MINISTRY OF LOCAL GOVERNMENT, HOUSING AND CONSTRUCTION

NATIONAL WATER SUPPLY AND DRAINAGE BOARD

SRI LANKA

CONTINUATION
OF
DESIGN MANUAL D2
ANNEX - A
CONVERSION FACTORS & USEFUL DATA

WATER SUPPLY AND SANITATION SECTOR PROJECT

(USAID SRI LANKA PROJECT 383-0088)

ANNEX - A

CONVERSION FACTORS & USEFUL DATA

CONVERSION FACTORS & USEFUL DATA

Metric to British Units / **British to Metric Units**

Length:

Metric to British:

1m = 39.37 in
1m = 3.2808 ft
1m = 1.0936 yd
1 km = 0.6214 mile

British to Metric:

1 in = 25.40 mm
1 ft = 0.3048 m
1 yd = 0.91440 m
1 mile = 1.60934 km

Note: In nominal sizing 300 mm is taken as equivalent to 1 ft and 25 mm as equivalent to 1 in.

Area:

Metric to British:

1mm^2 = 0.001550 in^2
1 m^2 = 10.764 ft^2
1 m^2 = 1.196 yd^2
1 ha = 2.471 acres
1km^2 = 0.386 square mile

British to Metric:

1 in^2 = 645.16 mm^2
1 ft^2 = 0.0929 m^2
1 yd^2 = 0.8361 m^2
1 acre = 0.4047 ha
1 square mile = 2.5900 km^2

Notes: 1 km^2 = 100 ha (hactares) and 1 ha = 10,000 m^2
1 square mile = 640 acres and 1 acre = 4840 yd^2

Volume:

Metric to British:

1m^3 = 35.314 ft^3
1m^3 = 1.3079 yd^3
1m^3 = 219.97 gallons*
1 litre = 0.21997 gallon
1 Ml = 0.21997 Mg

British to Metric:

1 ft^3 = 0.02832 m^3
1 ft^3 = 28.32 litres
1 yd^3 = 0.76456 m^3
1 gallon = 4.546 litres
1 US gallon = 3.785 litres
1 Mg = 4.546 x 10^3 m^3 = 4.546 Ml

Notes : 1 m^3 = 1000 l (litres) and 1 Ml = 1000 m^3
1 US gallon = 0.83267 gallon; also 1 ft^3 = 6.2288 gallon

Mass:

Metric to British:

1 kg = 2.2046 lb
50 kg = 0.9842 cwt
1 Mg = 19.684 cwt
1 tonne = 0.9842 ton

British to Metric:

1 oz = 28.3495 g
1 lb = 0.45359 kg
1 cwt = 50.802 kg
1 ton = 1.01605 Mg

Pressure:

Metric to British:

1mH_2O = 1.422 lb/in^2
1 kgf/cm^2 = 14.223 lb/in^2
1N/mm^2 = 145.038 lb/in^2

British to Metric:

1 ft H_2O = 0.03048 kgf/cm^2
= 0.002989 N/mm^2
1 lb/in^2 = 0.0703 kgf/cm^2
= 0.006895 N/mm^2

Notes : 1 N/mm^2 = 10.197 kgf/cm^2, 1 kgf/cm^2 = 10 metres head of water, and
1 bar = 10.197 metres head of water
1 lb/in^2 = 2.3067 ft head of water
1 Pa (Pascal) = 1 N/m^2

Density:

1 kg/m^3 = 0.06243 lb/ft^3

1 lb/ft^3 = 16.0185 kg/m^3

Flow Rates:

Metric to British:

1 m^3/s = 35.31 ft^3/s
1 m^3/s = 19.00 mgd
1 litre/s = 13.20 gpm = 0.019 mgd

British to Metric:

1 ft^3/s = 0.0283 m^3/s
1 mgd = 0.05262 m^3/s
1 gpm = 0.0758 litre/s

Notes : mgd = million gallons per day; gpm = gallons per minute
1m^3/s = 86.4 x 10^3 m^3/d = 86.4 Ml/d
1 ft^3/s = 86400ft^3/d = 0.53817 mgd

Hydrological units:

Metric to British:

1 litre/s per km^2 = 0.09146 ft^3/s per 1000 acres
1 mm rainfall per km^2
= 1000 m^3
= 0.220 Mg

British to Metric:

