 &amp; 2.



Table 5. Numbers of cases when the approximation to Penman p.e. was above, equal to and below the Penman value

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
25-station-yrs	Numbers of cases											
Approx > P.E	7	11	12	7	7	2	10	2	10	6	6	3
" = P.E	1	1	3	1	0	0	1	1	0	3	3	2
" < P.E	17	13	10	17	18	23	14	22	15	16	16	20
Kew 7 yrs												
Approx > P.E	0	0	1	1	0	0	0	1	4	0	0	0
" = P.E	0	1	1	0	0	0	0	0	0	2	0	0
" < P.E	7	6	5	6	7	7	7	6	3	5	7	7
Eskdalemuir 7 yrs												
Approx > P.E	3	1	2	5	6	5	3	1	7	3	2	3
" = P.E	2	1	0	2	1	0	1	1	0	1	0	0
" < P.E	2	5	5	0	0	2	3	5	0	3	5	4

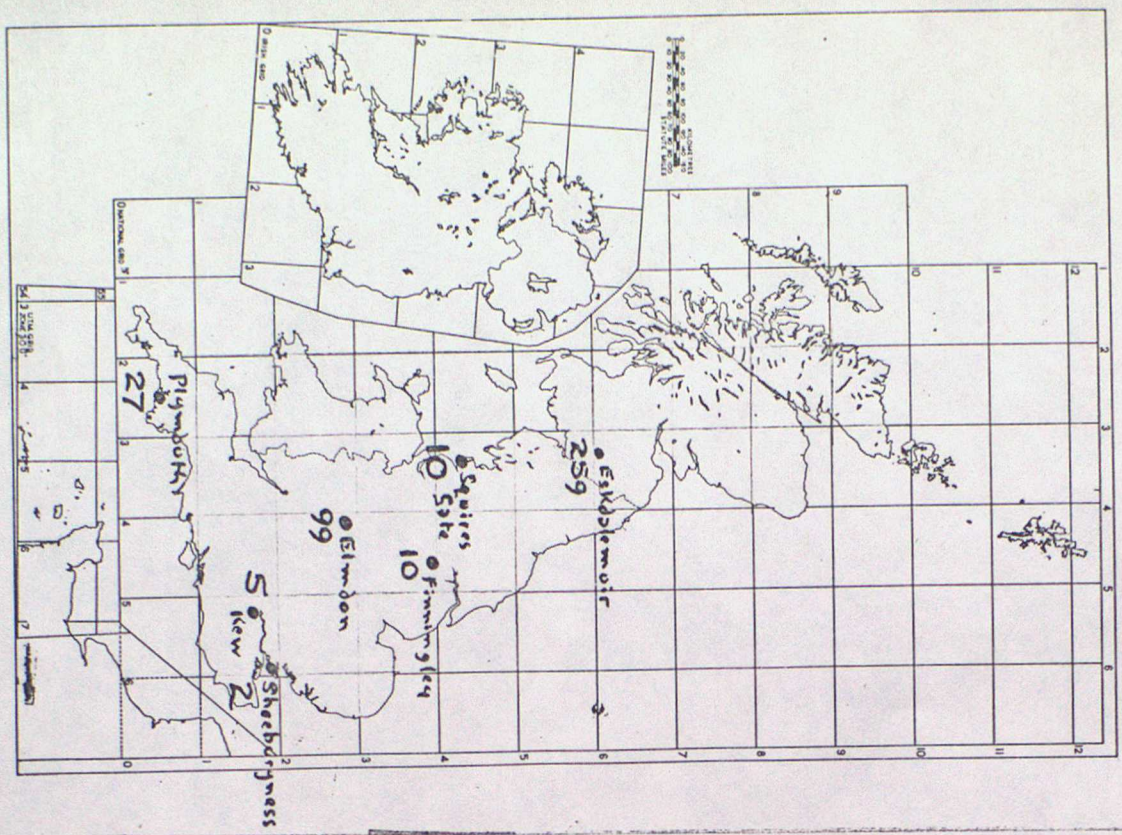


Fig. 1 Stations used in the study.  
(Hrs. amsl in m.)



