2.4. Sedimentation

Among several methods available to calculate suspended sediment load of rivers, the method using flow duration and sediment rating curve was employed in the study to evaluate sediment inflow to reservoirs. As the basic data for preparation of sediment rating curves, two parameters are to be needed namely (1) mean daily discharges of the river for a specific period of analysis and (2) sediment concentration with instantaneous river discharge on a number of occasions at different stages of river flow obtainable by sediment samplings.

Fortunately sufficient volume of such data are available from SWHP, WAPDA at Khanpur on the Haro river for evaluation of Khanpur sediment inflow and at Chirah on Soan river for Simly sediment inflow. Each set of sediment concentration and discharge was plotted, as shown in Figures A.II-5 and A.II-6 to produce representative rating curves which were derived by using method of least square.

Assuming that the rating curve is expressed in a form PPM = a x Q^b or log PPM = Log a + b log Q, constants a and b are solved by the method of least square as under;

$$b = \frac{n\ [\log PPM \cdot \log Q] - [\log PPM][\log Q]}{n\ [\log Q \cdot \log Q] - [\log Q \cdot \log Q]}$$

$$\log a = \frac{[\log PPM][\log Q \cdot \log Q] - [\log Q][\log PPM \cdot \log Q]}{n\ [\log Q \cdot \log Q] - [\log Q \cdot \log Q]}$$

$$a = 10^{\log a}$$

where PPM denotes suspended sediment concentration expressed in ppm by weight, Q discharge in cu.m/sec and n number of samplings.

SUSPENDED SEDIMENT RATING CURVE

River	Rating Curve
Haro river at Khanpur	$PPM = 27.9495\ Q^{1.2278}$
Soan river at Chirah	$PPM = 121.2807\ Q^{0.6810}$

Notes: (1) Suspended sediment concentration expressed in PPM by weight.

(2) Discharge in cu.m/sec.

Daily runoffs of the rivers at the points under consideration were ranked according to their magnitude, as presented in Figure A.II-7, to determine duration and magnitude of river discharges, and they were combined with the rating curves to compute suspended sediment inflows. Such procedures are shown in Tables A.II-21 and 22. An estimated bed load of 30% of suspended load thus calculated was added to arrive at the total sediment load which would flow into the reservoirs.

As concerns sediment inflow to the Rawal Lake, data from actual survey of sedimentation have been provided and are given in Table A.II-23.

To arrive at estimates of future sedimentation rates of the Khanpur, Simly and Rawal Reservoirs, the data from Tables A.II-21 to 23 were transferred to Table A.II-24. A comparison study was also made to demonstrate differences of estimates and is given in Table A.II-25. Reservoir sedimentations and effective live storages of reservoirs expected in future are then summarized as follows:

EFFECTIVE LIVE STORAGE OF RESERVOIR

Year	Khanpur (acre ft)	Simly (acre ft)	Rawal (acre ft)
1990	91,000	30,300	33,445
2000	89,200	30,300	30,205
2010	80,890	30,300	26,965
2020	72,580	30,300	23,725
2030	64,360	30,300	20,525

Reservoir capacity curves are then prepared as given in Figures A.II-8 to A.II-11.

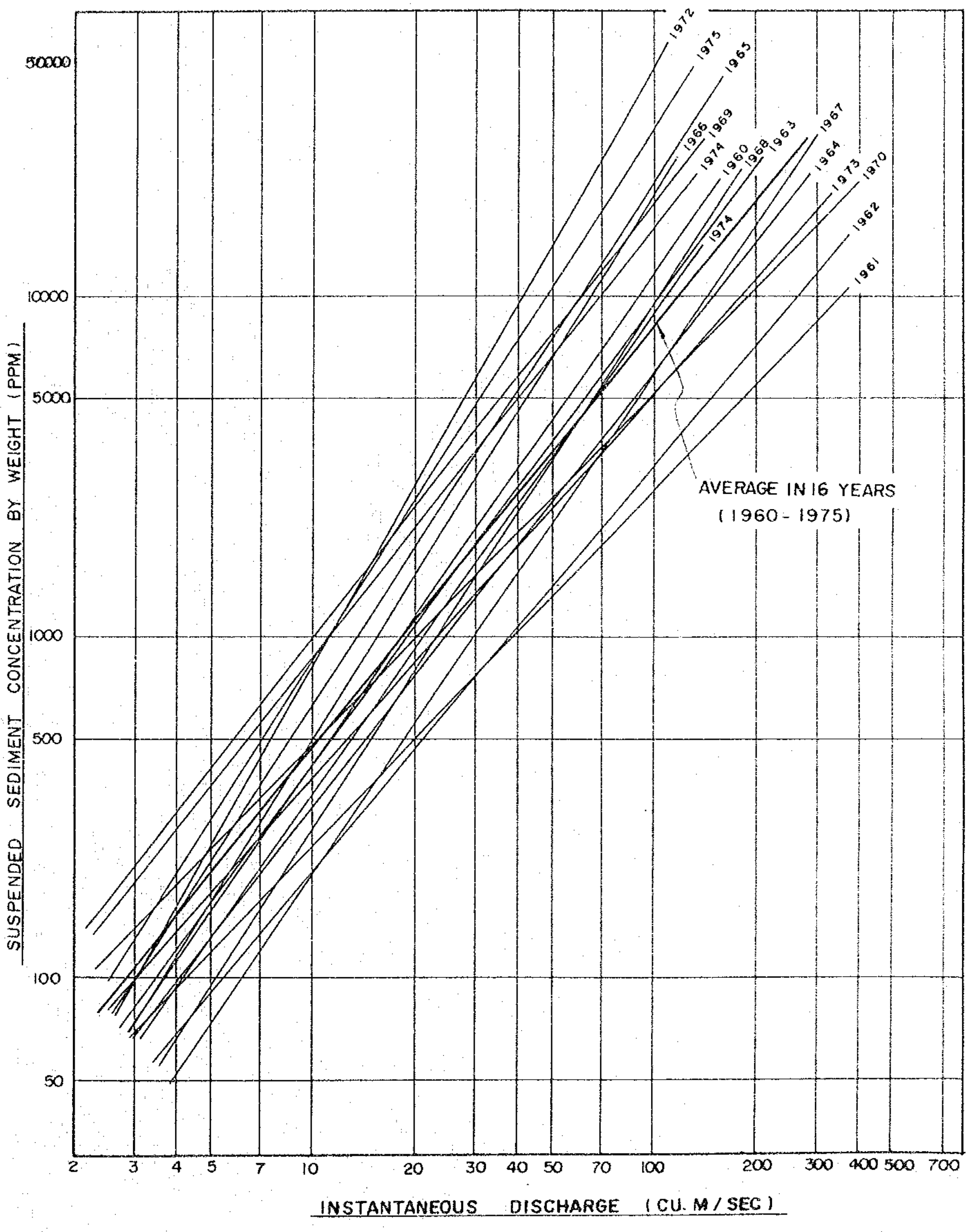


FIGURE A.II-5 SEDIMENT RATING CURVE AT KHANPUR ON HARO RIVER

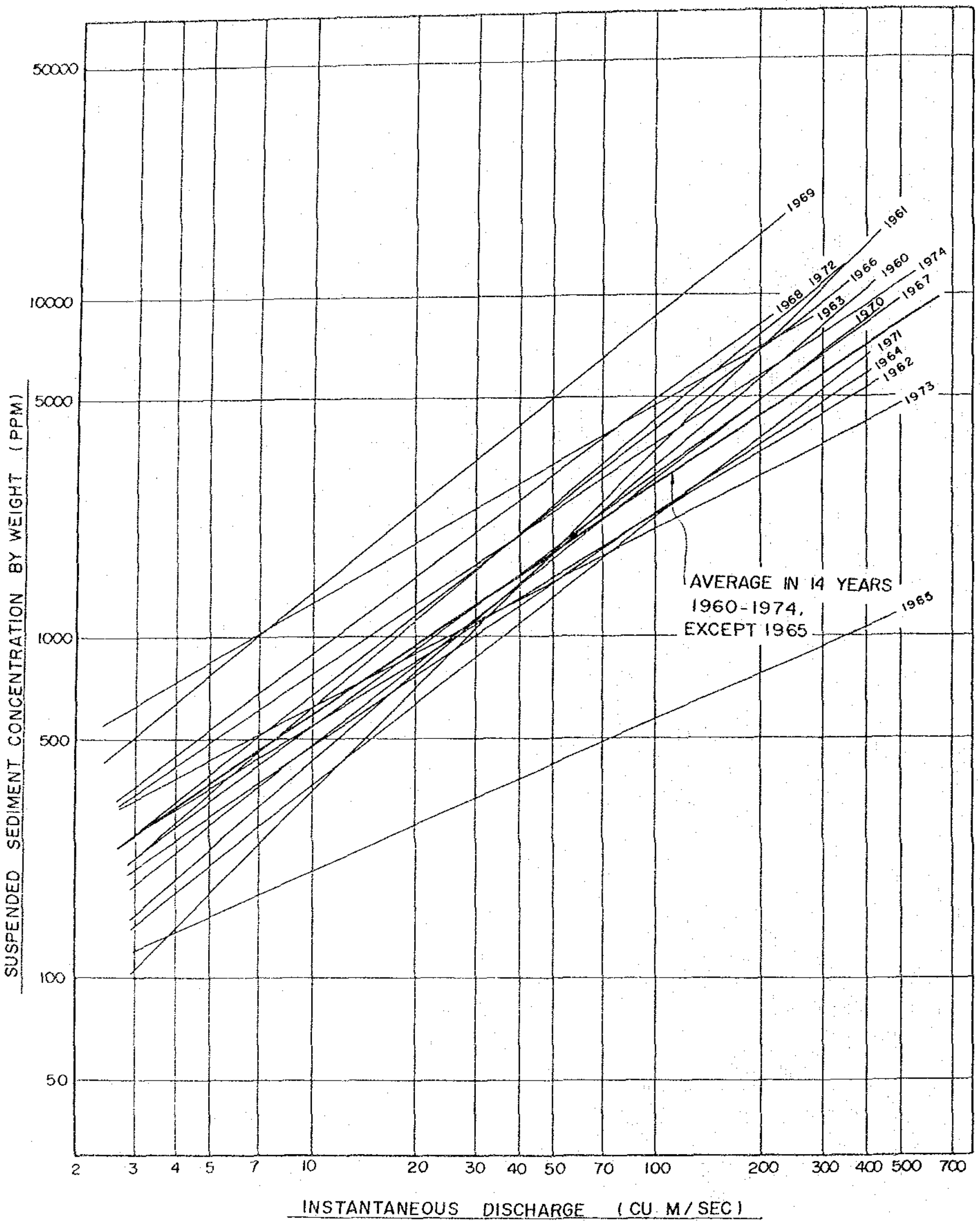


FIGURE A.II-6 SEDIMENT RATING CURVE AT CHIRAH ON SOAN RIVER

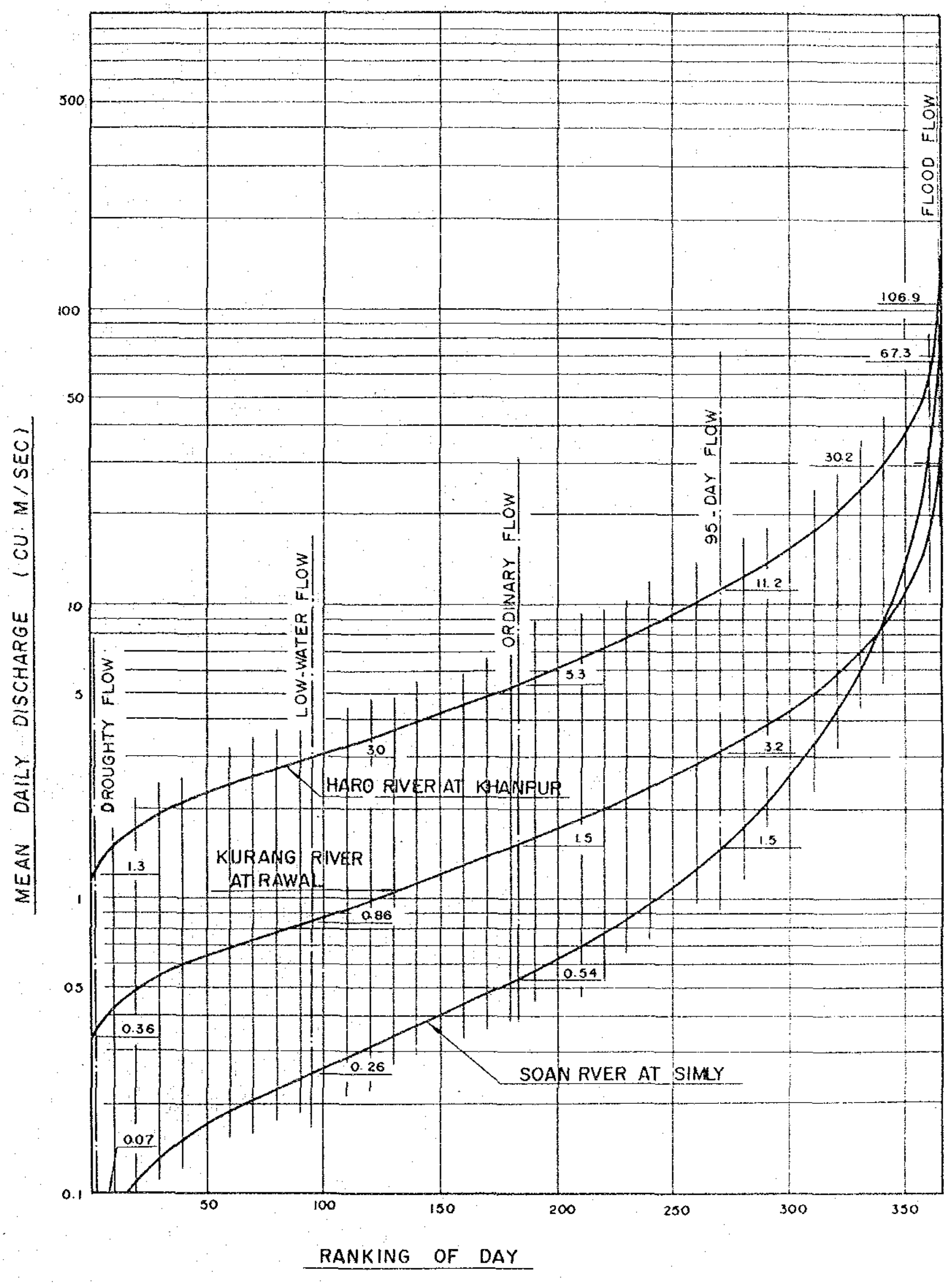


FIGURE A.II-7 RANKING OF RIVER DISCHARGE BY DAY

TABLE A.II-19 **SEDIMENT RATING CURVE OF HARO RIVER AT KHANPUR**

Equation: $C = A.Q^{B}$

C: Suspended Sediment Concentration by Weight (ppm)

Q: River Discharge (cu.m/sec)

A, B: Constants as below

Year	No. of Sampling	$\Sigma \log(C)$	$\Sigma \log(Q)$	$\Sigma\{\log(Q)\}^2$	$\Sigma(\log C.\log Q)$	A	B
1960	29	70.3489	25.1147	27.4032	69.1034	14.8865	1.4469
1961	45	112.1244	49.7908	68.3702	137.9732	21.4991	1.0477
1962	26	47.5402	15.7330	13.9577	34.0500	12.8261	1.1905
1963	42	102.7968	36.6709	45.1122	107.4414	18.5409	1.3508
1964	50	103.3338	33.7964	32.8551	82.6895	15.8318	1.2829
1965	37	96.5915	32.9176	38.7991	100.6293	17.2320	1.5447
1966	25	62.4043	21.9637	24.8251	63.6649	12.3462	1.5988
1967	22	47.9190	20.2302	28.3951	58.4471	6.7219	1.4688
1968	27	61.8379	24.6198	27.7257	64.5109	7.6956	1.5398
1969	95	223.9988	47.7844	50.8960	146.8963	52.1152	1.2742
1970	130	313.5715	95.9537	144.7400	307.4231	45.0225	1.0278
1971	73	179.7553	69.9067	110.9923	234.6490	12.6877	1.4192
1972	80	196.0662	60.0251	63.3862	179.6390	13.2036	1.7728
1973	75	202.3091	82.9460	119.9560	255.5609	28.2228	1.1274
1974	75	172.2266	37.8244	45.3660	120.2446	45.2793	1.2699
1975	80	205.9010	62.3348	75.1716	202.0653	22.6129	1.5650
Total	911	2198.7244	717.6116	917.9515	2164.9868	27.9495	1.2278

TABLE A.II-20 SEDIMENT RATING CURVE OF SOAN RIVER AT CHIRAH

Equation: $C = A.Q^B$

C: Suspended Sediment Concentration by Weight (ppm)

Q: River Discharge (cu.m/sec)

A, B: Constants as below

Year	No. of Sampling	$\Sigma\log(C)$	$\Sigma\log(Q)$	$\Sigma\{\log(Q)\}^2$	$\Sigma(\log C.\log Q)$	A	B
1960	22	44.4863	6.1702	9.9495	19.5442	60.3859	0.8599
1961	36	77.2797	21.9105	29.1423	62.8525	34.4829	1.0007
1962	34	72.1512	0.5572	23.7769	15.9882	129.3859	0.6229
1963	39	102.5264	7.1105	32.2695	36.4621	334.4124	0.5737
1964	35	79.1616	13.5636	29.3122	47.0140	99.6749	0.6791
1965	18	33.8148	0.9134	5.5646	4.2115	71.7216	0.4523
1966	19	41.5526	3.4063	17.9803	21.0105	111.4319	0.7807
1967	32	77.9415	19.0839	30.5126	60.6186	98.8568	0.7389
1968	32	82.4692	16.1691	30.4788	58.2990	158.6836	0.7454
1969	32	70.8962	-4.0329	16.8077	4.2945	207.8719	0.8116
1970	48	121.9142	39.4660	79.9452	137.0470	79.9260	0.7750
1971	22	53.4553	18.3892	47.2908	69.8086	59.1289	0.7872
1972	26	54.9299	5.2050	13.7597	21.7683	87.7259	0.8470
1973	26	65.9462	13.2521	25.2155	43.2405	186.4524	0.5215
1974	34	71.0804	-5.8194	30.5470	7.8373	160.8641	0.6769
Total	437	1015.7891	154.4310	416.9875	605.7844	121.2807	0.6810

Note: Data observed in 1965 were excluded from the study.