1 ft^3/s per 1000 acres = 6.997 litres/per km^2
1 ft^3/s per square mile
= 10.993 litres/s per km^3
1 in rainfall per square mile - 65786 m^3

* Gallons are Imperial (British) unless shown as US Gallons

Filtration rate:

Note : 100 gallons per ft² per hour = 117.44 m³ per m² per day
= 4.89 m/h
= 1.36 mm/s

Power:

1 joule (J) = 0.73756 ft lb

1 kW = 1.3410 hp

1 horsepower (hp) = 0.74570 kW

Notes: 1J/s = 1 watt (W)
1 Ml/d of water raised through 8.81 m = 1 kW (at 100% efficiency)
1 hp = 550 ft lb/s

Source : Twort, Water Supply (Ref. 25)

Useful Data:

Density of water at	10°C	0.99970 g/cm³
	20°C	0.99821
	30°C	0.99565
	40°C	0.99222

Acceleration due to gravity, g

at 45° latitude, sea level	9.80616 m/s²
for Sri Lanka, at 7° latitude, sea level	9.78121
- do - 500 m elevation	9.77967
- do - 1000 m elevation	9.77812
- do - 1500 m elevation	9.77658
- do - 2000 m elevation	9.77504

ANNEX - B

BRITISH STANDARDS FOR BUILDING AND CIVIL ENGINEERING

B.1 CODES OF PRACTICE

B.2 MATERIALS & WORKMANSHIP STANDARDS

B.3 PIPE STANDARDS

B.4 VALVE STANDARDS

BRITISH STANDARDS FOR BUILDING

AND

CIVIL ENGINEERING

Note: Reference to these may be made at the Sri Lanka Standards Institution Library, Galle Road, Colombo 4.

B.1 Codes of Practice

CP 3: Chapter III: 1972
Sound insulation and noise reduction

CP 3: Chapter V: Part 2: 1972
Wind loads (withdrawn, replaced by BS 6399: Part: 1984)

CP 101: 1972
Foundations and substructures for non-industrial buildings of not more than four storeys

CP 102: 1973
Protection of buildings against water from the ground

CP 110:
The structural use of concrete (withdrawn, replaced by BS 8110: 1985)

CP 110: Part 1: 1972
Design, materials and workmanship - do -

CP 110: Part 2: 1972
Design charts for singly reinforced beams doubly reinforced beams and rectangular columns - do -

CP 110: Part 3: 1972
Design charts for circular columns and prestressed beams - do -

CP 111: 1970
Structural recommendations for loadbearing walls

CP 114: 1969
Structural use of reinforced concrete in buildings - do -

CP 115: 1969
Structural use of prestressed concrete in buildings - do -

CP 116: 1969
The structural use of precast concrete - do -

CP 117: Part 1 1965
Simply-supported beams in building

CP 117: Part 2: 1967
Beams for bridges

CP 121: Part 1: 1973
Brick and block masonry (withdrawn, replaced by BS 5390: 1976)

CP 301: 1971
Building drainage

CP 310: 1965
Water supply (withdrawn, replaced by BS 6700: 1987)

CP 312: 1973
Plastics pipework (3 parts)

CP 326: 1965
The protection of structures against lightning

CP 1013: 1965
Earthing

CP 2004: 1972
Foundations (withdrawn, replaced by BS 8004: 1986)

CP 2005: 1968
Sewerage

CP 2010:
Pipelines

CP 2010: Part 1: 1966
Installation of pipelines in land

CP 2010: Part 2: 1970
Design and construction of steel pipelines in land

CP 2010: Part 3: 1972
Design and construction of iron pipelines in land (withdrawn, replaced by BS 8010: Section 2.1: 1987)

CP 2010: Part 4: 1972
Design and construction of asbestos cement pipelines in land

CP 2010: Part 5: 1974
Design and construction of prestressed concrete pressure pipelines in land

B.2 Standards

Materials and Workmanship Standards

BS 12: 1978
Specification for ordinary and rapid hardening Portland cement

BS 76: 1974
Tars for road purposes

BS 340: 1979
Specification for precast concrete kerbs, channels, edgings and quadrants

BS 368: 1971
Precast concrete flags

BS 449:
The use of structural steel in building

BS 449: Part 2: 1969
Metric units

BS 812:
Methods for sampling and testing of mineral aggregates, sands and filters