F • Finningley  
 E ◡ Elmdon (Birmingham)  
 P Δ Plymouth (Mount Batten)  
 B ◊ Blackpool (Squires Gate)  
 S ◡ Shoeburyness

1971-75 { 25 station-year mean.

X Kew  
 ◉ Eskdalemuir

1964-70

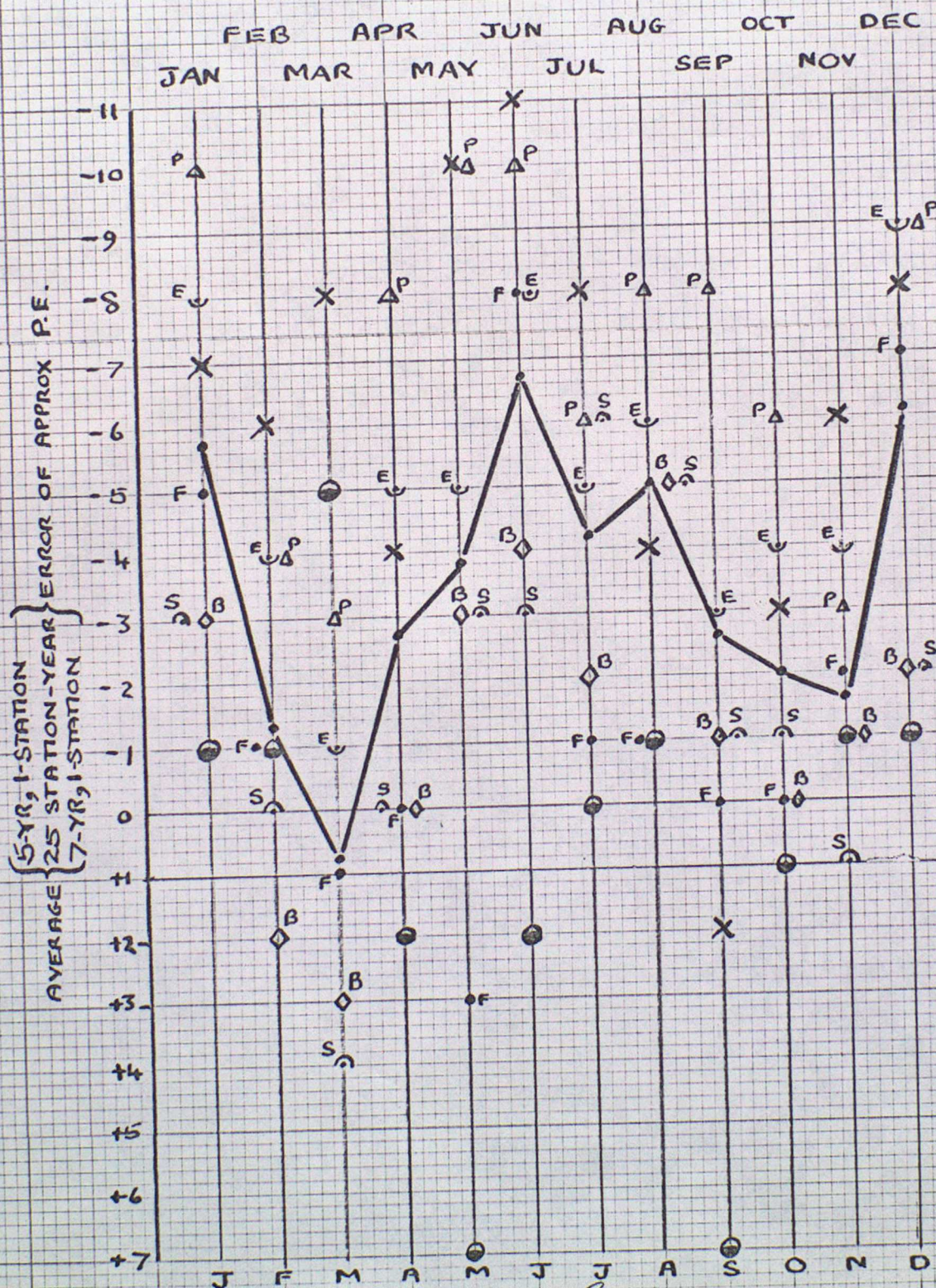


Fig. 2. Monthly errors of approx p.e.