TABLE A.II-21 FLOW DURATION AND SUSPENDED SEDIMENT (HARO RIVER AT KHANPUR)

Day Ranking	No. of day	Mean Daily Discharge (cu.m/sec)	Suspended Sediment Concentration (ppm)	Suspended Sediment Inflow (cu.m)
365-365	1	156.104	13785.	218740.
364-364	1	106.874	8658.	94051.
363-363	1	87.076	6732.	59587.
362-362	1	69.851	5136.	36466.
361-361	1	63.646	4582.	29641.
360-360	1	57.120	4012.	23293.
358-359	2	52.938	3654.	39326.
356-357	2	47.980	3239.	31589.
354-355	2	44.285	2935.	26425.
352-353	2	41.156	2683.	22445.
350-351	2	38.323	2458.	19147.
348-349	2	35.852	2265.	16505.
346-347	2	33.497	2083.	14187.
344-345	2	31.991	1969.	12805.
342-343	2	35.207	2215.	15852.
340-341	2	34.190	2136.	14850.
338-339	2	28.201	1687.	9669.
336-337	2	27.098	1606.	8847.
334-335	2	26.260	1545.	8249.
331-333	3	25.161	1466.	11249.
326-330	5	23.820	1371.	16594.
321-325	5	22.014	1244.	13922.
316-320	5	20.424	1135.	11780.
311-315	5	18.707	1019.	9687.
301-310	10	16.596	880.	14837.
291-300	10	14.570	750.	11102.
281-290	10	12.982	651.	8585.
271-280	10	11.692	572.	6800.
261-270	10	10.605	508.	5471.
241-260	20	9.339	434.	8243.
221-240	20	7.817	349.	5546.
201-220	20	6.613	284.	3822.
181-200	20	5.670	235.	2712.
151-180	30	4.753	189.	2746.
121-150	30	3.889	148.	1756.
91-120	30	3.204	117.	1141.
61- 90	30	2.693	94.	774.
31- 60	30	2.246	75.	517.
1- 30	30	1.635	51.	255.
TOTAL	365			839,210 m^3/yr
				= 0.839 MCM/yr
				= 1079 $m^3/km^2/yr$

Note: Specific Weight of Suspended Materials
= 53 pcf = 0.85 ton/cu.m

TABLE A-II-22 FLOW DURATION AND SUSPENDED SEDIMENT (SOAN RIVER AT SIMLY)

Day Ranking	No. of Day	Mean Daily Discharge (cu.m/sec)	Suspended Sediment Concentration (ppm)	Suspended Sediment Inflow (cu.m)
365-365	1	110.323	2985.	36197.
364-364	1	67.306	2132.	15773.
363-363	1	53.682	1828.	10784.
362-362	1	41.042	1522.	6867.
361-361	1	34.250	1346.	5066.
360-360	1	30.809	1252.	4240.
358-359	2	25.739	1108.	6269.
356-357	2	22.184	1001.	4883.
354-355	2	19.061	903.	3784.
352-353	2	16.771	827.	3051.
350-351	2	14.741	758.	2456.
348-349	2	12.973	695.	1982.
346-347	2	11.241	630.	1557.
344-345	2	10.162	588.	1314.
342-343	2	9.411	558.	1155.
340-341	2	8.589	525.	991.
338-339	2	7.738	489.	831.
336-337	2	7.187	465.	734.
334-335	2	6.774	446.	665.
331-333	3	6.127	417.	842.
326-330	5	5.497	387.	1169.
321-325	5	4.708	348.	901.
316-320	5	4.136	319.	725.
311-315	5	3.634	292.	583.
301-310	10	3.003	256.	847.
291-300	10	2.351	217.	561.
281-290	10	1.912	189.	396.
271-280	10	1.626	169.	302.
261-270	10	1.391	152.	232.
241-260	20	1.121	131.	323.
221-240	20	0.873	111.	212.
201-220	20	0.707	96.	149.
181-200	20	0.578	84.	106.
151-180	30	0.462	72.	109.
121-150	30	0.358	60.	71.
91-120	30	0.281	51.	47.
61- 90	30	0.220	43.	31.
31- 60	30	0.163	35.	19.
1- 30	30	0.101	25.	8.
Total	365			116.233 m^3/yr
				= 0.116 MCM/yr
				= 760 m^3/km^2/yr

Note: Specific Weight of Suspended Materials

= 49 pcf = 0.786 ton/cu.m

TABLE A.II-23 DATA FROM SEDIMENTATION SURVEYS OF RAWAL LAKE 1/

Time of Survey 2/	Capacity of Reservoir (Acre-feet)			Sediment Accumulation (Acre-feet)		Sedimentation Rate 3/ (Acre-feet/year)		
	EL 1752	EL 1745	EL 1726	Since 1960	Since Prev. Survey	Since 1960	Since Prev. Survey	
1960	47,500							
1966	41,400			6,100	6,100	1,017 6/	1,017 6/	
1969	40,230	29,020		7,270	1,170	808	390	Average (1969–1978) 342 AF/yr = 3.23 AF/mile^2/yr
1972	39,495		9,560	8,005	735	667	245	
1975	38,350 4/		9,325	9,150	1,145	610	382	
1978	37,300 5/			10,200	1,050	567	350	

Notes:
1/ All data from WAPDA, Dams Monitoring Organization (DMO) Report No.119, Inspection of Rawal Dam, February, 1979.
2/ Official dam opening was in 1962 but impoundment in 1960. Time of year of each survey not known.
3/ The time of year of each survey not known. Thus, if all surveys were not conducted during the same season of year, the apparent sedimentation rates may be in error.
4/ Estimated by WAPDA-DMO, by extrapolation of 9325 ac-ft at el. 1726, from Irrigation Research Institute Survey.
5/ Estimated by WAPDA-DMO.
6/ 1960 reservoir volumes estimated from contour map of reservoir; 1966 and later reservoir volumes estimated from echo soundings. If the two survey methods were in any way inconsistent, the 1960-66 sedimentation rates could be distorted.
7/ Data source: Rawalpindi Water Supply and Sewerage Project, Volume II Appendices, ADB, May 1980.

TABLE A.II-24 RESERVOIR SEDIMENTATIONS AND EFFECTIVE CAPACITIES

Reservoir	Suspended Sediment Inflow (AF/yr)	Drainage Area ($mile^2$)	Suspended Sediment Inflow ($AF/yr/mi^2$)	Water Inflow(1) (AF/yr)	Time after First Impoundment (years)	Reservoir Volume (AF) Total(2)	Reservoir Volume (AF) Live	(2)/(1)	Trap Efficiency[6/] (%)	Trapped Fines (AF/yr)	Bed Load[5/] (AF/yr)	Annual Storage Loss (AF/yr)
Khanpur[2/]	680	300	2.27	265,000	0 (1980)	106,000	91,000	0.40	95	646	194	840
					10 (1990)	97,600	91,000	0.37	95	646	194	840
					20 (2000)	89,200	89,200	0.34	94	639	192	831
					30 (2010)	80,890	80,890	0.31	94	639	192	831
					40 (2020)	72,580	72,580	0.27	93	632	190	822
					50 (2030)	64,360	64,360					
Simply[3/]	94	59	1.60	71,000	0 (1980)	38,300	30,300	0.54	96	90	27	117
					10 (1990)	37,130	30,300	0.52	96	90	27	117
					20 (2000)	35,960	30,300	0.51	96	90	27	117
					30 (2010)	34,790	30,300	0.49	95	89	27	116
					40 (2020)	33,630	30,300	0.47	95	89	27	116
					50 (2030)	32,470	30,300					
Rawal[4/]	262	106	2.48	75,000	0 (1975)	38,350	38,350	0.51	96	252	75	327
					15 (1990)	33,445	33,445	0.45	95	249	75	324
					25 (2000)	30,205	30,205	0.40	95	249	75	324
					35 (2010)	26,965	26,965	0.36	95	249	75	324
					45 (2020)	23,725	23,725	0.32	94	246	74	320
					55 (2030)	20,525	20,525					

Notes:
1/ Based on flow duration and sediment rating curve method, without consideration of the effects of any existing or future watershed management projects. Instanteneous discharge and suspended sediment concentration data from SWHP, WAPDA.
2/ Based on data for Haro river at Kahnpur.
3/ Based on data for Soan river at Chirah, reduced in ratio of drainage areas.
4/ Based on data from sedimentation surveys of Rawal Lake. Water inflow is based on unit flow rates of the Haro river at Khanpur.
5/ Estimated as 30% of suspended sediment inflow.
5/ Handbook of Applied Hydrology, PP-17-22.

TABLE A.II-25 COMPARISON STUDY ON SUSPENDED SEDIMENT INFLOW

Description		Haro River at Khanpur	Soan River at Simly	Kurrang River at Rawal
(1) Catchment Area:	sq.km	778	153	275
	sq.mile	300	59	106
(2) Runoff:	MCM/yr	326.9	87.1	92.4
	MCM/sq.km/yr	0.420	0.569	0.336
	AF/sq.mile/yr	883.4	1196.8	706.7
(3) Suspended Sedimentation: cu.m/sq.km/yr (AF/sq.mile/yr)				
- AESL Report 1/		2300 (4.8)	6600 (14.0)	2600 (5.5) 1534 (3.2) 2/ 1180 (2.48) 3/
- ACE 1962 Report		580 (1.22)		
- PCI Proforma (1976)		690 (1.45)		
- TECSULT Report			694 (1.46)	
- WAPDA (CDO) Report 1/			2673 (5.62)	
- JICA Study		1079 (2.27)	760 (1.60)	1180 (2.48) 3/

Notes: 1/ Based on the annual accumulation of suspended sediment inflow analysed by SWHP, WAPDA, while others are based on the raw data of instantaneous river discharge and suspended sediment concentration.

2/ Data before 1966 was excluded in consideration of (1) 1960 reservoir volume estimated from contour map of reservoir while 1966 and later estimated from echo soundings, and (2) data under and right after construction of dam often influenced by unsteady condition of reservoir profile.

3/ Actual measurement of reservoir sedimentation considered to include 30% of bed load materials.

2.5. Reservoir Operation

In order to confirm the availability of surface water from the Haro, Kurang and Soan rivers and to evaluate the expected firm yield from reservoirs, detailed water balance simulations were carried out for the entire period of available data. The study was mainly based on the fundamental dimensions of the Projects given in P.C. I Proformas and Completion Reports, and on hydro-meteorological data prepared and provided by CDA and WAPDA as well as by Regional Meteorological Centre, Lahore.

2.5.1. Khanpur Reservoir

A. Water Demand

Phased requirements of water communicated by beneficiaries are presented in Table A.II-11. Seasonal variations of municipal (urban) water supply for both Rawalpindi and Islamabad are estimated as below. In this connection, rate of industrial water consumption is considered to be uniform throughout a year.

SEASONAL VARIATION OF WATER SUPPLY

	Municipal Water			Industrial Water		
Month	Rate	Islamabad (MGD)	Rawalpindi (MGD)	Rate	POF (MGD)	PIDC (MGD)
Jan.	0.80	26.40	55.50	1.00	15.0	13.5
Feb.	0.85	28.05	58.96	1.00	15.0	13.5
Mar.	0.90	29.70	62.43	1.00	15.0	13.5
Apr.	1.00	33.00	69.37	1.00	15.0	13.5
May	1.15	37.95	79.78	1.00	15.0	13.5
Jun.	1.25	41.25	86.71	1.00	15.0	13.5
Jul.	1.05	34.65	72.84	1.00	15.0	13.5
Aug.	1.00	33.00	69.37	1.00	15.0	13.5
Sep.	1.05	34.65	72.84	1.00	15.0	13.5
Oct.	1.05	34.65	72.84	1.00	15.0	13.5
Nov.	1.00	33.00	69.37	1.00	15.0	13.5
Dec.	0.90	29.70	62.43	1.00	15.0	13.5
Average	1.00	33.00	69.37	1.00	15.0	13.5

Regarding irrigation water requirements, a detailed study was conducted, for which brief explanation is given as in the followings:

Cropping Intensity

Irrigation intensities of cultivation are available in P.C. I Proforma, second revised, as under.

- Cropping Intensity 130%
- Kharif Rabi Ratio 1: 1.1

Rabi Cropping	Wheat	44.0%	
	Sugar Cane	3.5	
	Fodder	6.0	
	Orchards	3.5	
	Others	11.0	Total 68%
Kharif Cropping	Maize	30.0	
	Tobacco	8.0	
	Fodder	6.0	
	Orchard	3.5	
	Sugar Cane	3.5	
	Others	11.0	Total 62%

Cropping Schedule

Since no information in this concern is available, an appropriate cropping schedule was prepared by JICA Study Team, based on the information provided in "Irrigation Requirements of Crops in the Punjab" by Directorate of Land Reclamation, Irrigation and Power Department, Government of Punjab, in June 1980. Figures A.II-13 and A.II-14 present the cropping pattern and calendar employed in the study.

Consumptive Use of Crops

Reference crop evapotranspirations by season were calculated based on the climatic conditions observed at Rawalpindi

Meteorological Station by applying Modified Penman Method through procedures given in FAO Technical Publication No.24. Computed Penman's reference crop evapotranspirations are as in Table A.II-26.

Crop Coefficient

Crop growth stage coefficients (kc) developed for Pakistan using experimental data collected in the country are available in "On Farm Water Management, Field Manual, Volume IV: Irrigation Water management", published in December 1980 by Water Management Wing, Ministry of Food, Agriculture & Cooperatives. The FAO method of developing kc values was also used to supplement experimental data.

Effective Rainfall

Effective rainfall was computed by a carry-over system under the following conditions:

- If a daily rainfall is less than or equal to 5 mm, then the effective rainfall is zero

- If the daily rainfall is more then 5 mm, then the effective rainfall is obtainable by multiplying the daily rainfall by 80%

Total readily available moisture content (TRAM) value of 50 mm derived from soil condition was employed. The daily moisture content value was memorized in the computer and the carry-over is construed as a soil moisture heldover to the following day. When the moisture exceeded TRAM value, the surplus water would be spilled as surface flow or deep percolation.

Land Preparation Water Requirement

Total amount of water of 50 mm in depth was added for crops planted during dry period, to meet water requirement for land preparation.

Field Irrigation Requirement

Based on the field irrigation requirement prepared for each crop as shown in Tables A.II-27 to A.II-35, computation was made on a daily basis taking into account the carry-over of soil moisture and rotational irrigation with seven-day intervals.

Irrigation Efficiency

In the study, an overall irrigation efficiency was taken as 72.0% (90% for conveyance system x 80% for application) including all of efficiencies from diversion point up to the root zone of crops.

Irrigation Diversion Water Requirement

Unit diversion water requirement for irrigation so computed is presented in Table A.II-36.

B. Water Balance Simulation

Water balance study of the Khanpur reservoir was undertaken combining every aspect of hydrology, such as inflow into the reservoir, water demand for municipal and industrial water supply and for irrigation, and water losses from the reservoir surface and bottom.

To cope with the simulation of actual reservoir operation under the conditions prepared by the Project, various cases of water balance computations were processed giving various combinations of water demands requested by beneficiaries, aiming at finding firm yield from the reservoir which would be satisfied even during critically droughty period of once in five years probability. Regarding the return period of drought, it has been agreed to at the meeting held on 24th September, 1984 in the office of Member (Water), WAPDA, Wapda House, Lahore, that the study is based on the drought of five year return period.

The computation was made for the period of 21 years from 1960 to 1980 with a ten-daily unit, employing a simple assumption that the surplus water in the reservoir above full water level during any ten-daily interval would be released through a spill during the corresponding ten-daily interval.

Prior to this, for the purpose of demonstrating the time gap between the available inflow into and the requested demand from the reservoir, seasonal variations of inflow and demand were plotted as shown in Figure A.II-15.

Regarding water losses from the reservoir, deduction of 10% from the available inflow was considered to be sufficient to account for both evaporation and seepage.

From the summary of computation, major parameters which indicate the status of shortage or spillage are extracted and presented in Table A.II-37. To visualize the problem, behaviour of the Khanpur reservoir storages as simulated is plotted for the selected few cases of the water balance study, as given in Figure A.II-16 and A.II-17.

In review of various cases of water balance study, size or capacity of the Khanpur reservoir would be sufficient to satisfy various water requirements. However, inflow is small in contrast with demand, and hence there are frequent occasions of relatively long period before the reservoir water level comes back to its full water level meaning that practically water shortage would occur in most years. Frequency of shortage decreases with deduction of water demand to be released from the reservoir, but the benefit also decreases correspondingly. A review of the study in terms of probability of shortage occurrence indicates that about 75% of the present water requirement would be optimal when the capacity of the reservoir and the rate of inflow are combined. With deduction of water demand to 75% of that presently projected, the Khanpur reservoir would provide full amount of water supply just to meet requirement even during a drought period of once in five years frequency. Frequency analysis made on annual shortage of water supply for the Khanpur reservoir is given in Figure A.II-18.

2.5.2. Simly Reservoir

The water supply system of Islamabad has been planned on the basis of two major water sources viz Khanpur dam and Simly dam. The Simly dam has been commissioned in 1982 and 12.0 MGD of water is at present being received from the dam and conveyed to Islamabad through one conduction main pipe. The Simly Filtration Plant, located nearby the dam site, has already been completed in 1965 with the designed water production capacity of 24.0 MGD. The other conduction line is expected to be ready by the end of 1984, and thus full yield of 24.0 MGD of Simly Reservoir is scheduled to be available soon.

In parallel with this, as previously mentioned in 2.2.2., installation of three 25 ft high gates are advantageously programmed in near future within five years to raise the conservation level of the reservoir to 2315 ft accordingly increasing live storage by 11.8

MCM, resulting in gain of a subtantial safe yield from the reservoir. In this connection, CDA's estimate on safe yield from the reservoir after raising the dam has been reported as 48.0 MGD.

To confirm the availability of water, at present and in future, from the reservoir, detailed studies of water balance simulation were carried out through procedures employed for Khanpur reservoir operation. Table A.II-38 presents the summary extracted from cases of computations, and the simulated reservoir storages for period 1961 to 1979 are visulaized as shown in Figures A.II-19 and A.II-20.