BS 812: Part 1: 1974
Sampling size, shape and classification

BS 812: Part 2: 1975
Physical properties

BS 812: Part 3: 1975
Mechanical properties

BS 812: Part 4: 1976
Chemical properties

BS 812: Part 101: 1984
Guide to sampling and testing aggregates

BS 812: Part 102: 1984
Methods for sampling

BS 882: 1983
Specification for aggregates from natural sources for concrete

BS 903: (63 parts)
Methods of testing vulcanized rubber

BS 1194: 1969
Concrete porous pipes for under-drainage

BS 1198: 1199: 1200: 1976
Building sands from natural sources

BS 1243: 1978
Specification for metal ties for cavity wall construction

BS 1247: 1975
Manhole step irons

BS 1305: 1974
Batch type concrete mixers

BS 1881:
Methods of testing concrete

BS 1881: Part 1: 1970
Methods of sampling fresh concrete

BS 1881: Part 3: 1970
Methods of making and curing test specimens

BS 1881: Part 5: 1970
Methods of testing hardened concrete for other than strength

BS 1881: Part 6: 1971
Analysis of hardened concrete

BS 1881: Part 101: 1983
Method of sampling fresh concrete on site

BS 1881: Part 102: 1983
Method of determination of slump

BS 1881: 103: 1983
Method of determination of compacting factor

BS 1881: 104: 1983
Method of determination of Vebe time

BS 1881: 105: 1984
Method of determination of flow

BS 1881: 106: 1983
Method for determination of air content of fresh concrete

BS 1881: 107: 1983
Method of determination of density of compacted fresh concrete

BS 1881: 108: 1983
Method for making test cubes from fresh concrete

BS 1881: 109: 1983
Method for making test beams from fresh concrete

BS 1881: 110: 1983
Methods for making test cylinders from fresh concrete

BS 1881: 111: 1983
Method of normal curing of test specimens (20°C method)

BS 1881: 112: 1983
Methods of accelerated curing of test cubes

BS 1881: 113: 1983
Method for making and curing no-fines test cubes

BS 1881: 114: 1983
Methods for determination of density of hardened concrete

BS 1881: 115: 1983
Specification for compression testing machines for concrete

BS 1881: 116: 1983
Method for determination of compressive strength of concrete cubes

BS 1881: 117: 1983
Method for determination of tensile splitting strength

BS 1881: 118: 1983
Method for determination of flexural strength

BS 1881: 119: 1983
Method for determination of compressive strength using portions of beams broken in flexure (equivalent cube method)

BS 1881: 120: 1983
Method for determination of the compressive strength of concrete cores

BS 1881: 121: 1983
Method for determination of static modulus
of elasticity in compression

BS 1881: 122: 1983
Method for determination of water
absorption

BS 3148: 1980
Methods of test for water for making concrete
(including notes on the suitability of the water)

BS 3680:
Methods of measurement of liquid flow in open channels (31 parts)

BS 4346: Part 3: 1982
Specification for solvent cement

BS 4449: 1978 (1984)
Specification for hot rolled steel bars for the
reinforcement of concrete

BS 4461: 1968 (1984)
Specification for cold worked steel bars
for the reinforcement of concrete

BS 4466: 1981
Specification for bending dimensions and
scheduling of reinforcement for concrete

BS 4482: 1969
Hard drawn mild steel wire for the
reinforcement of concrete

BS 4483: 1969
Steel fabric for the reinforcement of concrete

BS 4486: 1980
Specification for hot rolled
and processed high tensile alloy steel bars
for the prestressing of concrete

BS 5328: 1981
Methods for specifying concrete, including
ready-mixed concrete

BS 5337: 1976
Code of practice for the structural use of
concrete for retaining aqueous liquids

BS 5390: 1976 (1974)
Code of Practice for Stone Masonry

BS 5493: 1977
Code of practice for protective coating of iron and steel structures against corrosion (Formerly CP 2008)

BS 5628: 1978
Code of practice for the use of masonry (3 Parts)

BS 5728: Part 1: 1979 (1987)
Specification for single meters

BS 5834
Surface boxes and guards for underground stopvalves for gas and waterworks purposes

BS 5834: Part 1: 1980
Specification for guards

BS 5834: Part 2: 1983
Specification for small surface boxes

BS 5930: 1981
Code of practice for site investigations (formerly CP 2001)