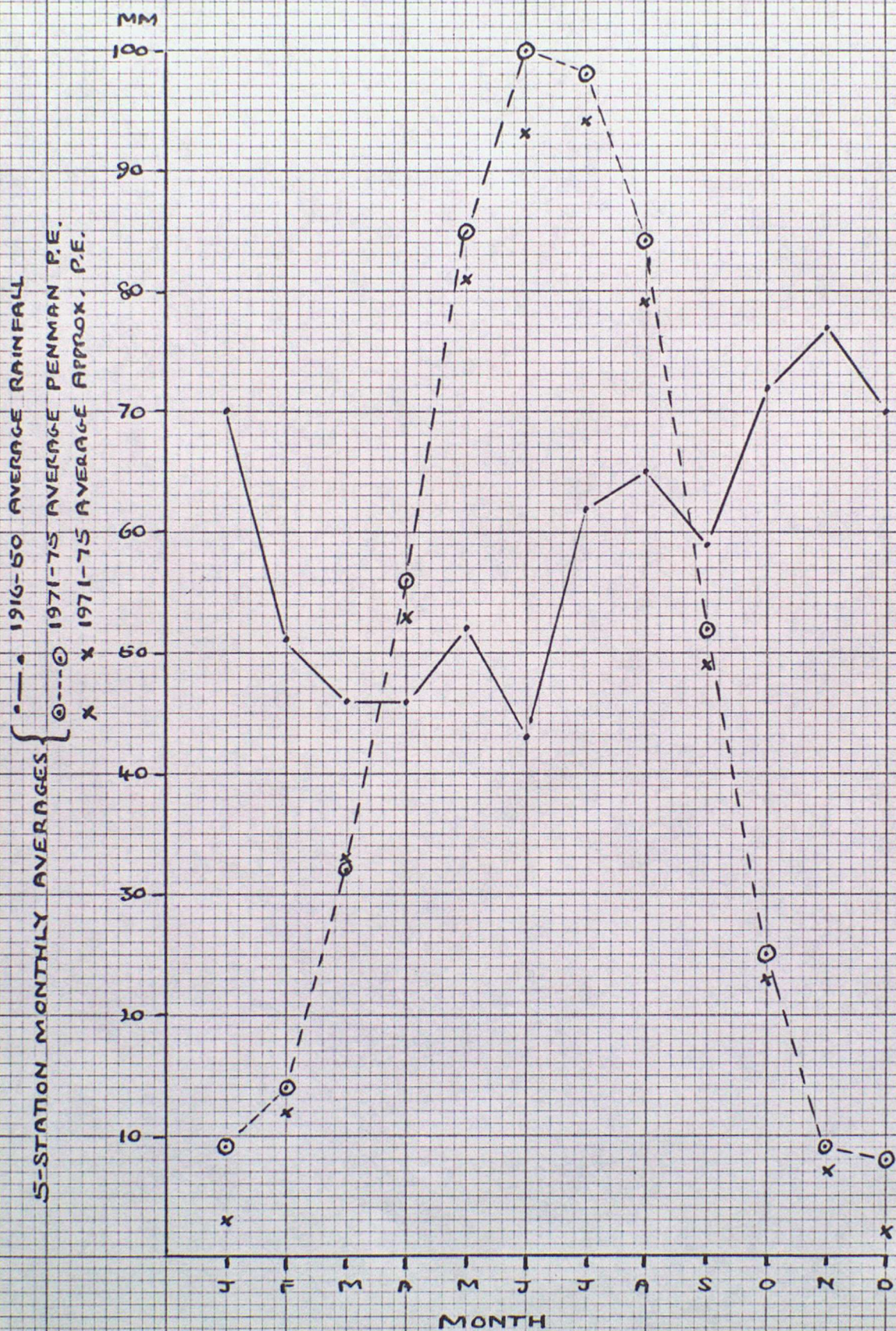