Computed results were then put into statistical evaluation, as given in Figure A.II-21, and it is concluded that (1) the Simly Reservoir under the existing condition of storage capacity would satisfy the scheduled amount of water supply even in five-year dry year, and (2), on the contrary, after raising of the dam the reservoir would produce 38.4 MGD of firm yield, which is equivalent to 160% of the present requirement or 80% of the CDA's estimate under the future condition of the dam. As concerns the above, a simple comparative study was progressed between the Khanpur and Simly, to make understandings clear;

COMPARATIVE STUDY ON SAFE YIELDS

Items	Khanpur Dam	Simly Dam Existing	Simly Dam After Raising
(1) Inflow (MCM/yr)	327.0	87.1	87.1
(2) Effective Storage (MCM)	112.3	25.5	37.4
(3) (2)/(1)	0.34	0.29	0.43
(4) Projected Demand (MGD) 1/	186.0	20.16	40.32
(5) Safe Yield (MGD) 1/	139.5	28.22	32.26
(6) (5)/(4)	0.75	1.40	0.80
(7) (5)/(1)	0.71	0.54	0.62

Note: 1/ Expressed by average amount of raw water requirement to be released from the reservoir.
Thus, considering 5% of water losses for treatment, 24.0 (maximum) x 105%/1.25 = 20.16 MGD
and 48.0 x 105%/1.25 = 40.32 MGD

2.5.3. Rawal Reservoir

The existing condition of water supply of the Rawal Reservoir is, according to Small Dams Organization, as under.

Distribution	Supply (MGD)	Remarks
Rawalpindi Water Supply	21.0	
CDA	2.0	Temporary
CDA by Pumping Up	1.5 - 2.0	-do-
Irrigation	Balance	
Total	28.0	When available

The above allocation of water will be revised in near future and by the end of 1986 it is scheduled that the whole amount of Rawal yield is conveyed to Rawalpindi and Cantonment. It is therefore considered as the existing condition that only the water supply to Rawalpindi (including Cantonment) is the consumer of Rawal water, and to confirm the availability of reservoir water detailed studies of water balance simulation were conducted. After examination of sedimentation study, the following dimensions of the reservoir were inputted;

DIMENSION OF RAWAL RESERVOIR

Description	Present (1984)	Future (2000)
Full Water Level (ft)	1,752	1,752
Dead Water Level (ft)	1,722	1,729
Maximum Storage (MCM)	58.59	58.59
Dead Storage (MCM)	14.93	21.33
Effective Storage (MCM)	43.66	37.26

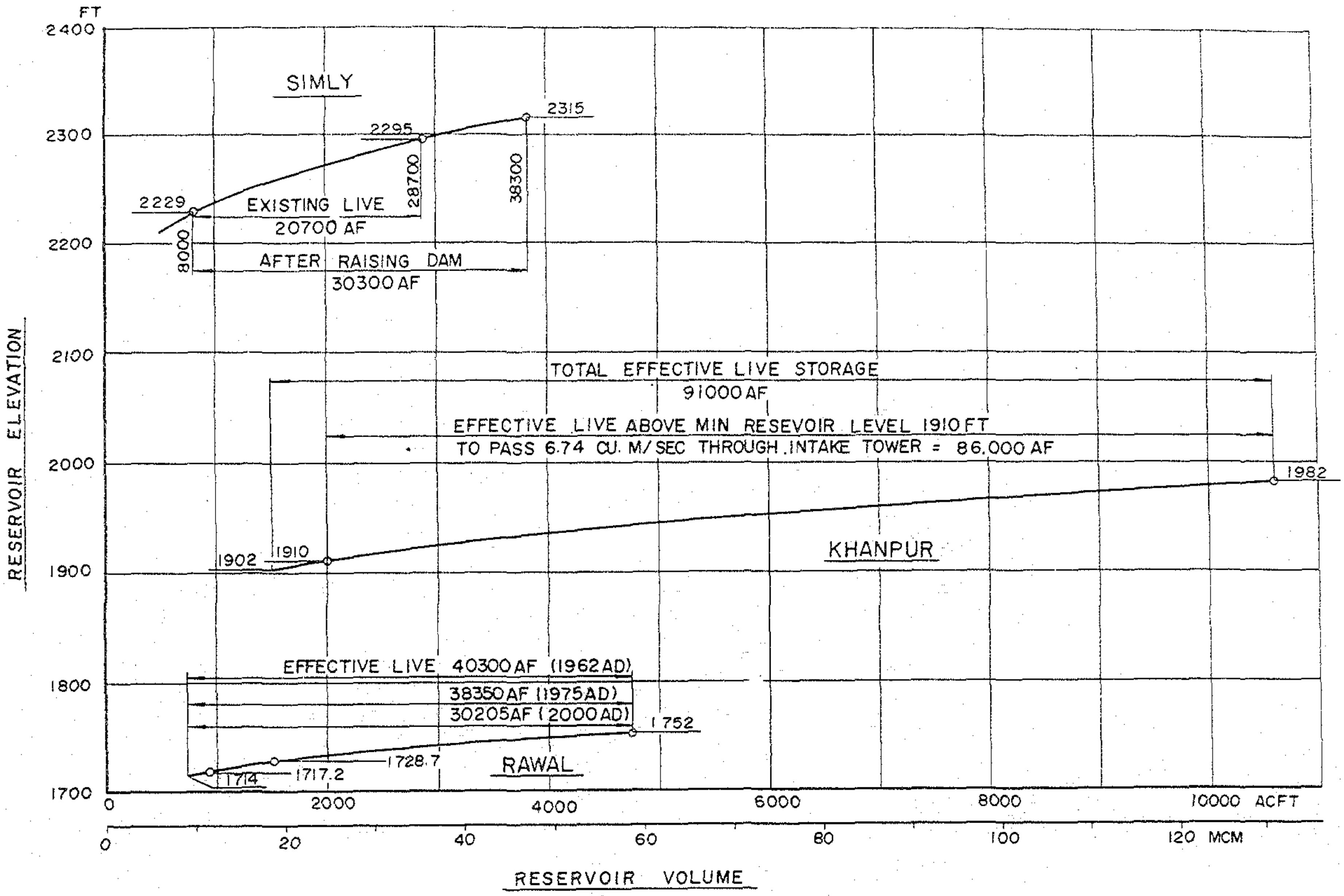
Table A.II-39 presents the summary extracted from cases of computations, and the simulated reservoir storages for the period of 21 years from 1960 to 1980 have been visualized as given in Figures A.II-22 and A.II-23. Then statistical evaluations were progressed on shortage of reservoir water as shown in Figure A.II-24 and major findings are summarized as follows:

- The existing Rawal Reservoir would provide scheduled amount of firm yield successfully throughout periods of once in five-year probability drought and still have some excess water available in the reservoir.

- In the year 2000 A.D., 180% of at present programmed yield would still be available from the reservoir. This is equivalent to 50.4 MGD as maximum or 40.3 MGD as average after treatment.

Summaries extracted from cases of computations are compiled in the end of this Appendix.

FIGURE A.II-8 RESERVOIR CAPACITY CURVES



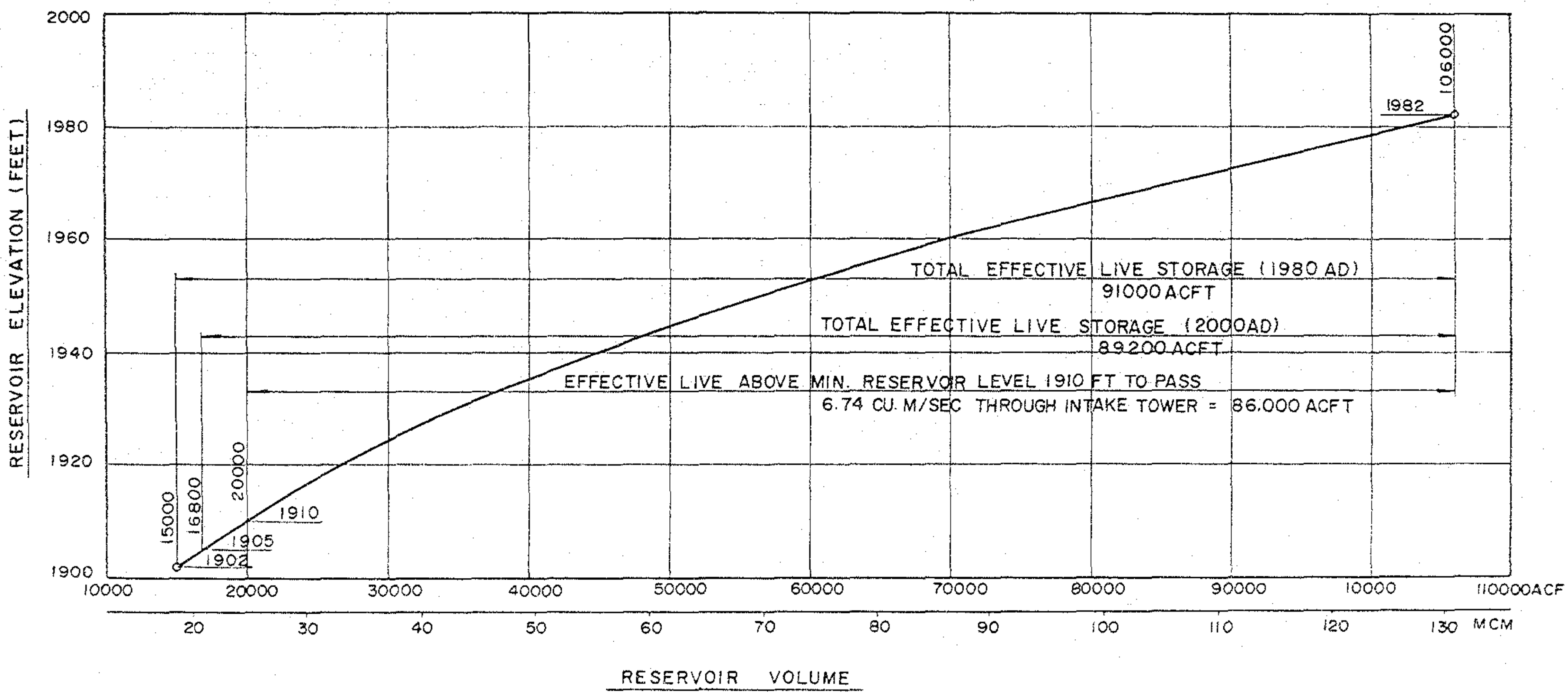


FIGURE A.II-9 KHANPUR RESERVOIR CAPACITY CURVE

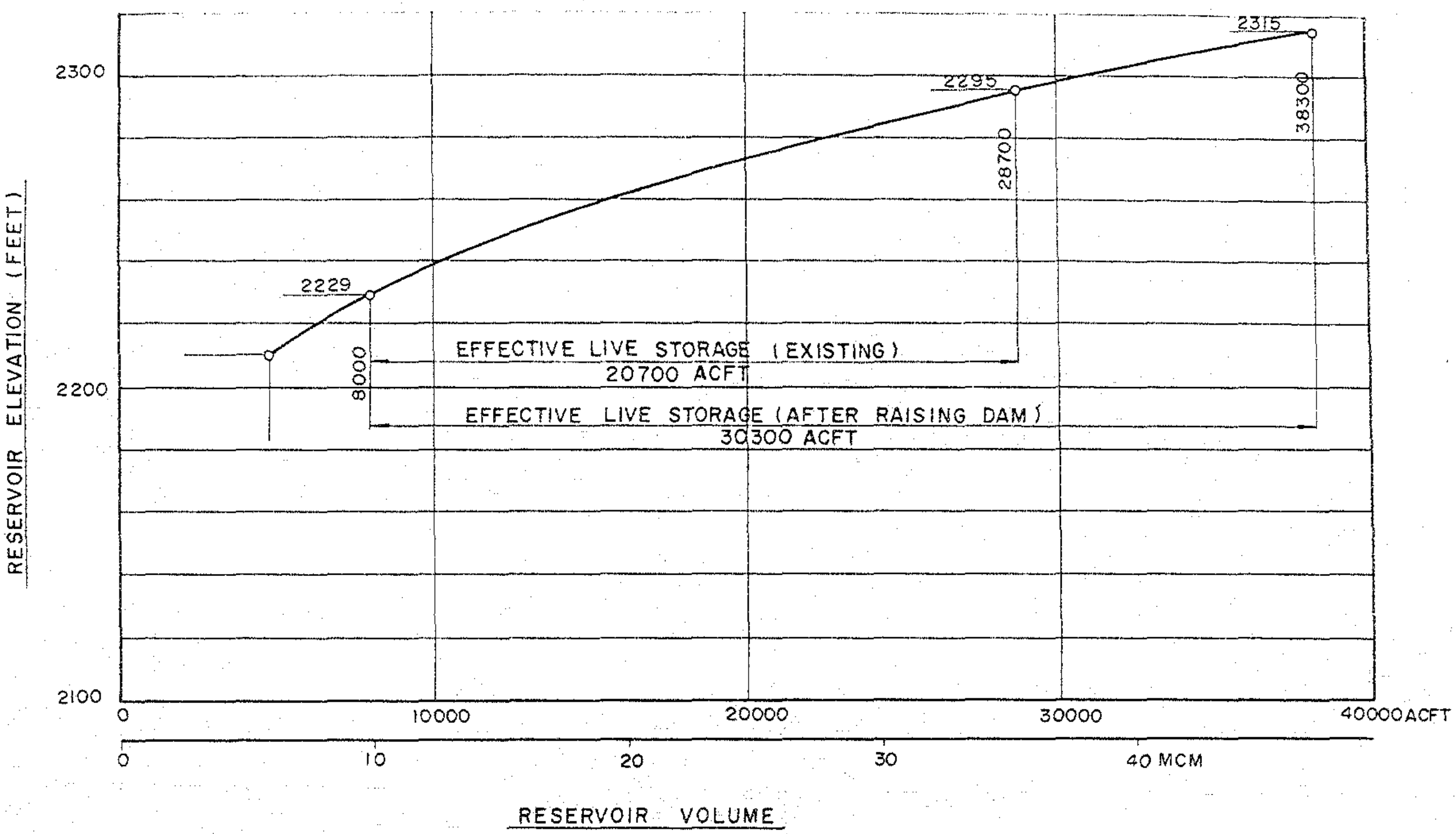


FIGURE A.II-10 SIMLY RESERVOIR CAPACITY CURVE

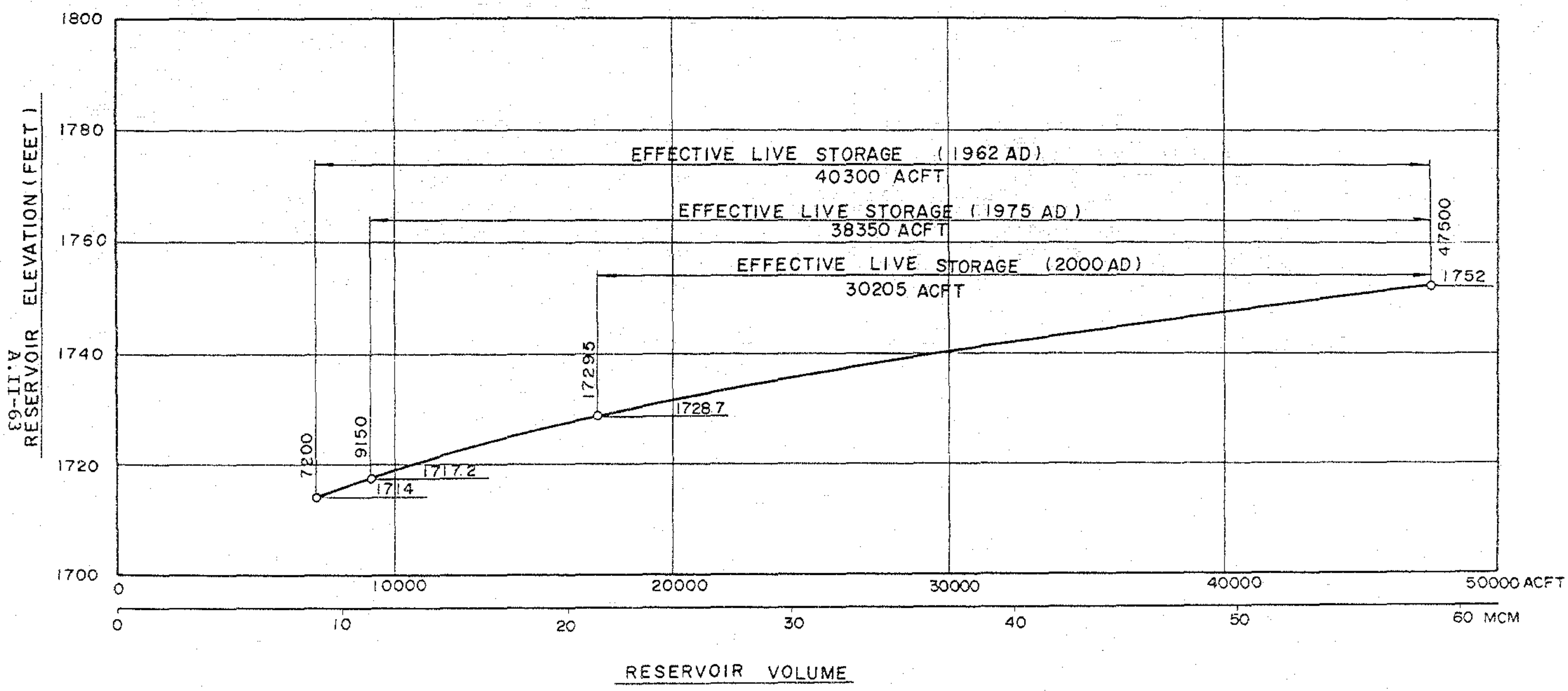


FIGURE A.II-11 RAWAL RESERVOIR CAPACITY CURVE

FIGURE A.II-12 SEASONAL VARIATIONS OF MUNICIPAL WATER SUPPLY (FOR BOTH ISLAMBAD AND RAWALPINDI)

		WATER SUPPLY	
MONTH	RATE	ISLAMABAD	RAWALPINDI
JAN	0.80	26.40	55.50
FEB	0.85	28.05	58.96
MAR	0.90	29.70	62.43
APR	1.00	33.00	69.37
MAY	1.15	37.95	79.78
JUN	1.25	41.25	86.71
JUL	1.05	34.65	72.84
AUG	1.00	33.00	69.37
SEP	1.05	34.65	72.84
OCT	1.05	34.65	72.84
NOV	1.00	33.00	69.37
DEC	0.90	29.70	62.43
TOTAL	12.00	396.00	832.44
AVERAGE	1.00	33.00	69.37