BS 6031: 1981
Code of practice for earthworks (Formerly CP 2003)

BS 6073:
Precast concrete masonry units

BS 6073: Part 1: 1981
Specification for precast concrete masonry units

BS 6073: Part 2: 1981
Method for specifying precast concrete masonry units

BS 6089: 1981
Guide to the assessment of concrete strength in existing structures

BS 6093: 1981
Code of practice for the design of joints and jointing in building construction

BS 6316: 1983
Code of practice for test pumping water wells

BS 6399: Part 1: 1984
Code of practice for dead and imposed loads (formerly CP 3: Chapter V: Part 2)

BS 6700: 1986
Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages

BS 8110: 1985
Structural use of concrete:
Part 1: Code of practice for design and construction

B.3 Pipes

BS 65: 1981
Specification for vitrified clay pipes, fittings and joints

BS 460: 1981
Cast iron rainwater goods

BS 486: 1981
Specification for asbestos-cement pressure pipes and joints

BS 534: 1981
Specification for steel pipes and specials for water and sewage

BS 1972: 1967
Polythene pipe (Type 32) for cold water services

BS 2871: Part 1
Copper and alloy tubes for water, gas and sanitation

BS 3284: 1967
Polythene pipe (Type 50) for cold water services

BS 3505: 1968
Unplasticized PVC pipe for cold water services

BS 4515: 1984
Specification for process of welding of steel pipelines onland and offshore

BS 4625:
Specification for prestressed concrete pipe

BS 4772: 1980
Specification for ductile iron pipes and fittings

BS 5480:
Specification for glass reinforced plastics (GRP) pipes and fittings for use for water supply and sewerage

BS 5911
Precast concrete pipes and fittings for drainage and sewerage

BS 5911: Part 1: 1981
Specification for concrete cylindrical pipes, bends, junctions and manholes, unreinforced or reinforced with steel cages or hoops

BS 5911: Part 2: 1982
Specification for inspection chambers and gullies

BS 5911: Part 3: 1982
Specification for ogee jointed concrete pipes, bends and junctions, unreinforced or reinforced with steel cages or hoops

BS 5927: 1980
Guide for laying asbestos-cement pipelines

BS 6572: 1985
Specification for blue polyethylene pipe for cold potable water services

BS 8010: Section 2: 1987
Design and installation of ductile iron pipelines

B.4 Valves

BS 5150: 1974
Cast iron wedge and double disk gate valves for general purposes

BS 5151: 1974 (1983)
Cast iron gate (parallel slide) valves for general purposes

BS 5152: 1974 (1983)
Cast iron globe and globe stop and check valves for general purposes

BS 5153: 1974 (1983)
Cast iron check valves for general purposes

BS 5154: 1983
Copper alloy globe, globe stop and check, check and gate valves for general purposes

BS 5155: 1984
Specification for butterfly valves

BS 5156: 1974
Screw down diaphragm valves for general purposes

BS 5157: 1976
Steel gate (parallel side) valves for general purposes

BS 5158: 1974
Cast iron and carbon steel plug valves
for general purposes

BS 5159: 1974
Cast iron and carbon steel ball valves for
general purposes

BS 5160: 1977
Specification for flanged steel globe
valves, globe stop and check valves
for general purposes

BS 5163: 1974
Double flanged cast iron wedge gate valves
for waterworks purposes

ANNEX - C

CALCULATIONS FOR POPULATION,
WATER DEMAND & DISTRIBUTION SYSTEM

Table	C.1	POPULATION DISTRIBUTION SURVEY DATA
	C.2	POPULATION & WATER DEMAND CALCULATION
	C.3	DISTRIBUTION PIPING CALCULATION (For Rural/Semi Urban Water Supplies)
	C.4	DISTRICT ANNUAL POPULATION GROWTH RATES (%) 1991-2011
	C.5	POPULATION OF TOWNS - 1971 and 1981

CALCULATIONS FOR POPULATION, WATER DEMAND & DISTRIBUTION SYSTEM

(Tables C-1 to C-3)

The following procedures should be adopted, for small communities (see Section **8.1.3 for larger** schemes):

1. Prepare a sketch plan showing the general layout of the water distribution area, Location of streets, paths, institutions, bazaar area and other salient features should be shown.