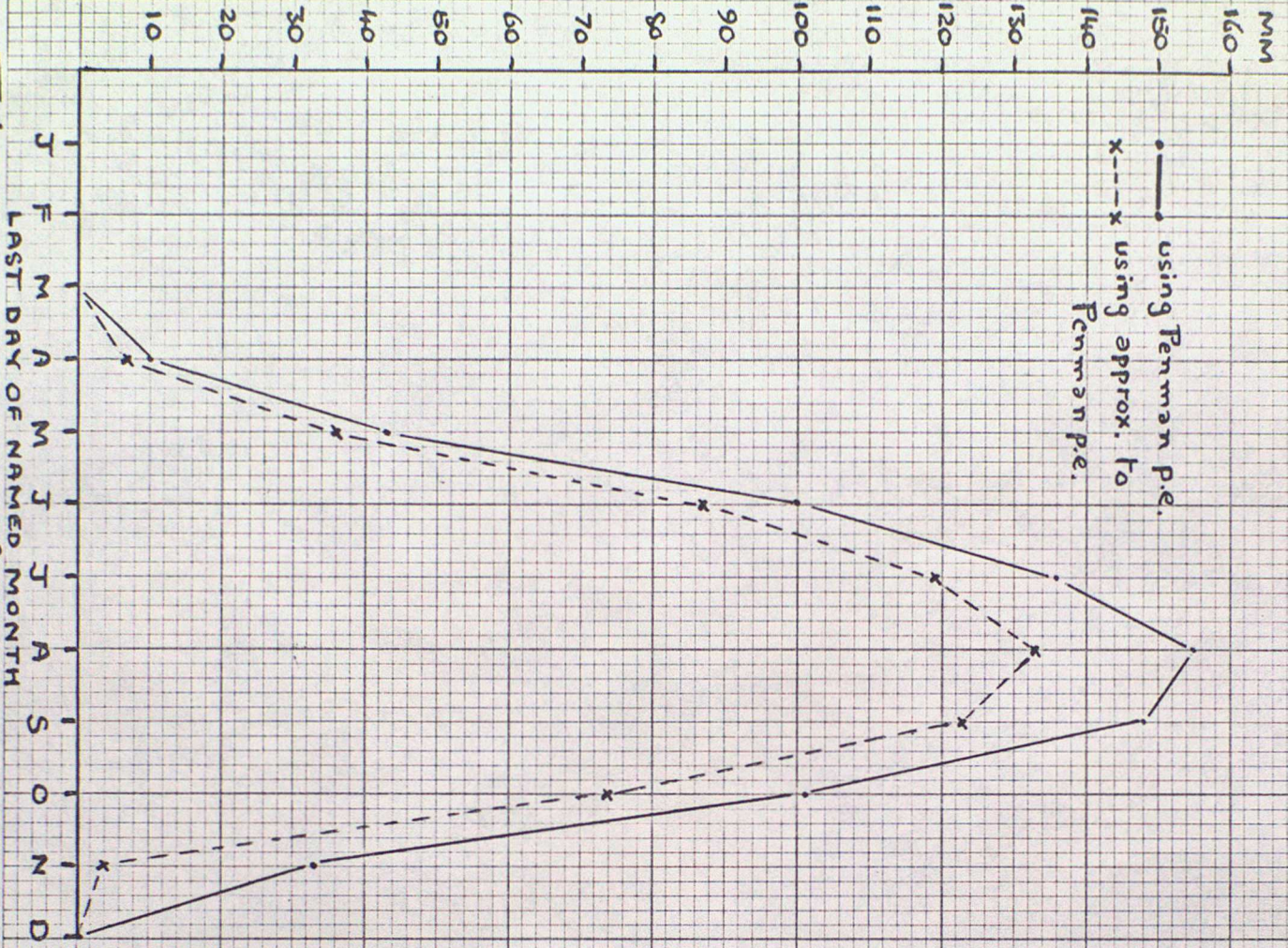