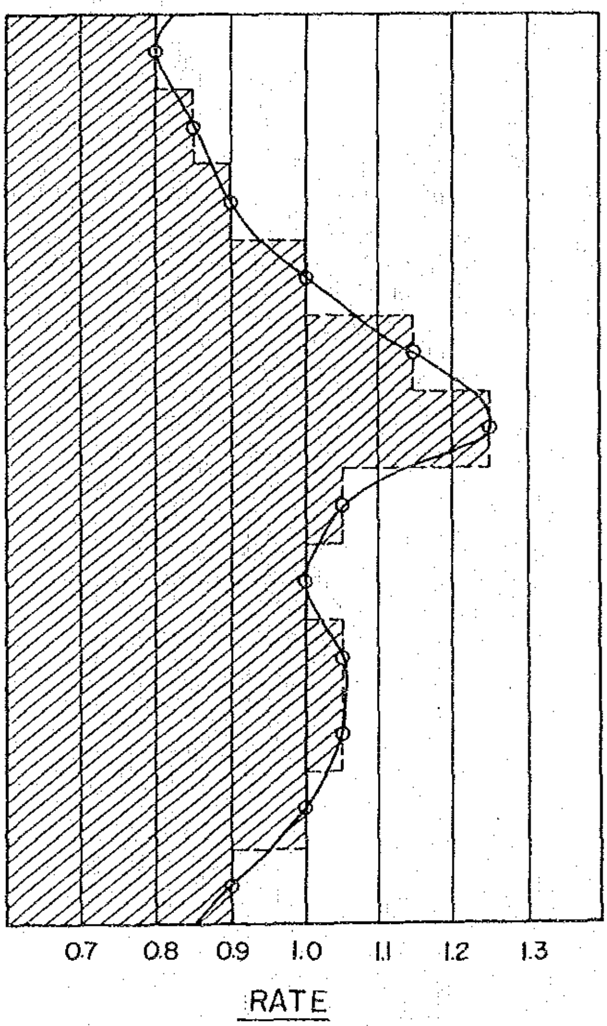


FIGURE A.II-13 CROPPING PATTERN AND CALENDER

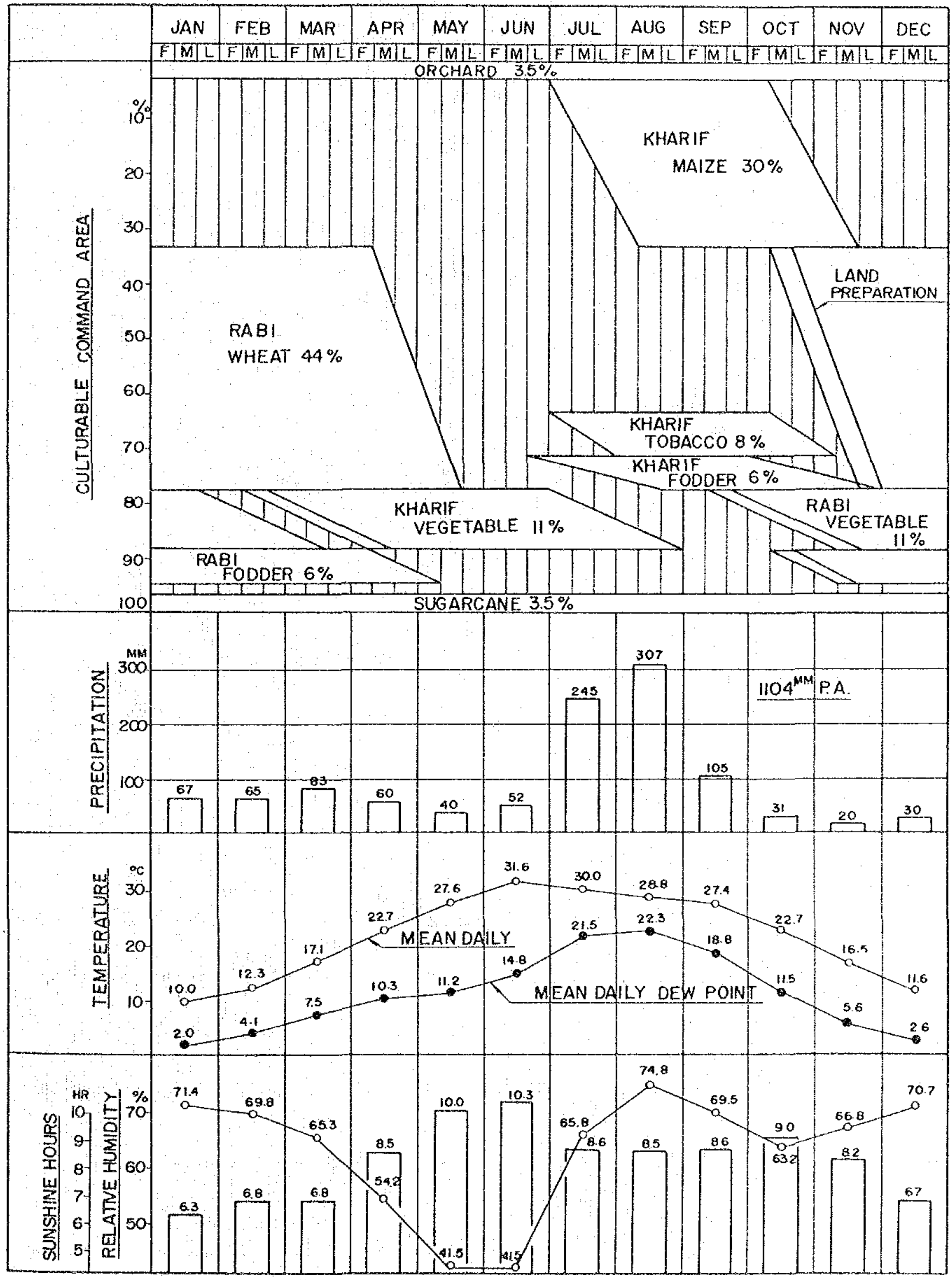


FIGURE A.II-14 CROPPING CALENDER

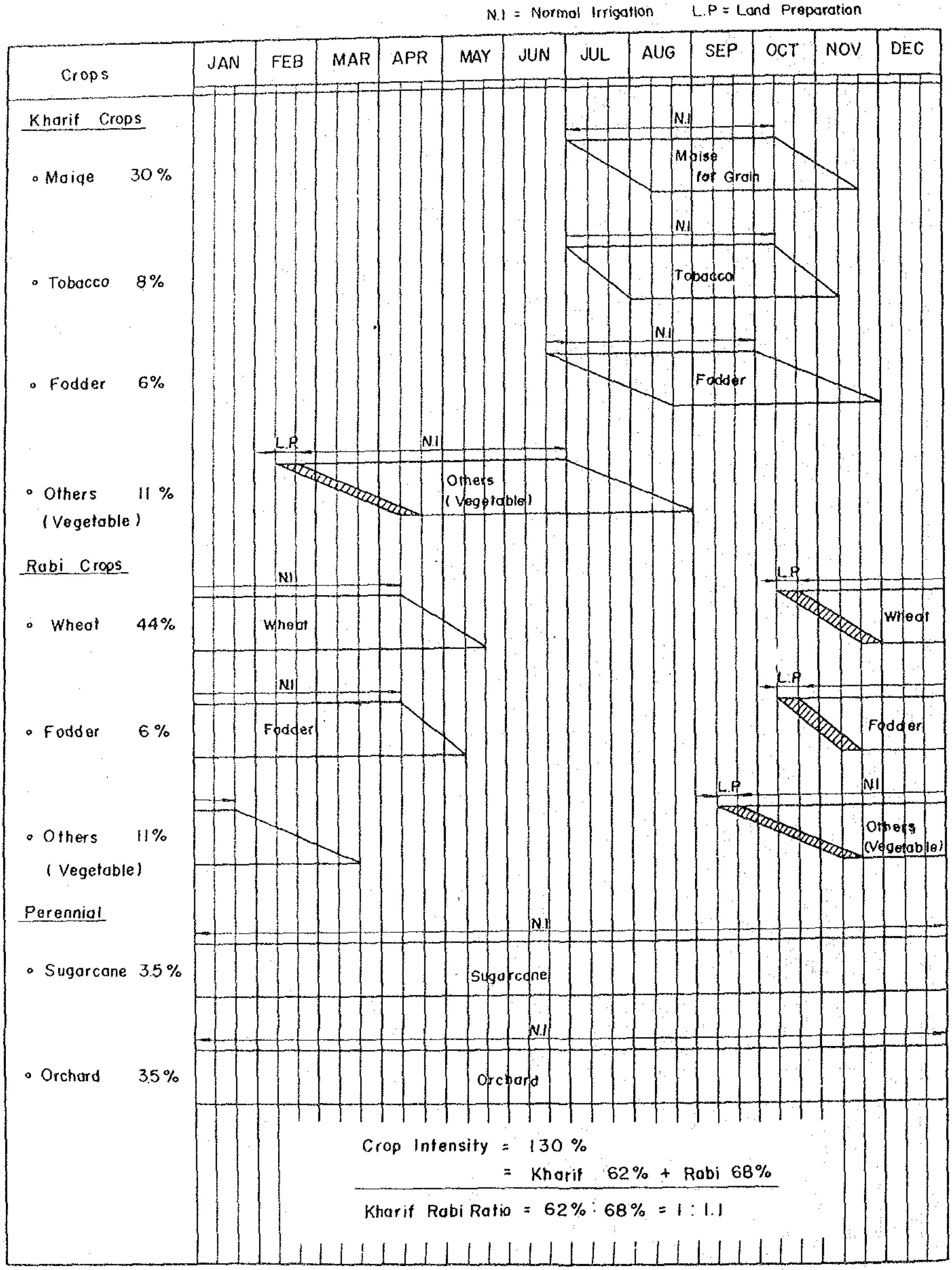
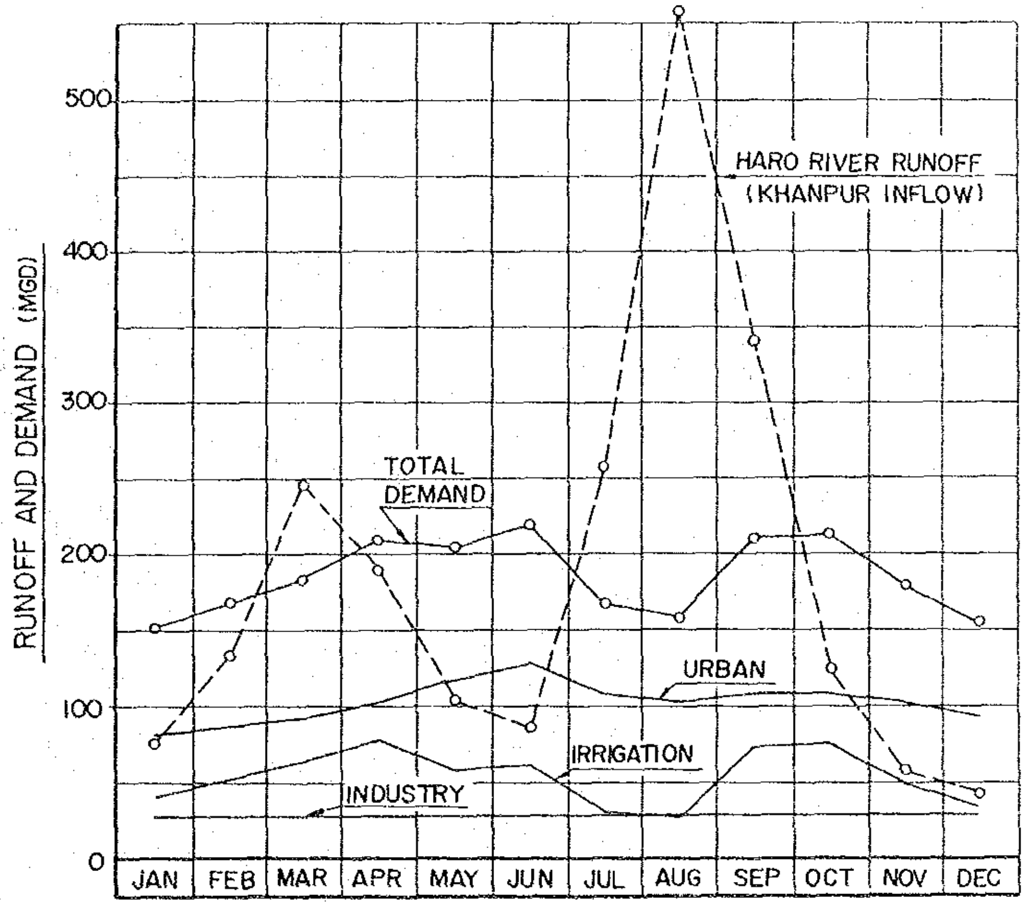


FIGURE A.II-15 SEASONAL VARIATIONS OF INFLOW AND DEMAND (KHANPUR RESERVOIR)



		Water Demand Programmed in 1976						
		Urban		Industry		Irrigataion		
Month	Khanpur Inflow	Islama.	Rawal.	P.O.F	PIDC	R.B.C	L.B.C	Total
Jan.	75.4	26.4	55.5	15.0	13.5	15.1	25.2	150.7
Feb.	133.1	28.0	59.0	15.0	13.5	19.5	32.5	167.5
Mar.	244.7	29.7	62.4	15.0	13.5	22.6	39.2	183.4
Apr.	189.2	33.0	69.4	15.0	13.5	29.4	48.9	209.2
May	103.7	37.9	79.8	15.0	13.5	21.7	36.2	204.1
Jun.	85.5	41.3	86.7	15.0	13.5	23.0	38.4	217.9
Jul	256.3	34.7	72.8	15.0	13.5	11.5	19.2	166.7
Aug.	558.4	33.0	69.4	15.0	13.5	9.8	16.4	157.1
Sep.	340.2	34.7	72.8	15.0	13.5	29.8	46.2	210.0
Oct.	124.7	34.7	72.8	15.0	13.5	28.4	47.4	211.8
Nov.	57.5	33.0	69.4	15.0	13.5	18.0	30.1	179.0
Dec.	42.7	29.7	62.4	150.0	13.5	12.7	21.1	154.4
Average	184.9	33.0	69.4	15.0	13.5	20.0	33.4	184.3

FIGURE A.II-16 KHANPUR RESERVOIR STORAGE, SPILLAGE AND SHORTAGE (CASE-1)

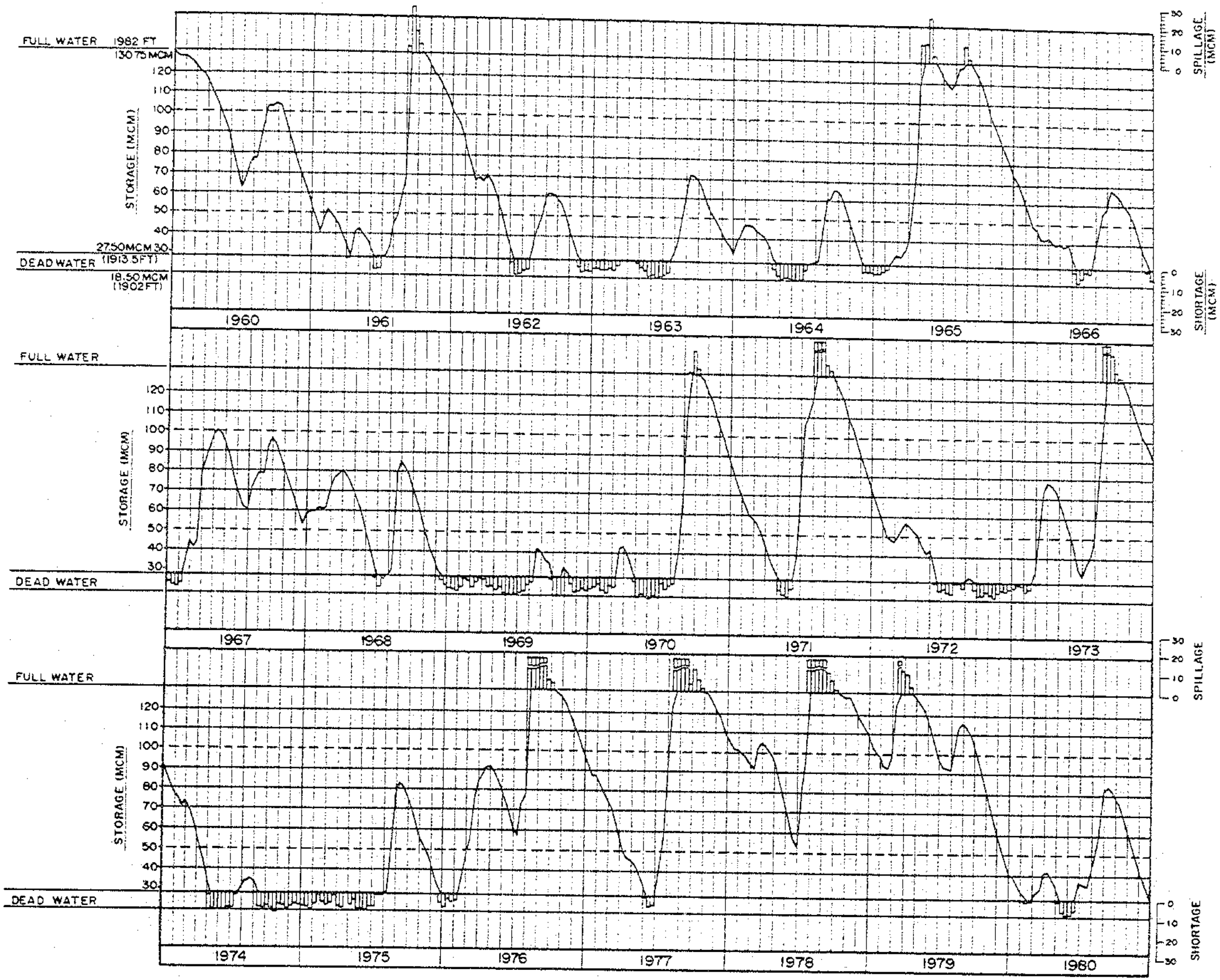


FIGURE A.II-17 KHANPUR RESERVOIR STORAGE, SPILLAGE AND SHORTAGE (CASE-6)