2. Superimpose on the layout plan, a distribution skeleton marking numerically all junctions and ends of lines. Ground elevations at junctions and ends of lines and at intermediate points should be shown on the sketch map. Locate the proposed storage site.

3. Table C-1 - Population distribution survey data:

   Prepare an inventory of the existing number and location of houses, shops, institutions, and other water users. The data should be collected in increments of 150 m length. Institutions and other users should be described in the remarks column in sufficient detail to establish their water demands. House connection and standpost locations should be ascertained and shown in this survey.

4. Table C-2 - Population and water demand calculation:

   Use the population data in Table C-1 and calculate the water demands for different categories of users. The population increase computed in this Table will be used in the following step.

5. Table C-3 - Distribution piping calculation:

   Tabulate the population (P) for each section of distribution line in 300 m lengths (L) by multiplying the number of houses by 6 persons per house (or other value as appropriate).

6. Distribution of the expected population increase (calculated in - Table C-2) is made in the following manner:

   a. Calculate the L^2/P factor for each length, L.

   b. Add up the L^2/P factors to obtain $\sum L^2/P$.

   c. Multiply the expected population increase by $\frac{L^2/P}{\sum L^2/P}$ to obtain the population increase for each length L.

   Care must be used in applying the L^2/P factor in small rural schemes where it is unlikely that the population will increase adjacent to cemeteries, temples, churches, paddy fields, institutional lands, steep embankments and other difficult or unsuitable sites. Population increases should be only applied to areas where there is the likelihood of growth.

7. The average water demand columns are prepared by:

   a. Multiplying the average domestic per capita consumption from Table C-2 by the design population to obtain the domestic demand.

   b. For hotels, shops, institutions and other demands, the present water demand is used unless there is an expected increase.

8. Peak demand is calculated by multiplying the average domestic, hotels, and shop demands by peaking factor. Peaking factors are not applied to institutions and other users which have storage tanks.

9. Cumulative peak flow is computed based on the peak draw off at the end of each length. A tentative pipe size is selected based on pipe velocity of 0.6 - 0.9 m/s and the headloss factor read from the Hazen-Williams chart. The headloss for the length is then calculated.

10. In the case of a scheme with a ground reservoir, the proposed lowest water level is first established, and starting from the reservoir, the distribution system is sized for the section and at other critical points in the section to establish acceptable operating heads.

11. This trial and error approach will require adjustment in the pipe sizes to arrive at the final distribution system. Where the residual pressure is too high, a break pressure tank or other pressure reducing device would be required.

12. In the case of flat areas where an elevated water tower is used, the sizing of the pipes would start from the farthest end of the distribution and work towards the tank. To minimize height of the water tower, pipe sizes are chosen such that the friction losses are reduced.

TABLE- C-1

POPULATION DISTRIBUTION SURVEY DATA

SCHEME ....

....

Prepared by: .... Date: ....

Checked by : .... Date: ....

Name of Road	Distance	Section (as per map)	Houses		Commercial				Public Institutions		Other*		Culvert Locations	Remarks
					Hotels		Shops							
			L.	R.	L.	R.	L.	R.	L.	R.	L.	R.		

* Other water users (e.g. Factories, Tourist Hotels, Textile Mills, etc.)

TABLE - C.2

POPULATION & WATER DEMAND CALCULATION

I. POPULATION

1. Population in 19 . = ...
2. Assumed population increase = ... %
3. Designed population in 19 . = ... Population increase = ...

II. WATER DEMAND

A. Domestic

1. Population supplied by standpost = % @ .... l/d/capita
2. Population supplied by house connection = % @ .... l/d/cap
3. Average domestic consumption = (%) (l/d/cap)+ (%) (l/d/cap) = ...l/d/cap
4. Domestic water demand = ... persons x ...... l/d/cap = ... l/d

Total Domestic Demand = ... m^3/d

B. Commercial

No.	Type of Establishment	Consumptive Rate	Demand

Total Commercial = ... m^3/d

C. Institutional

Type of Establishment	No. of Users	Consumptive Rate	Demand

Total Institutional = ... m^3/d

D. Other

Type of Demand	Demand

Total other = ... m^3/d

E. Summary of Total Daily Demand

a. Domestic = ... m^3/d

b. Commercial = ...

c. Institutional = ...

d. Other = ...

Total Daily Demand = ________ m^3/d

Prepared by : .... Date :..............

Checked by : .... Date :...............