Fig. 3 1971-75 monthly average Penman and approx. p.e. v.s. 1916-50 monthly average rainfall. (5 station averages)



# ESTIMATED POTENTIAL SOIL MOISTURE DEFICIT



# ESTIMATED ACTUAL SOIL MOISTURE DEFICIT FOR PENMAN 3-INCH ROOT CONSTANT

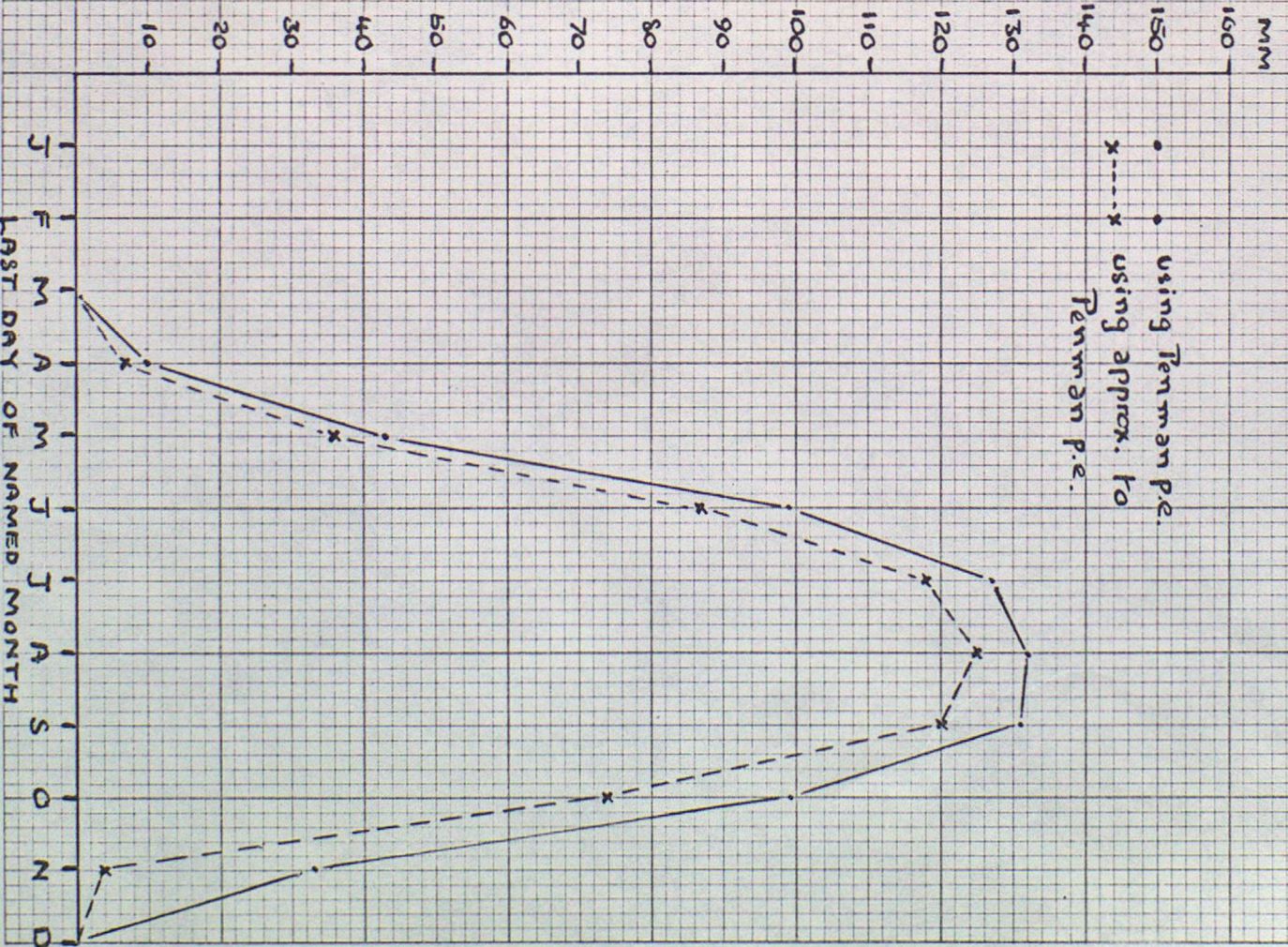


Fig. 4.5 - Station averages of potential and actual (3" root constant) soil moisture deficit.