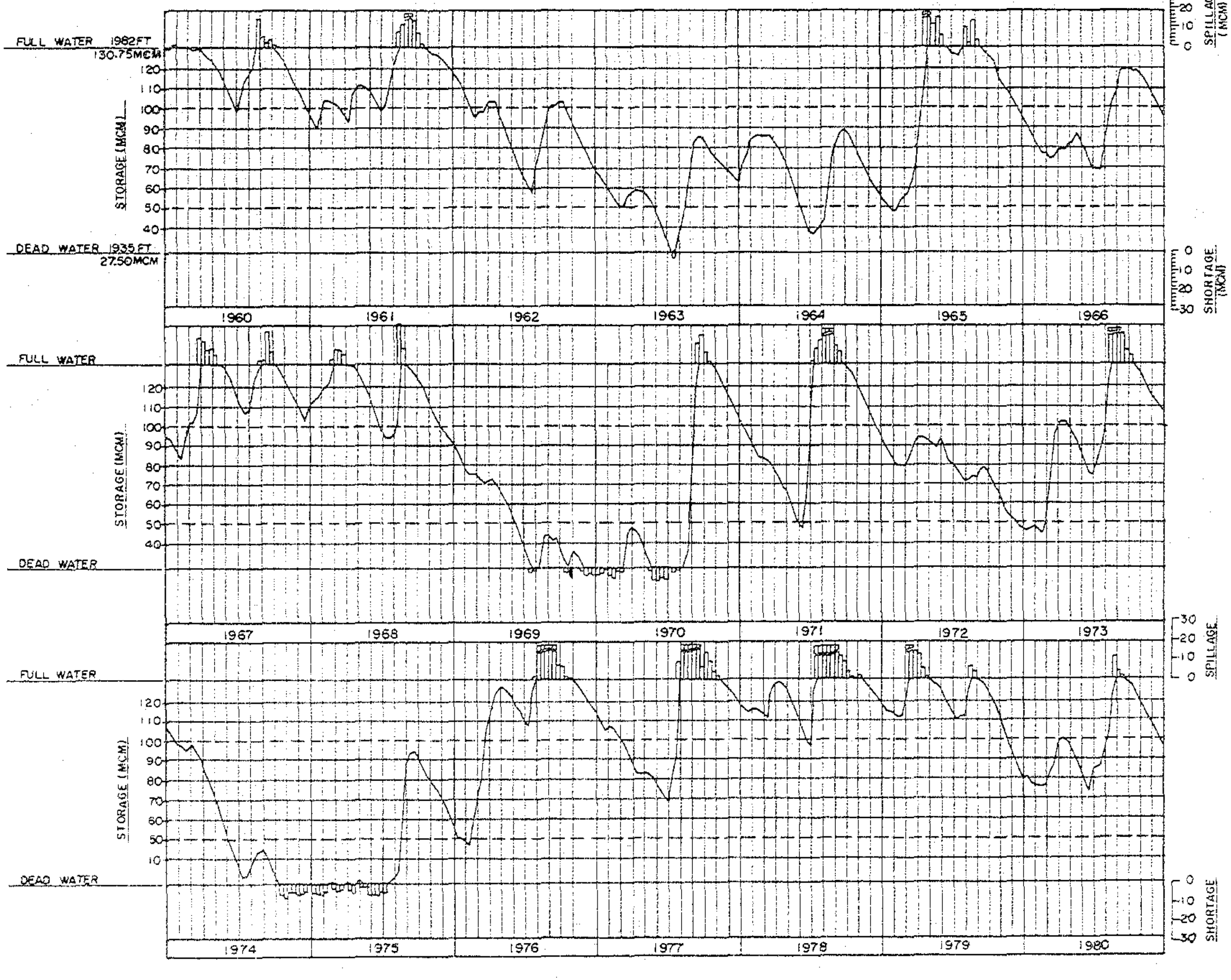
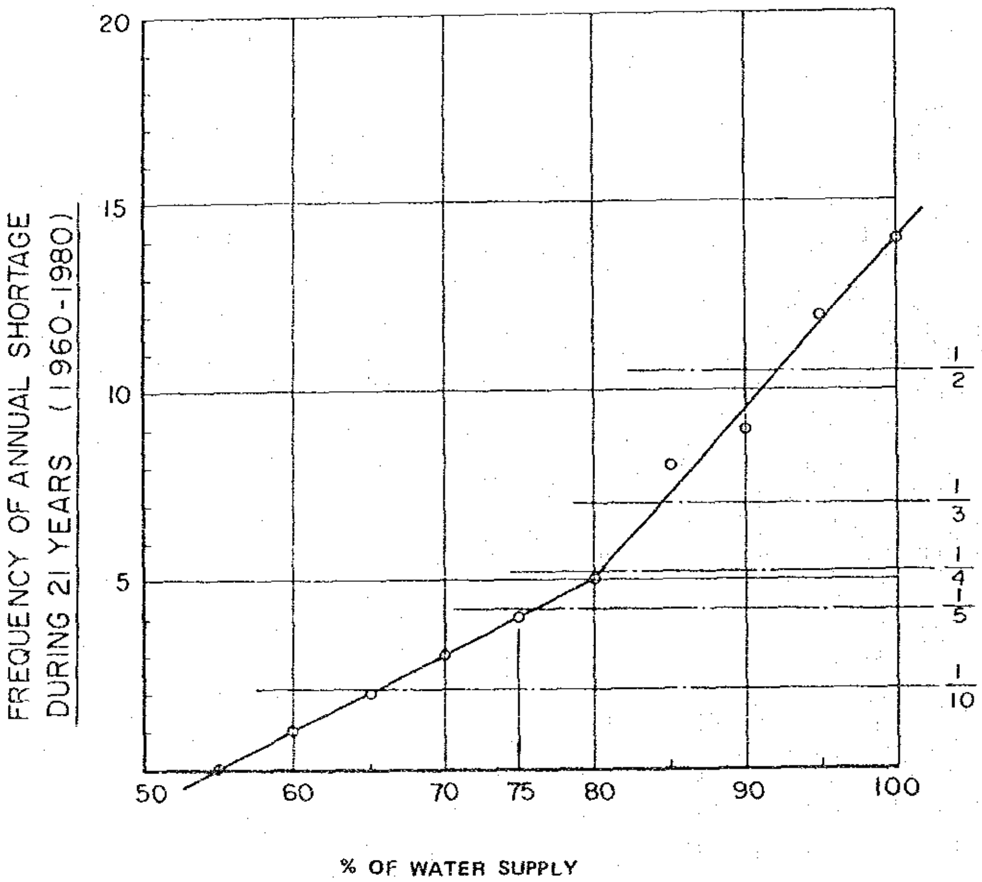


FIGURE A.II-18 FREQUENCY ANALYSIS ON ANNUAL SHORTAGE OF WATER SUPPLY FOR KHANPUR RESERVOIR



WATER DEMAND		(Acft)	(MGD)
URBAN	ISLAMABAD	44,286	33.0
	RAWALPINDI	93,094	69.37
INDUSTRIAL	WAR	20,130	15.0
	TAXILA	18,250	13.5
IRRIGATION	RBC	46,740	
	LBC	27,520	
TOTAL		250,000 = 100%	

FIGURE A.II-19 SIMLY RESERVOIR STORAGE, SPILLAGE AND SHORTAGE

(CASE 1 & 2: BEFORE RAISING DAM)

FIGURE A.II-20 SIMLY RESERVOIR STORAGE, SPILLAGE AND SHORTAGE

(CASE-8: AFTER RAISING DAM)

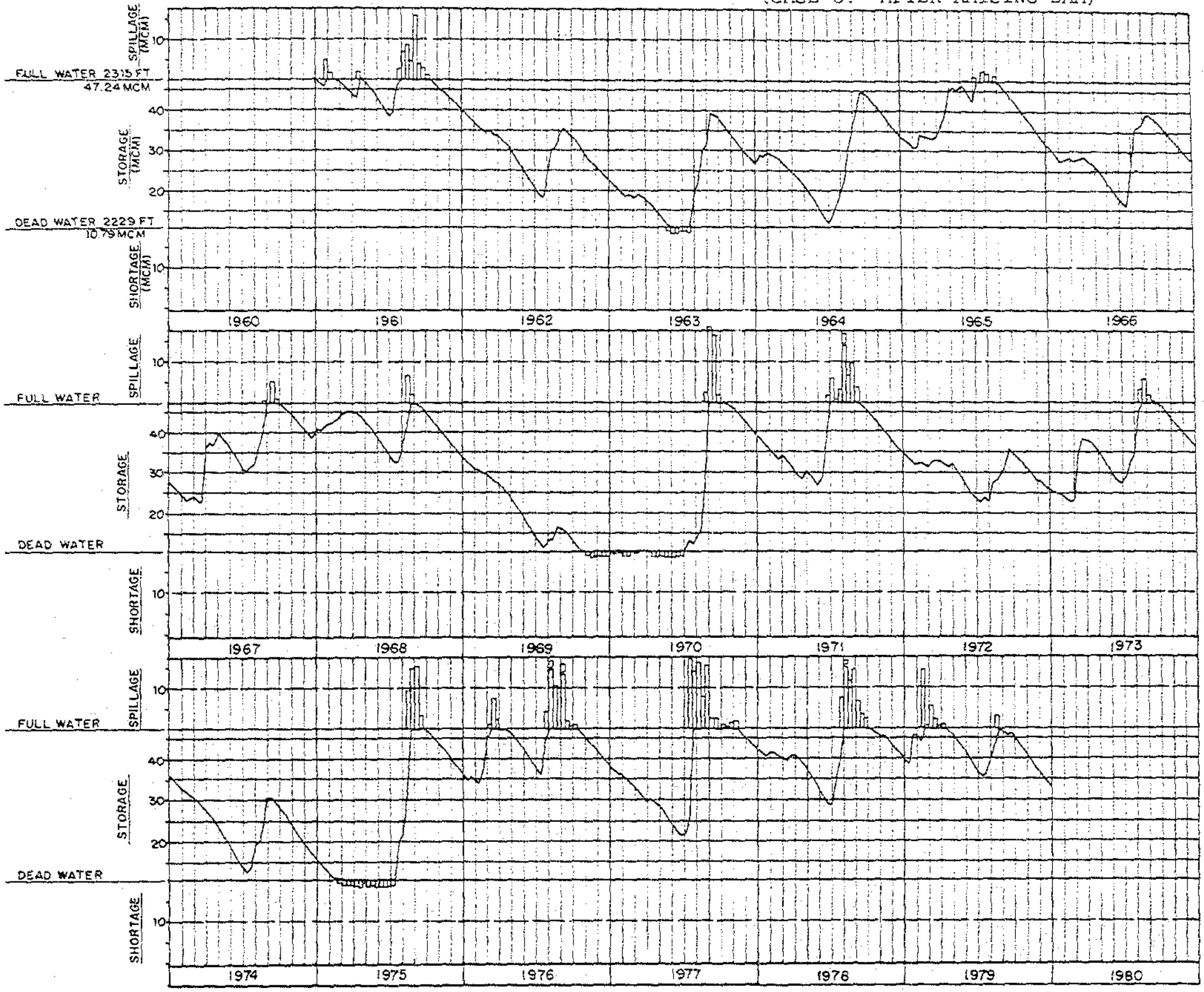


FIGURE A.II-21 FREQUENCY ANALYSIS ON ANNUAL SHORTAGE OF WATER SUPPLY FOR SIMLY RESERVOIR

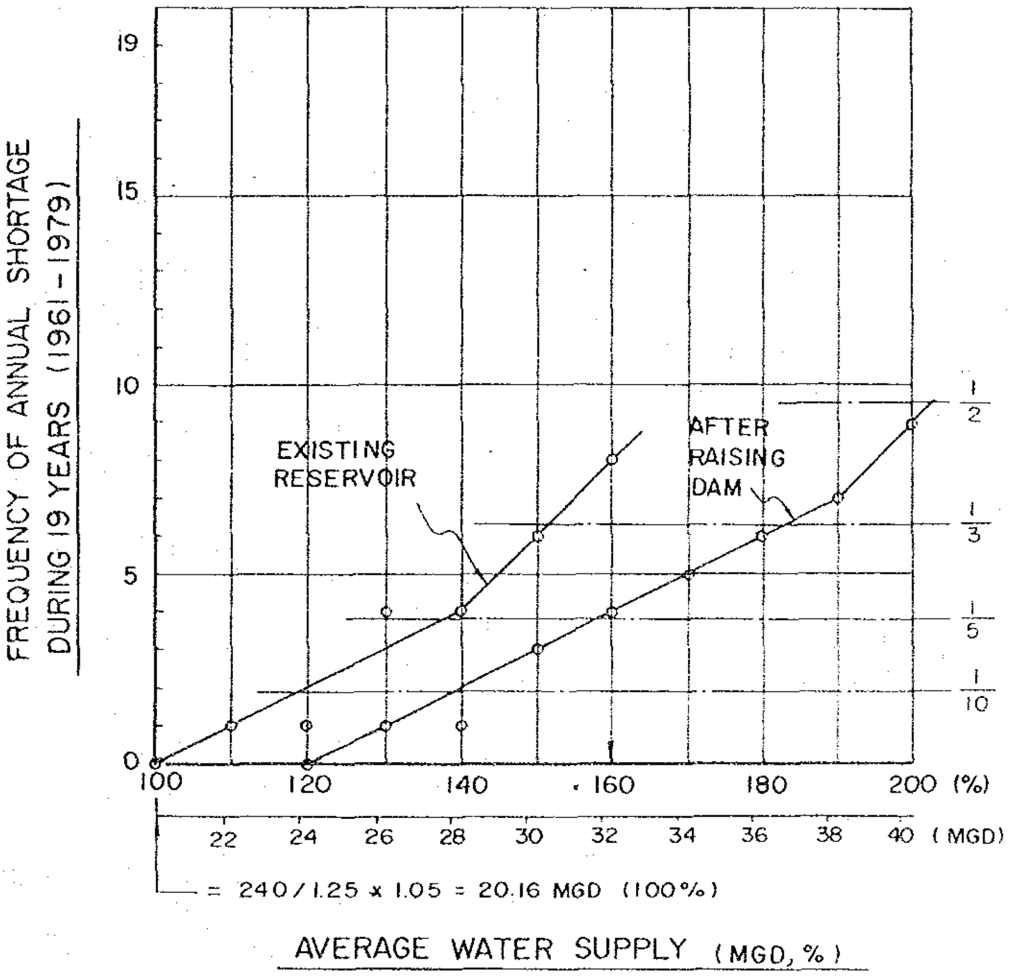


FIGURE A.II-22 RAWAL RESERVOIR STORAGE, SPILLAGE AND SHORTAGE

(CASE-1 & 2: WITH 1984 CONDITION)

FIGURE A.II-23 RAWAL RESERVOIR STORAGE, SPILLAGE AND SHORTAGE

(CASE-6: WITH 2000 CONDITION)

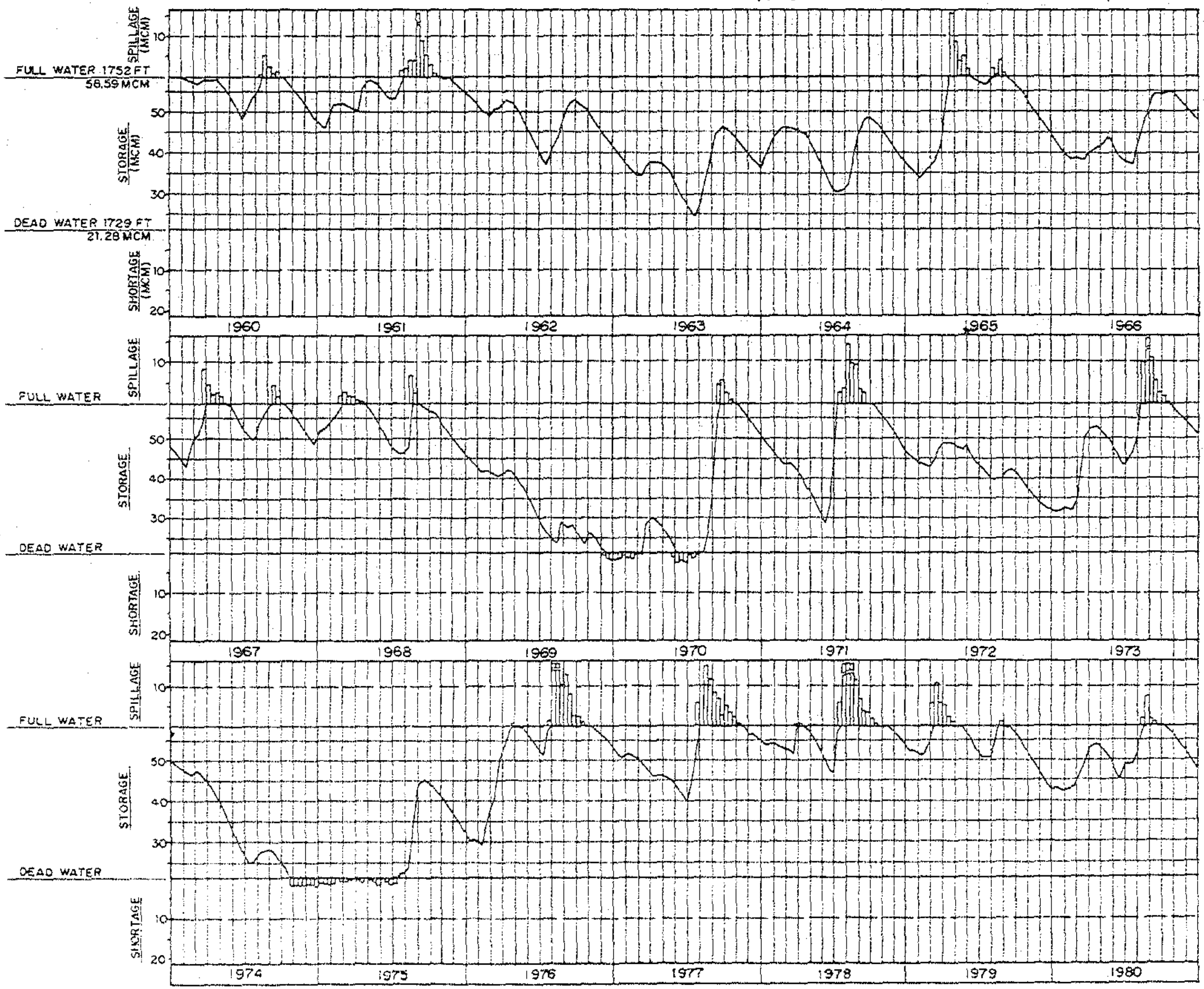


FIGURE A.II-24 FREQUENCY ANALYSIS ON ANNUAL SHORTAGE OF WATER SUPPLY FOR RAWAL RESERVOIR

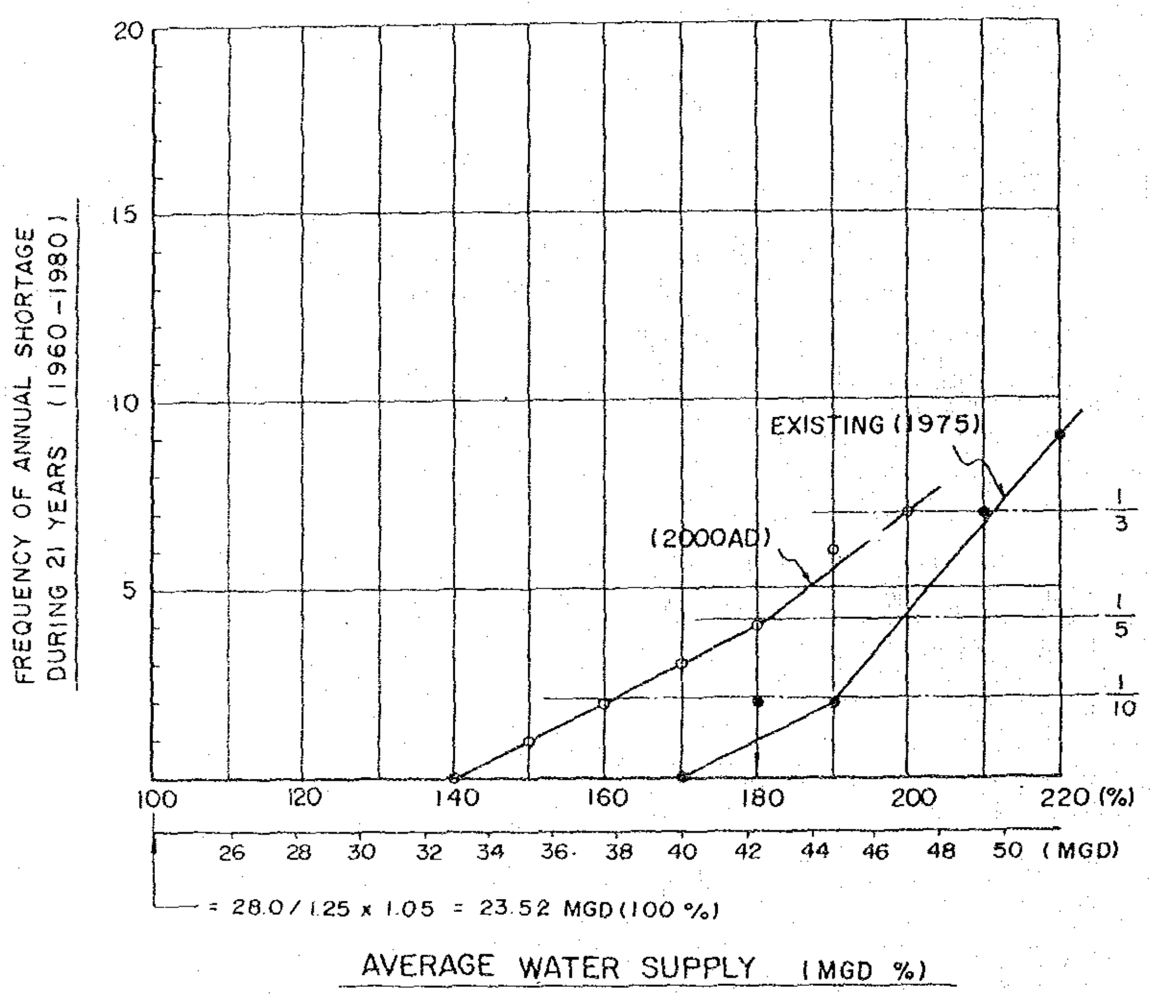


TABLE A.II-26 CALCULATION CHART OF PENMAN REFERENCE CROP ETo

Place: RAWALPINDI Latitude: 33°35' Longitude: 73°03' Altitude: 510 m

Factor	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Note/Equation
T mean	°C	10.0	12.3	17.1	22.7	27.6	31.6	30.0	28.8	27.4	22.7	16.5	11.6	given data
RH mean	%	71.4	69.8	65.3	54.2	41.5	41.5	65.8	74.8	69.5	63.2	66.3	70.7	- do -
ea	mbar	12.3	14.3	19.5	27.6	37.0	46.5	42.4	39.6	36.5	27.6	18.8	13.6	
ed	mbar	8.8	10.0	12.7	15.0	15.4	19.3	27.9	29.6	25.4	17.4	12.5	9.6	ea x RH mean/100
(ea-ed)	mbar	3.5	4.3	6.8	12.6	21.6	27.2	14.5	10.0	11.1	10.2	6.3	4.0	(1)
u	km/day	102	138	160	160	164	155	147	111	93	80	75	80	given data
u_2	km/day	102	138	160	160	164	155	147	111	93	80	75	80	u at 2m Height
f(u)	-	0.55	0.64	0.70	0.70	0.71	0.69	0.67	0.57	0.52	0.49	0.47	0.49	$0.27 (1 + u_2/100)$
1 - W	-	0.43	0.40	0.34	0.27	0.22	0.19	0.21	0.22	0.22	0.28	0.35	0.42	
(1-W) f(u) (ea-ed)	mm/day	0.83	1.10	1.62	2.38	3.37	3.57	2.04	1.25	1.27	1.40	1.04	0.82	(2)
Ra	mm/day	8.38	9.88	12.48	14.84	16.50	17.98	16.80	15.52	13.44	10.88	8.61	7.33	
n	hr/day	6.3	6.8	6.8	8.5	10.0	10.3	8.6	8.5	8.6	9.0	8.2	6.7	given data
N	hr/day	10.2	11.0	11.9	13.0	13.9	14.4	14.2	13.4	12.4	11.4	10.4	9.9	
Rs	mm/day	4.68	5.52	6.69	8.56	10.06	10.92	9.29	8.80	8.02	7.01	5.55	4.31	(0.25 + 0.50n/N) Ra
Rns	mm/day	3.51	4.14	5.01	6.42	7.55	8.19	6.97	6.60	6.02	5.26	4.16	3.23	0.75 Rs
f(T mean)	-	12.7	13.2	14.0	15.1	16.2	17.1	16.7	16.5	16.2	15.1	13.9	13.0	
f(ed)	-	0.21	0.20	0.18	0.17	0.17	0.15	0.11	0.10	0.12	0.16	0.18	0.20	$0.34 - 0.044\sqrt{ed}$
f(n/N)	-	0.66	0.66	0.61	0.69	0.75	0.74	0.65	0.67	0.72	0.81	0.81	0.71	0.1 + 0.9 n/N
Rnℓ	mm/day	1.76	1.74	1.54	1.77	2.07	1.90	1.19	1.11	1.40	1.96	2.03	1.85	f(T mean)·f(ed) ·f(n/N)
Rn	mm/day	1.75	2.40	3.47	4.65	5.48	6.29	5.78	5.49	4.62	3.30	2.13	1.38	RNs - Rnℓ
W	-	0.57	0.60	0.66	0.73	0.78	0.81	0.79	0.78	0.78	0.72	0.65	0.58	1 - (1 - W)
W.Rn	mm/day	1.00	1.44	2.29	3.39	4.27	5.09	4.57	4.28	3.60	2.38	1.38	0.80	(3)
ETo	mm/day	1.8	2.5	3.9	5.8	7.6	8.7	6.6	5.5	4.9	3.8	2.4	1.6	(2) + (3)

TABLE A.II-27 FIELD IRRIGATION REQUIREMENT (WHEAT)

MONTH	OCT			NOV			DEC			IAN			FEB			MAR			APR			MAY					
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN		LS								NI WHEAT (RABI)																	
1. ELEMENT																											
% OF GROWING SEASON			6	12	18	24	30	35	41	47	53	59	65	71	77	82	88	94	100								
CROP COEFFICIENT (kc)			0.48	0.65	0.87	1.09	1.25	1.35	1.42	1.45	1.45	1.41	1.33	1.23	1.07	0.96	0.83	0.73	0.65								
				0.48	0.65	0.87	1.09	1.25	1.35	1.42	1.45	1.45	1.41	1.33	1.23	1.07	0.96	0.83	0.73	0.65							
					0.48	0.65	0.87	1.09	1.25	1.35	1.42	1.45	1.45	1.41	1.33	1.23	1.07	0.96	0.83	0.73	0.65						
						0.48	0.65	0.87	1.09	1.25	1.35	1.42	1.45	1.45	1.41	1.33	1.23	1.07	0.96	0.83	0.73	0.65					
							0.48	0.65	0.87	1.09	1.25	1.35	1.42	1.45	1.45	1.41	1.33	1.23	1.07	0.96	0.83	0.73	0.65				
Kc AVERAGE			0.48	0.57	0.67	0.77	0.87	1.04	1.20	1.31	1.38	1.42	1.41	1.37	1.30	1.20	1.08	0.96	0.8	0.79	0.74	0.69	0.65				
ETo (MM/DAY)	3.8			2.4			1.6			1.8			2.5			3.9			5.8			7.6					
ET (MM/DAY)			1.8	1.4	1.6	1.8	1.4	1.7	1.9	2.4	2.5	2.6	3.5	3.4	3.3	4.7	4.2	3.7	4.9	4.6	4.3	5.2	4.9				
SOIL SATURATION (MM)	50																										
2. EQUATION																											
LAND SOAKING		1/5	1/5	1/5	1/5	1/5																					
NORMAL IRRIGATION			1/5	2/5	3/5	4/5	5/5	→										→	5/5	4/5	3/5	2/5	1/5				
3. WATER REQUIREMENT																											
LAND SOAKING (MM)		10	10	10	10	10																					
NORMAL IRRIGATION (MM/DAY)			0.4	0.6	1.0	1.4	1.4	1.7	1.9	2.4	2.5	2.6	3.5	3.4	3.3	4.7	4.2	3.7	4.9	3.7	2.6	2.1	1.0				
MM / 10 DAYS		10	14	16	20	24	14	17	19	24	25	26	35	34	33	47	42	37	49	37	26	21	10				
MM / MONTH	24			60			50			75			102			126			112			31					

TABLE **A.II-28** FIELD IRRIGATION REQUIREMENT (RABI FODDER)

MONTH	OCT			NOV			DEC			JAN			FEB			MAR			APR			MAY					
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN		LS						FODDER (RABI)		NI																	
1. ELEMENT																											
% OF GROWING SEASON			6	12	18	24	29	35	41	47	53	59	65	71	76	82	88	94	100								
CROP COEFFICIENT (Kc)			0.95																			0.95					
Kc AVERAGE			0.95																			0.95					
ETo (MM/DAY)		3.8			2.4			1.6			1.8			2.5			3.9			5.8			7.6				
ET (MM/DAY)			3.6	2.3	2.3	2.3	1.5	1.5	1.5	1.7	1.7	1.7	2.4	2.4	2.4	3.7	3.7	3.7	5.5	5.5	5.5	7.2					
SOIL SATURATION (MM)		50																									
2. EQUATION																											
LAND SOAKING		1/4	1/4	1/4	1/4																						
NORMAL IRRIGATION			1/4	2/4	3/4	4/4													4/4	3/4	2/4	1/4					
3. WATER REQUIREMENT																											
LAND SOAKING (MM/DAY)		13	13	12	12																						
NORMAL IRRIGATION (MM/DAY)			0.9	1.2	1.7	2.3	1.5	1.5	1.5	1.7	1.7	1.7	2.4	2.4	2.4	3.7	3.7	3.7	5.5	4.1	2.8	1.8					
MM/10DAYS		13	22	24	29	23	15	15	15	17	17	17	24	24	24	37	37	37	55	41	28	18					
MM/MONTH		35			76			45			51			72			111			124			18				

TABLE A.II-29 FIELD IRRIGATION REQUIREMENT (RABI. VEGETABLE)

MONTH	SEP			OCT			NOV			DEC			JAN			FEB			MAR								
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN		L.S						N.I			VEGETABLE (RABI)																
1. ELEMENT																											
% OF GROWING SEASON			8	17	25	33	42	50	58	67	75	83	92	100													
CROP COEFFICIENT (kc)			0.27	0.32	0.43	0.58	0.77	0.97	1.07	1.11	1.08	1.00	0.90	0.78													
				0.27	0.32	0.43	0.58	0.77	0.97	1.07	1.11	1.08	1.00	0.90	0.78												
					0.27	0.32	0.42	0.58	0.77	0.97	1.07	1.11	1.08	1.00	0.90	0.78											
						0.27	0.32	0.43	0.58	0.77	0.97	1.07	1.11	1.08	1.00	0.90	0.78										
							0.27	0.32	0.43	0.58	0.77	0.97	1.07	1.11	1.08	1.00	0.90	0.78									
								0.27	0.32	0.43	0.58	0.77	0.97	1.07	1.11	1.08	1.00	0.90	0.78								
									0.27	0.32	0.43	0.58	0.77	0.97	1.07	1.11	1.08	1.00	0.90	0.78							
Kc AVERAGE			0.27	0.30	0.34	0.40	0.47	0.56	0.63	0.75	0.86	0.94	0.99	0.99	0.99	0.97	0.94	0.89	0.84	0.78							
ETo (MM/DAY)		4.9			3.8			2.4			1.6			1.8			2.5			3.9							
ET (MM/DAY)			1.3	1.1	1.3	1.5	1.1	1.3	1.5	1.2	1.4	1.5	1.8	1.8	1.8	2.4	2.4	2.2	3.3	3.0							
SOIL SATURATION (MM)		50																									
2. EQUATION																											
LAND SOAKING		1/7	1/7	1/7	1/7	1/7	1/7	1/7																			
NORMAL IRRIGATION			1/7	2/7	3/7	4/7	5/7	6/7	7/7	←——			——→	7/7	6/7	5/7	4/7	3/7	2/7	1/7							
3. WATER REQUIREMENT																											
LAND SOAKING (MM/DAY)		8	7	7	7	7	7	7																			
NORMAL IRRIGATION (MM/DAY)			0.2	0.3	0.6	0.9	0.8	1.1	1.5	1.2	1.4	1.5	1.8	1.8	1.5	1.7	1.4	0.9	0.9	0.4							
MM / 10 DAYS		8	9	10	13	16	15	18	15	12	14	15	18	18	15	17	14	9	9	4							
MM / MONTH		17			39			48			41			51			40			13							

TABLE A.II-30 FIELD IRRIGATION REQUIREMENT (MAIZE)

MONTH				JUL			AUG			SEP			OCT			NOV											
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN									N.I																		
									MAIZE (KHARIF)																		
1. ELEMENT																											
% OF GROWING SEASON				10	20	30	40	50	60	70	80	90	100														
CROP COEFFICIENT (kc)				0.45	0.65	0.87	1.06	1.19	1.27	1.29	1.25	1.17	1.08														
					0.45	0.65	0.87	1.06	1.19	1.27	1.29	1.25	1.17	1.08													
						0.45	0.65	0.87	1.06	1.19	1.27	1.29	1.25	1.17	1.08												
							0.45	0.65	0.87	1.06	1.19	1.27	1.29	1.25	1.17	1.08											
								0.45	0.65	0.87	1.06	1.19	1.27	1.29	1.25	1.17	1.08										
Kc AVERAGE				0.45	0.55	0.66	0.76	0.84	1.01	1.14	1.21	1.23	1.21	1.20	1.17	1.13	1.08										
ETo (MM/DAY)					6.6			5.5			4.9			3.8			2.4										
ET (MM/DAY)				3.0	3.6	4.4	4.2	4.6	5.6	5.6	5.9	6.0	4.6	4.6	4.4	2.7	2.6										
SOIL SATURATION (MM)																											
2. EQUATION																											
LAND SOAKING																											
NORMAL IRRIGATION				1/5	2/5	3/5	4/5	5/5	→	→	→	→	5/5	4/5	3/5	2/5	1/5										
3. WATER REQUIREMENT																											
LAND SOAKING (MM/DAY)																											
NORMAL IRRIGATION (MM/DAY)				0.6	1.4	2.6	3.4	4.6	5.6	5.6	5.9	6.0	4.6	3.7	2.6	1.1	0.5										
MM / 10DAYS				6	14	26	34	46	56	56	59	60	46	37	26	11	5										
MM / MONTH					46			136			175			109			16										

TABLE A.II-31 FIELD IRRIGATION REQUIREMENT (TOBACCO)

MONTH				JUL			AUG			SEP			OCT			NOV											
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN									N.I	TOBACCO (KHARIF)																	
1. ELEMENT																											
% OF GROWING SEASON				10	20	30	40	50	60	70	80	90	100														
CROP COEFFICIENT (kc)				0.39	0.43	0.56	0.79	0.98	1.06	1.07	1.01	0.86	0.50														
					0.39	0.43	0.56	0.79	0.98	1.06	1.07	1.01	0.86	0.50													
						0.39	0.43	0.56	0.79	0.98	1.06	1.07	1.01	0.86	0.50												
							0.39	0.43	0.56	0.79	0.98	1.06	1.07	1.01	0.86	0.50											
Kc AVERAGE				0.39	0.41	0.46	0.54	0.69	0.85	0.98	1.03	1.00	0.86	0.79	0.68	0.50											
ETo (MM/DAY)					6.6			5.5			4.9			3.8			2.4										
ET (MM/DAY)				2.6	2.7	3.0	3.0	3.8	4.7	4.8	5.0	4.9	3.3	3.0	2.6	1.2											
SOIL SATURATION (MM)																											
2. EQUATION																											
LAND SOAKING																											
NORMAL IRRIGATION				1/4	2/4	3/4	4/4	←				→	4/4	1/4	2/4	1/4											
3. WATER REQUIREMENT																											
LAND SOAKING (MM/DAY)																											
NORMAL IRRIGATION (MM/DAY)				0.7	1.4	2.3	3.0	3.8	4.7	4.8	5.0	4.9	3.3	3.0	2.6	1.2											
MM/10 DAYS				7	14	23	30	38	47	48	50	49	33	30	26	12											
MM/MONTH					44			115			147			89			12										

TABLE A.II-32 FIELD IRRIGATION REQUIREMENT (KHARIF FODDER)

MONTH	JUN			JUL			AUG			SEP			OCT			NOV											
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN								N.I			FODDER (KHARIF)																
1. ELEMENT																											
% OF GROWING SEASON			10	20	30	40	50	60	70	80	90	100															
CROP COEFFICIENT (Kc)																											
Kc AVERAGE			0.95	←													→	0.95									
ETo (MM/DAY)		8.7			6.6			5.5			4.9			3.8			2.4										
ET (MM/DAY)			8.3	6.3	6.3	6.3	5.2	5.2	5.2	4.7	4.7	4.7	3.6	3.6	3.6	2.3	2.3	2.3									
SOIL SATURATION (MM)																											
2. EQUATION																											
LAND SOAKING																											
NORMAL IRRIGATION			1/7	2/7	3/7	4/7	5/7	6/7	7/7	—	—	7/7	6/7	5/7	4/7	3/7	2/7	1/7									
3. WATER REQUIREMENT																											
LAND SOAKING (MM/DAY)																											
NORMAL IRRIGATION (MM/DAY)			1.2	1.8	2.7	3.6	3.7	4.5	5.2	4.7	4.7	4.7	3.1	2.6	2.1	1.0	0.7	0.3									
MM / 10 DAYS			12	18	27	26	37	45	52	47	47	47	31	26	21	10	7	3									
MM / MONTH		12			71			134			141			78			20										

TABLE A.II-33 FIELD IRRIGATION REQUIREMENT (KHARIF VEGETABLE)

MONTH	FEB			MAR			APR			MAY			JUN			JUL			AUG								
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN		LS								NI	VEGETABLE (KHARIF)																
1. ELEMENT																											
% OF GROWING SEASON			8	15	13	31	38	46	54	62	69	77	85	92	100												
CROP COEFFICIENT (kc)			0.27	0.31	0.40	0.54	0.69	0.89	1.03	1.09	1.10	1.06	0.98	0.89	0.78												
				0.27	0.31	0.40	0.54	0.69	0.89	1.03	1.09	1.10	1.06	0.98	0.89	0.78											
					0.27	0.31	0.40	0.54	0.69	0.89	1.03	1.09	1.10	1.06	0.98	0.89	0.78										
						0.27	0.31	0.40	0.54	0.69	0.89	1.03	1.09	1.10	1.06	0.98	0.89	0.78									
							0.27	0.31	0.40	0.54	0.69	0.89	1.03	1.09	1.10	1.06	0.98	0.89	0.78								
								0.27	0.31	0.40	0.54	0.69	0.89	1.03	1.09	1.10	1.06	0.98	0.89	0.78							
									0.27	0.31	0.40	0.54	0.69	0.89	1.03	1.09	1.10	1.06	0.98	0.89	0.78						
kc AVERAGE			0.27	0.29	0.33	0.38	0.44	0.52	0.59	0.71	0.82	0.91	0.98	1.01	0.99	0.98	0.96	0.93	0.88	0.84	0.78						
ETo (MM/DAY)		2.5			3.9			5.8			7.6			8.7			6.6			5.5							
ET (MM/DAY			0.7	1.1	1.3	1.5	2.6	3.0	3.4	5.4	6.2	6.9	8.5	8.8	8.6	6.5	6.3	6.1	4.8	4.6	4.3						
SOIL SATURATION (MM)		50																									
2. EQUATION																											
LAND SOAKING		1/7	1/7	1/7	1/7	1/7	1/7	1/7																			
NORMAL IRRIGATION			1/7	2/7	2/7	4/7	5/7	6/7	7/7	←			→		7/7	6/7	5/7	4/7	3/7	2/7	1/7						
3. WATER REQUIREMENT																											
LAND SOAKING (MM)		8	7	7	7	7	7	7																			
NORMAL IRRIGATION (MM/DAY)			0.1	0.3	0.6	0.9	1.9	2.6	3.4	5.4	6.2	6.9	8.5	8.8	8.6	6.5	6.3	6.1	4.8	4.6	4.3						
MM / 10DAYS		8	8	10	13	16	26	33	34	54	62	69	85	88	86	65	63	61	48	46	43						
MM / MONTH		16			39			93			185			259			189			137							

TABLE A.II-34 FIELD IRRIGATION REQUIREMENT (SUGARCANE)

MONTH	MAR			APR			MAY			JUN			JUL			AUG		
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN																	N.I	
	SUGARCANE (PERENIAL)																	
1. ELEMENT																		
% OF GROWING SEASON																		
CROP COEFFICIENT (kc)																		
Kc AVERAGE	0.45	0.55	0.65	0.74	0.80	0.85	0.90	0.93	0.96	0.99	1.01	1.03	1.04	1.06	1.07	1.08	1.08	1.07
ETo (MM/DAY)	3.9			5.8			7.6			8.7			6.6			5.5		
ET (MM/DAY)	1.8	2.1	2.5	4.3	4.6	4.9	6.8	7.1	7.3	8.6	8.8	9.0	6.9	7.0	7.1	5.9	5.9	5.9
SOIL SATURATION (MM)																		
2. EQUATION																		
LAND SOAKING																		
NORMAL IRRIGATION	1/1																	
3. WATER REQUIREMENT																		
LAND SOAKING (MM/DAY)																		
NORMAL IRRIGATION (MM/DAY)	1.8	2.1	2.5	4.3	4.6	4.9	6.8	7.1	7.3	8.6	8.8	9.0	6.9	7.0	7.1	5.9	5.9	5.9
MM/10DAYS	18	21	25	43	46	49	68	71	73	86	88	90	69	70	71	59	59	59
MM/MONTH	64			138			212			264			210			177		

MONTH	SEP			OCT			NOV			DEC			JAN			FEB		
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN																		
	SUGARCANE (PERENIAL)																	
1. ELEMENT																		
% OF GROWING SEASON																		
CROP COEFFICIENT (kc)																		
Kc AVERAGE	1.07	1.06	1.06	1.05	1.04	1.02	1.02	1.00	0.97	0.95	0.92	0.88	0.84	0.79	0.73	0.67	0.60	0.53
ETo (MM/DAY)	4.9			3.8			2.4			1.6			1.8			2.5		
ET (MM/DAY)	5.2	5.2	5.2	4.0	4.0	3.9	2.4	2.4	2.3	1.5	1.5	1.4	1.5	1.4	1.3	1.7	1.5	1.3
SOIL SATURATION (MM)																		
2. EQUATION																		
LAND SOAKING																		
NORMAL IRRIGATION																		1/1
3. WATER REQUIREMENT																		
LAND SOAKING (MM/DAY)																		
NORMAL IRRIGATION (MM/DAY)	5.2	5.2	5.2	4.0	4.0	3.9	2.4	2.4	2.3	1.5	1.5	1.4	1.5	1.4	1.3	1.7	1.5	1.3
MM/10DAYS	52	52	52	40	40	39	24	24	23	15	15	14	15	14	13	17	15	13
MM/MONTH	156			119			71			44			42			45		

TABLE A.II-35 FIELD IRRIGATION REQUIREMENT (ORCHARD)

MONTH	MAR			APR			MAY			JUN			JUL			AUG		
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN											ORCHARD (PERENIAL)					N.I		
1. ELEMENT																		
% OF GROWING SEASON																		
CROP COEFFICIENT (Kc)																		
Kc AVERAGE	085 →																	
ETo (MM/DAY)		3.9			5.8			7.6			8.7			6.6			5.5	
ET (MM/DAY)	33	3.3	3.3	49	49	49	65	65	65	74	74	44	5.6	56	56	47	47	47
SOIL SATURATION (MM)																		
2. EQUATION																		
LAND SOAKING																		
NORMAL IRRIGATION	1/1 →																	
3. WATER REQUIREMENT																		
LAND SOAKING (MM/DAY)																		
NORMAL IRRIGATION (MM/DAY)	3.3	3.3	33	4.9	4.9	4.9	6.5	6.5	6.5	7.4	7.4	7.4	5.6	5.6	5.6	4.7	47	47
MM / 10DAYS	3.3	3.3	3.3	49	49	49	65	65	65	74	74	74	56	56	56	47	47	47
MM / MONTH		99			147			195			222			168			141	

MONTH	SEP			OCT			NOV			DEC			JAN			FEB		
10 DAY	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CROPPING PATTERN																		
1. ELEMENT																		
% OF GROWING SEASON																		
CROP COEFFICIENT (Kc)																		
Kc AVERAGE												→ 085	0.9 →					0.9
ETo (MM/DAY)		4.9			3.8			2.4			1.6			1.8			2.5	
ET (MM/DAY)	42	42	42	32	32	32	20	2.0	20	1.4	1.4	1.4	1.6	1.6	1.6	23	23	23
SOIL SATURATION (MM)																		
2. EQUATION																		
LAND SOAKING																		
NORMAL IRRIGATION																		→ 1/1
3. WATER REQUIREMENT																		
LAND SOAKING (MM/DAY)																		
NORMAL IRRIGATION (MM/DAY)	4.2	4.2	4.2	3.2	3.2	3.2	20	20	20	1.4	1.4	1.4	1.6	1.6	1.6	2.3	2.3	2.3
MM / 10DAYS	42	42	42	32	32	32	20	20	20	14	14	14	16	16	16	23	23	23
MM / MONTH		126			96			60			42			48			69	

TABLE A.II-36 UNIT IRRIGATION DIVERSION WATER REQUIREMENT

----IRRIGATION DIVERSION WATFR REQUIREMENT FOR KHANPUR JICA-CDA PROJECT----

CROPPING PATTERN K.MAIZE =0.300 K.TOBACO =0.080 K.FODDER =0.060 K.VEGETBL=0.110 R.WHEAT =0.440

R.FODDER =0.060 R.VEGETBL=0.110 SUGARCANE=0.035 ORCHARD =0.035

CROPPING INTENSITY = 130.0% IRRIGATION EFFICIENCY = 72.0%

(UNIT...MCM/1000HA)

YEAR	(JAN)	(FEB)	(MAR)	(APR)	(MAY)	(JUN)	(JUL)	(AUG)	(SEP)	(OCT)	(NOV)	(DEC)	ANNUAL
1960	0.202	0.665	0.532	0.690	0.669	0.623	0.216	0.217	0.669	0.834	0.634	0.428	6.378
1961	0.320	0.348	0.941	0.457	0.639	0.598	0.263	0.284	0.177	0.618	0.208	0.472	5.324
1962	0.311	0.550	0.528	0.873	0.588	0.559	0.276	0.135	0.643	0.881	0.445	0.217	6.005
1963	0.581	0.571	0.613	0.774	0.422	0.622	0.389	0.052	0.577	0.915	0.270	0.215	6.000
1964	0.101	0.566	0.941	0.744	0.581	0.596	0.189	0.440	0.956	0.938	0.634	0.448	7.132
1965	0.429	0.201	0.482	0.104	0.321	0.598	0.389	0.580	1.001	0.819	0.429	0.405	5.758
1966	0.666	0.312	0.408	0.645	0.542	0.492	0.276	0.310	0.622	0.590	0.523	0.419	5.805
1967	0.360	0.448	0.411	0.714	0.533	0.615	0.222	0.130	0.839	0.758	0.634	0.123	5.788
1968	0.358	0.273	0.524	0.725	0.532	0.620	0.274	0.093	0.997	0.687	0.238	0.171	5.494
1969	0.662	0.370	0.686	0.838	0.466	0.604	0.386	0.257	0.868	0.603	0.136	0.485	6.361
1970	0.498	0.358	0.338	0.913	0.646	0.584	0.283	0.194	0.315	0.661	0.584	0.426	5.800
1971	0.542	0.658	0.730	0.717	0.458	0.389	0.292	0.161	0.645	0.946	0.534	0.486	6.557
1972	0.311	0.233	0.429	0.520	0.603	0.547	0.651	0.823	0.509	0.481	0.327	0.120	5.554
1973	0.366	0.518	0.428	0.868	0.586	0.486	0.145	0.107	0.594	0.750	0.634	0.346	5.829
1974	0.622	0.729	0.849	0.865	0.629	0.472	0.198	0.330	0.910	0.822	0.634	0.264	7.326
1975	0.628	0.284	0.624	0.823	0.445	0.617	0.227	0.194	0.561	0.940	0.634	0.448	6.425
1976	0.252	0.069	0.293	0.550	0.677	0.590	0.246	0.055	0.685	0.529	0.621	0.486	5.053
1977	0.407	0.533	0.956	0.611	0.432	0.491	0.070	0.290	0.978	0.863	0.418	0.366	6.414
1978	0.636	0.594	0.441	0.893	0.657	0.589	0.172	0.026	0.479	0.507	0.024	0.438	5.456
1979	0.234	0.419	0.366	0.890	0.587	0.583	0.351	0.137	0.685	0.697	0.415	0.313	5.677
1980	0.132	0.340	0.339	0.805	0.616	0.523	0.142	0.178	0.610	0.675	0.574	0.368	5.303
MEAN	0.410	0.430	0.565	0.715	0.554	0.562	0.269	0.238	0.682	0.739	0.455	0.354	5.973

TABLE A.II-37 SUMMARY OF KHANPUR RESERVOIR OPERATION STUDY

Case	Water Demand (1)	Inflow (2) (MCM/yr)	Spillage Volume (3) (MCM/yr)	Spillage (3)/(2)	Spillage Frequency (Yrs)	Shortage Volume (4) (MCM/yr)	Shortage (4)/(1)	Shortage Frequency[2/] (Yrs)
1	100% of Projected Demand[3/] = 186.03 MGD = 308.4 MCM/yr	326.9	41.1	0.13	9	47.6	0.16	14
2	95% = 176.7 MGD = 293.0 MCM/yr	326.9	44.8	0.14	9	36.6	0.13	12
3	90% = 167.4 MGD = 277.6 MCM/yr	326.9	49.5	0.15	9	27.3	0.10	9
4	85% = 158.1 MGD = 262.1 MCM/yr	326.9	55.8	0.17	13	19.3	0.07	8
5	80% = 148.8 MGD = 246.7 MCM/yr	326.9	64.4	0.20	13	12.9	0.05	5
6	75% = 139.5 MGD = 231.3 MCM/yr	326.9	75.1	0.23	13	8.5	0.04	4
7	70% = 130.2 MGD = 215.9 MCM/yr	326.9	87.5	0.27	15	5.8	0.03	3
8	65% = 120.9 MGD = 200.5 MCM/yr	326.9	99.8	0.31	17	3.1	0.02	2
9	60% = 111.6 MGD = 185.0 MCM/yr	326.9	113.1	0.35	18	1.2	0.01	1
10	55% = 102.3 MGD = 169.6 MCM/yr	326.9	127.0	0.39	18	-	-	-

Notes: 1/ Computation period: 21 years (1960 - 1980)

2/ Annual shortage less than 5% of demand neglected

3/ Projected demand

Water supply: Islamabad 33.0 + Rawalpindi 69.37 = 102.37 MGD

Industrial : Wah 15.0 + Taxila 13.5 = 28.5 MGD

Irrigation : RBC 22785 + LBC 13685 = 36470 acre = 55.16 MGD

TABLE A.II-38 SUMMARY OF SIMLY RESERVOIR OPERATION STUDY

Case	Water Demand (1)	Inflow (2) (MCM/yr)	Spillage Volume (3) (MCM/yr)	Spillage (3)/(2)	Spillage Frequency (Yrs)	Shortage Volume (4) (MCM/yr)	Shortage (4)/(1)	Shortage Frequency (Yrs)
Before raising of dam (Full water level = 2,295 ft, Full storage = 35.4 MCM)								
1.	24.0/1.25 x 105% = 20.16 MGD 1/	87.1	45.2	0.52	18	-	-	-
2.	24.0 x 105% = 25.2 MGD 2/	87.1	37.8	0.43	16	0.8	0.02	2
3.	110% of Case-1 demand	87.1	42.1	0.48	18	0.2	0.01	1
4.	120% of Case-1 demand	87.1	39.1	0.45	16	0.5	0.01	1
5.	130% of Case-1 demand	87.1	36.6	0.42	16	1.3	0.03	4
6.	140% of Case-1 demand	87.1	34.3	0.39	14	2.3	0.05	4
7.	150% of Case-1 demand	87.1	32.1	0.37	14	3.4	0.07	6
8.	160% of Case-1 demand	87.1	30.1	0.35	14	4.6	0.09	8
After raising of dam (Full water level = 2,315 ft, Full storage = 47.2 MCM)								
1.	24.0/1.25 x 105% = 20.16 MGD 1/	87.1	45.2	0.52	18	-	-	-
2.	24.0 x 105% = 25.2 MGD 2/	87.1	37.1	0.43	16	0.1	0.00	0
3.	110% of Case-1 demand	87.1	41.9	0.48	18	-	-	-
4.	120% of Case-1 demand	87.1	38.6	0.44	16	-	-	-
5.	130% of Case-1 demand	87.1	35.5	0.41	16	0.2	0.01	1
6.	140% of Case-1 demand	87.1	32.6	0.37	13	0.6	0.01	1
7.	150% of Case-1 demand	87.1	30.0	0.34	12	1.3	0.03	3
8.	160% of Case-1 demand	87.1	27.7	0.32	12	2.3	0.04	4
9.	170% of Case-1 demand	87.1	25.5	0.29	10	3.4	0.06	5
10.	180% of Case-1 demand	87.1	24.0	0.28	9	5.2	0.09	6
11.	190% of Case-1 demand	87.1	22.6	0.26	8	7.0	0.11	7
12.	200% of Case-1 demand	87.1	21.6	0.25	8	9.3	0.14	9

Notes:
1/ Projected production of simly filtration plant = 24.0 MGD.
Raw water requirement from reservoir = 24.0 x 105% = 25.2 MGD (Maximum).
Average demand = 25.2/1.25 = 20.16 MGD = 33.5 MCM/yr.
2/ Demand throughout a year = 25.2 MGD (Peak = constant) = 41.8 MCM/yr.
3/ Annual shortage less than 5% of demand neglected.
4/ Computation period: 19 years (1961-1979)

TABLE A.II-39 SUMMARY OF RAWAL RESERVOIR OPERATION STUDY

Case	Water Demand (1)	Inflow (2) (MCM/yr)	Spillage Volume (3) (MCM/yr)	Spillage (3)/(2)	Spillage Frequency (Yrs)	Shortage Volume (4) (MCM/yr)	Shortage (4)/(1)	Shortage Frequency (Yrs)
1984 A.D. with effective live storage of 47.3 MCM								
1.	28.0/1.25 x 105% = 23.52 MGD 1/	92.4	44.2	0.48	21	-	-	-
2.	28.0 x 105% = 29.4 MGD 2/	92.4	34.6	0.37	18	-	-	-
3.	170% of Case-1 demand	92.4	15.3	0.17	12	1.2	0.02	2
4.	180% of Case-1 demand	92.4	14.7	0.16	11	1.4	0.02	2
5.	190% of Case-1 demand	92.4	12.0	0.13	8	2.3	0.03	2
6.	200% of Case-1 demand	92.4	10.4	0.11	7	4.2	0.05	7
7.	210% of Case-1 demand	92.4	8.9	0.10	7	6.3	0.08	7
8.	220% of Case-1 demand	92.4	7.8	0.08	6	8.8	0.10	9
2000 A.D. with effective live storage of 37.3 MCM								
1.	28.0/1.25 x 105% = 23.52 MGD 1/	92.4	44.2	0.48	21	-	-	-
2.	140% of Case-1 demand	92.4	28.8	0.31	17	-	-	-
3.	150% of Case-1 demand	92.4	25.2	0.27	17	0.3	0.01	1
4.	160% of Case-1 demand	92.4	22.0	0.24	13	1.0	0.02	2
5.	170% of Case-1 demand	92.4	18.8	0.20	13	1.6	0.02	3
6.	180% of Case-1 demand	92.4	15.8	0.17	13	2.4	0.03	4
7.	190% of Case-1 demand	92.4	13.5	0.15	10	3.7	0.05	6
8.	200% of Case-1 demand	92.4	11.8	0.13	8	5.7	0.07	7

Notes:
1/ Projected production of Rawal in near future = 28.0 MGD.
Raw water requirement from reservoir = 28.0 x 105% = 29.4 MGD (Maximum).
Average demand = 29.4/1.25 = 23.52 MGD = 39.0 MCM/yr.
2/ Demand throughout a year = 29.4 MGD (Peak = constant) = 48.8 MCM/yr.
3/ Annual shortage less than 5 % of demand neglected.
4/ Computation period: 21 years 1960-1980.

2.6. Availability of Stream Water

Actual measurement of water production from the existing head works, which are receiving water from streams inclusive of spring water, are available from CDA as tabulated in Table A.II-40. Average monthly productions of water by source have also been obtained for selected years of 1977 and 1983. Both data indicate that the production of water is, as a whole, increasing year by year mainly due to the extension of facilities, and that the monthly variation of production is less. The safe yield from stream surface water is, therefore, considered to be the lowest production, for each head work, in the recent five years which corresponds to once in five years level.

2.7. Availability of Groundwater

2.7.1. General Description

Availability of groundwater to be developed in the areas of Islamabad and Rawalpindi is discussed in this section.

Geologic strata in the area are roughly classified into three groups: limestone layers of Eocene age and earlier, Murree Formation of Miocene age consisting of sandstone and mudstone, and alluvium of Quaternary age. In these three groups, strata which embrace practically available amount of groundwater are the limestone layers and gravel layers of the alluvium.

Since groundwater of the limestone layers which lies mainly in the Margalla Hill has been already utilized as spring water, only the gravel layers intercalated between alluvium clay layers are aquifers to be developed.

Groundwater investigations have considerably been executed mainly by WAPDA, of which only WAPDA 1966 report deals with availability of groundwater in view of water balance study.

TABLE A.II-40 AVERAGE PER DAY PRODUCTION OF SURFACE WATER

Name of Source	Capacity	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	Average
Kurang 1/	2.4	(2.5)	(2.5)	(3.1)	(3.6)	(3.2)	(3.3)	(4.0)	(6.3)	(5.9)	(9.5)	(4.4) 1/
Shahdara	1.7	0.3	0.2	0.9	1.0	0.9	1.4	1.5	1.6	1.7	1.6	1.1
Nurpur	0.7	0.3	0.4	0.6	0.4	0.5	0.5	0.8	0.8	0.7	0.7	0.6
Saidpur	0.8	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.8	0.8	0.8	0.6
Old Golf Course	2.2	2.1	2.4	2.0	2.1	2.2	2.1	2.2	2.2	2.2	2.3	2.2
New Golf Course	2.7	2.2	2.0	2.0	2.0	1.9	1.7	2.0	2.5	2.6	2.6	2.2
G-10	2.0	1.7	1.7	1.9	1.8	1.7	2.0	2.2	2.1	1.9	2.0	1.9
Total	12.5	(9.4)	(9.6)	(10.9)	(11.4)	(10.9)	(11.6)	(13.3)	(16.3)	(15.8)	(19.5)	(13.0) 1/

Notes:

1/ Including water production of the Simly Filtration Plant. Kurang Head works have been closed since 1983.

2/ Increases of production mainly due to extension of facilities.

3/ Safe yield from stream surface water is taken as the lowest value in the recent five years.

4/ Unit is given in MGD.

5/ Data source: "Statement Showing Source-wise Average per Day in One Year from 1974 to 1984", by Directorate of Water & Sewerage Maint, CDA.

According to WAPDA, availability of groundwater to be developed in Islamabad is 50 to 160 MLD (11 to 12 MGD). ASEL in 1980, on the contrary, estimated 130 to 170 MLD (29 MGD and 38 MGD) of water availability for Islamabad and Rawalpindi, respectively, however those figures are considered to be mere assumptions and not acceptable.

A standard of availability of groundwater is generally called as "safe yield". The safe yield means such yield which can satisfy the following three conditions.

- Lowering of groundwater level which occurs inevitably by pumping should not induce any serious problems as land subsidence, salifying of water, much decrease of yield of existing wells etc.

- Water should be producted economically.

- Production of water should be sustained perpetually.

In order to estimate safe yield of an area, a large scale water balance simulation of the entire groundwater basin is to be examined and the three points mentioned above should be checked. For this purpose, rainfalls, river discharges, aquifer coefficients and data regarding distribution of aquifers are to be collected together with long-term simultaneous observations of groundwater level and distribution of groundwater yields during the corresponding period of observations. However, such data are not available in the time since monitorings for the existing wells have not been carried out.

Although it is unavoidable that the study is to some extent based on assumptions, water availability is estimated within the limits of water balance regarding source and recharge of groundwater. In most parts of the area, as is also recognized by WAPDA (1967), main source of groundwater is considered to be direct percolation of rain waters. Considering that the annual coefficients of river runoffs within and in the vicinity of the area are of the order of 30%, it can be assumed that 20% of annual rainfall of about 1,000 mm*, which is equivalent to 200 mm/year, is available as the source of groundwater recharge. In this connection through inspection of several hydrographs, WAPDA (1967) has assumed the annual available recharge of groundwater as 150 mm/year estimated from annual fluctuation of groundwater tables.

* Although the average annual rainfall of Rawalpindi during this 30 years is about 1,100 mm/year, 1,000 mm/year was adopted in the study excluding the recent 8 years data, which are considered to be rich years.

2.7.2. Well Field

In the area, groundwater is received from aquifers of gravel and sand layers contained in alluvium. Accordingly the wide area where thick layers of alluvium possibly exist can be hopeful well fields. Distributions of the existing wells and geology are shown in the attached maps. These maps and available data are carefully reviewed and, as shown in Figure A.II-25 as well as in Table A.II-41, seven potential zones of well field are investigated. In these 7 zones, several areas such as National Park Area, Rawalpindi Area and Sectoral Area (existing) may be linked each other to form a groundwater basin.

Distribution of specific capacities of the existing wells is shown in an attached map which may be useful for estimating capacity of aquifer.

2.7.3. Availability of Groundwater in Each Well Field

National Park Area

Specific capacity of existing wells varies from 500 to 1,000 cu.m/day/m (33,500 to 67,000 GPD/ft) and it is considered that the most potential aquifers are distributed in this zone having several to ten times productivity as compared to the other zones. According to WAPDA, alluvium layers are thin in the area east of Gumrah Kas and potential aquifers are unexpected. Major aquifers are distributed spreaded over the area of about 55 sq.km on the southeast of the Rawal Lake and west of Gumrah Kas, where the existing wells are distributed. At present groundwater yield from this zone for water supply purposes are reported at 56 MLD (12.2 MGD), corresponding to 370 mm/yr. This high value of productivity may not be explained only by recharge from rain water, and as is commonly believed, a considerable portion of groundwater seems to be recharged from Rawal Lake and nearby rivers.

WAPDA also mentioned in 1967 report that discharge of Kurang river at Lithrar were observed about 73 MLD (30 cusec or 16 MGD) greater than those at just downstream of the Rawal dam. Since the development of groundwater had not been yet in progress at that time and so the feasible potentiality of groundwater in this zone would be this order, under the assumption that the difference in discharge would be accounted for groundwater runoff from the drainage basin. Accordingly additional potentiality of groundwater development would be more or less 23 MLD (5 MGD), with expectation of increase of recharge resulted by pumping of groundwater. More intensive development should be investigated after collecting necessary data by means of monitoring of wells.

Sectoral Area (Existing)

In the existing development area of about 40 sq.km of the Sectoral Area, specific yield of groundwater has been observed at 160 to 230 mm/yr, almost corresponding to the standard value. Therefore, no more intensive development is desirable in this area unless detailed investigations on the basis of monitoring is accompanied.

Rawalpindi Area

In the Rawalpindi Area of about 55 sq.km involving the commanded area by RMC and small zone situated on the west bank of Lai Nulla, specific yield of groundwater has been found to be about 410 mm/year solely for water supply purpose, and if the other uses are included, the amount equivalent to more than 50% of annual rainfall has been derived from groundwater. In fact, operation time at each well has been shortened due to falls of groundwater level. It means over-production of groundwater and further development in this are is to be prohibited.

West Sectoral Area

About 18 MLD (4 MGD) of groundwater production is expected in this undeveloped area of about 32 sq.km, yielding water from alluvium layers distributed in Sectors E-11 to E-14 and F-11 to F-14 around Golra. According to the data FC-32 and 36 provided in WAPDA 1967 report, specific capacity expected is 30 to 40 cu.m/day/m (2,000 to 2,700 GDP/ft), and only lower productivity, as compared with the existing well field of sectoral area, could be available.

Southwest Sectoral Area

About 16 MLD (3.5 MGD) of groundwater production is expected from about 30 sq.km of almost undeveloped area spreaded around Dadha

Kalan in the Sectors G-16, H-16, H-17, I-13, I-14, and I-16. No good result has been analysed from the data collected from test holes in the northern part of this area by WAPDA (1967), and therefore high productivity can not be expected.

West Rawalpindi Area

Spreading over 70 sq.km of undeveloped area on the west of Rawalpindi, about 38 MLD (8.5 MGD) of production would be expected from groundwater in this area.

Soan River Area

In the area of 40 sq.km expanding adjacent to southwest of National Park Area along Soan river, unconfined aquifers, from which some waters are available, are existing. According to WAPDA (1967), specific capacity has been found at the order of 250 cu.m/day/m (17,000 GPD/ft) and relatively high productivity would be expected. Accordingly, 23 MLD (5 MGD) has been expected to be drawn from this area.

2.7.4. Development Plan of Groundwater

As shown in Table A.II-41, the present production of groundwater for drinking and domestic uses is about 30 MGD and in future additional 26 MGD of groundwater development could be expected. However, by the end of the target year, 2000 A.D., only West Sectoral Area, Southwest Sectoral Area and a part of West Rawalpindi Area would be developed, since waters drawn from tube wells are, from economic point of view, to be distributed nearby areas of wells.

According to the existing Development plan prepared by CDA, phased developments of groundwater of 8 MGD by 1990 in the National Park Area, 5.5 MGD by the end of 1985 and 19 MGD by 1990 in Sectoral

Area have been scheduled. On the contrary for Rawalpindi and CB, 3 MGD of groundwater development has been programmed. However, based on the above investigations, it is concluded that the existing CDA's development plan is over estimation and that the feasible productivity of groundwater in future would be the order of figures which are shown in Table A.II-42.

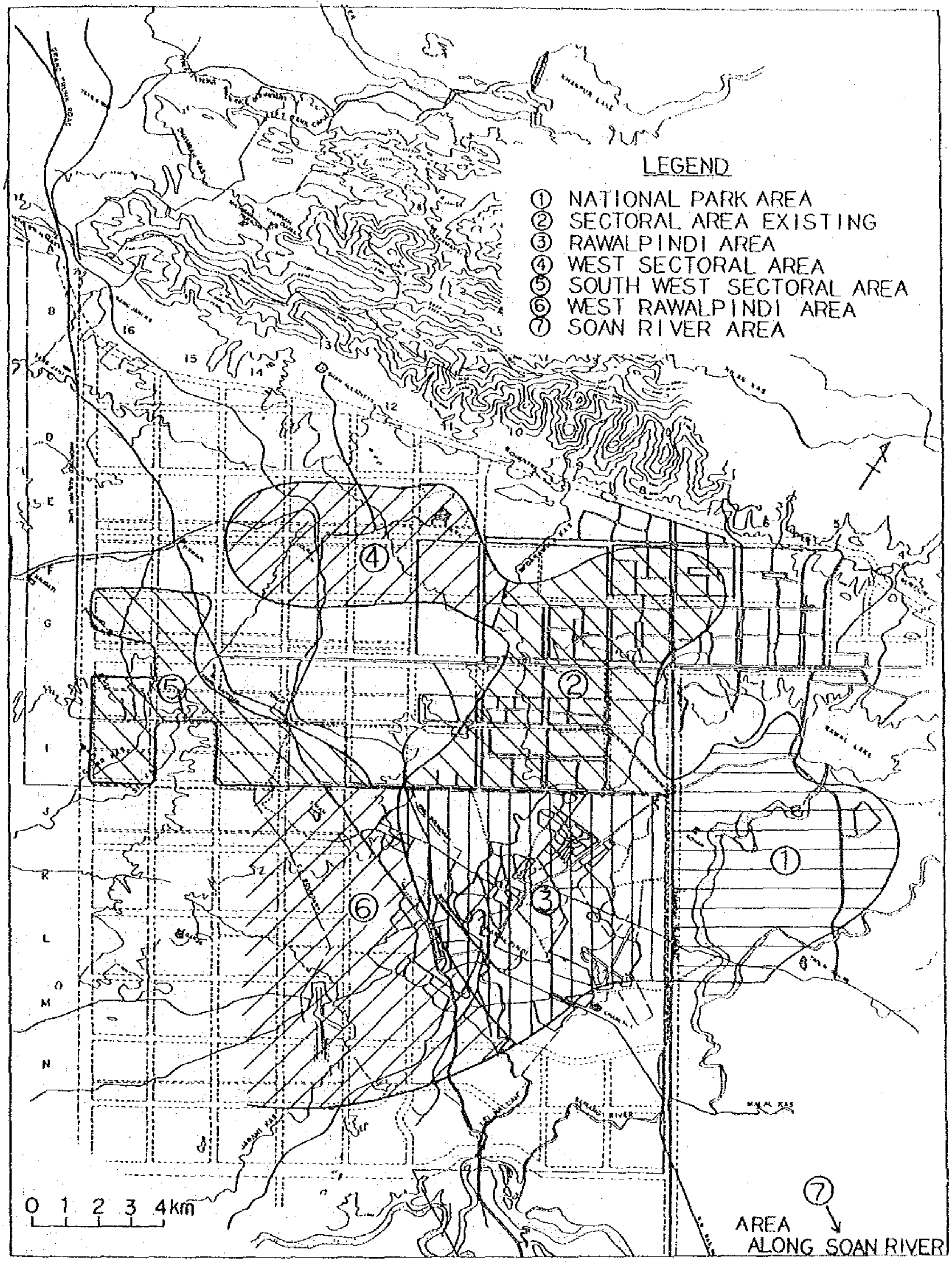


FIGURE A.II-25 WELL FIELDS IN ISLAMABAD/RAWALPINDI AREA

TABLE A.II-41 AVAILABILITY OF GROUNDWATER

Name of Well Field	Area (sq.km)	Present Production [1/] MGD (MLD)	Production Per Area (mm/yr)	Possible Future Production MDG (MLD)	Total MGD (MLD)
National Park Area	55	12.2 (55.5) [2/]	370	5.0 (22.8)	17.2 (78.3)
Sectoral Area (Existing)	40	3.8 (17.3)	160	Not recommendable	3.8 (17.3)
Rawalpindi Area	55	13.7 (62.3) [3/]	410	Not recommendable	13.7 (62.3)
West Sectoral Area	32	-	-	4.0 (18.2)	4.0 (18.2)
Southwest Sectoral Area	30	-	-	3.5 (15.9)	3.5 (15.9)
West Rawalpindi Area	70	-	-	8.5 (38.7)	8.5 (38.7)
Soan River Area	40	-	-	5.0 (22.8)	5.0 (22.8)
Total		29.7 (135.1)		26.0 (118.4)	55.7 (253.5)

Notes:
1/ Public water supply only.
2/ National Park Area and Golf Course Area of CDA, Sohan Village TW of PHED, and TW of PAF Combined.
3/ Excluding Sohan village TW and PAF TW.

TABLE A.II-42 PRODUCTION OF GROUND WATER IN AD 2000

Unit: MGD (MLD)

Area	Present Production	Future Development	Total
Islamabad			
National Park Area	8.0 (36.4)	5.0 (22.8)	13.0 (59.2)
Sectoral Area	3.8 (17.3)	7.5 (34.1)	11.3 (51.4)
Sub-total	11.8 (53.7)	12.5 (56.9)	24.3 (110.6)
Rawalpindi	17.9 (81.4) 1/	3.0 (13.7) 2/	20.9 (95.1)
Total	29.7 (135.1)	15.5 (70.6)	45.2 (205.7)

Notes: 1/ 4.2 MGD from National Park Area.

2/ Developed in CB area.