TABLE - C.3

DISTRIBUTION PIPING CALCULATION (For Rural/Semi Urban Water Supplies)

SCHEME : ______________________________

Prepared by: .... Date: ....

Checked by: .... Date: ....

Section	Length L (m)	POPULATION				AVERAGE WATER DEMAND (m^3/d)									PEAK DEMAND (m^3/hr)		Cumulative Flow (m^3/h)	Pipe Type & Dia (mm)	Headloss		Location Point	Ground Level (m)	Total Head (m)	Residual head (m)	Remarks
		Exist. Yr.....	L³/P	Increase	Design Total	(1) Domestic	(2) Hotels	(3) Shops	(4) TOTAL Cols. (1)+(2)+(3)		(5) Insti-tutions	(6) Other	(7) TOTAL Cols. (5)+(6)		(8) Col.(4)x Peak Factor	Total Col.(7) + Col(8)			Headloss $h_f/1000$	Headloss (m)					
									(m^3/d)	(m^3/h)			(m^3/d)	(m^3/h)											
Totals																									

TABLE C.4

DISTRICT ANNUAL POPULATION GROWTH RATES (%) 1991 - 2011

District/Province	1991-2001	2001-2011
Colombo	1.41	1.35
Gampaha	1.41	1.36
Kalutara	1.29	1.22
W. Province	1.38	1.32
Kandy	0.92	1.01
Matale	1.45	1.41
Nuwara Eliya	0.91	1.04
C. Province	1.02	1.09
Galle	0.92	0.94
Matara	0.78	0.84
Hambantota	1.92	1.66
S. Province	1.13	1.11
Jaffna	1.20	1.04
Mannar	2.17	2.37
Vavuniya	3.07	2.47
Mullaitivu	3.51	3.40
N. Province	1.71	1.61
Batticaloa	2.14	1.75
Ampara	2.00	1.75
Trincomalee	1.83	1.75
E. Province	2.00	1.75
Kurunegala	1.54	1.30
Puttalam	2.35	1.99
N.W. Province	1.80	1.53
Anuradhapura	2.10	1.83
Polonnaruwa	2.71	2.00
N.C. Province	2.30	1.89
Badulla	0.82	0.85
Moneragala	2.13	1.71
Uva Province	1.29	1.19
Ratnapura	1.25	1.21
Kegalle	0.76	0.79
Sabaragamuwa Province	1.03	1.03
Sri Lanka	1.46	1.37

Source: All Island Population Projections, Medium Variant, Department of Census and Statistics, Colombo.

TABLE C-5 POPULATION OF TOWNS 1971 AND 1981

Town and type of area		1971	1981	Growth Rate (%/annum)
Municipal Councils				
Colombo		562,420	587,647	0.44
Dehiwala-Mt. Lavinia		154,194	173,529	1.19
Negombo		56,795	60,762	0.69
Kandy		93,303	97,872	0.48
Matale		30,095	29,752	-0.11
Nuwara Eliya		17,283	20,471	1.70
Galle		71,266	76,863	0.76
Jaffna		107,184	118,224	0.99
Batticaloa		36,696	42,963	1.59
Kurunegala		24,357	26,198	0.73
Badulla		35,470	33,068	-0.70
Ratnapura		30,614	37,497	2.05
	Total	1,219,692	1,304,845	0.68
Urban Councils				
Avissawella		15,590	14,147	-0.97
Kotte		93,680	101,039	0.76
Moratuwa		96,267	134,826	3.43
Kolonnawa		37,429	41,095	0.92
Horana		7,576	8,812	1.52
Beruwala		19,768	26,320	2.90
Panadura		27,720	31,090	1.15
Kalutara		28,634	31,503	0.96
Gampola		21,270	21,224	-0.02
Kadugannawa		1,536	1,493	-0.28
Nawalapitiya		13,547	12,440	-0.85
Wattegama		3,761	6,472	5.58
Talawakele-Lindulla		8,522	5,083	-5.04
Hatton-Dickoya		9,122	9,850	0.78
Ambalangoda		14,298	15,454	0.79
Matara		36,554	38,843	0.61
Weligama		16,324	17,722	0.83
Tangalle		8,748	9,594	0.93
Hambantota		6,895	8,577	2.21
Chavakachcheri		17,799	19,707	1.02
Point-Pedro		13,703	15,023	0.92
Valvettiturai		12,191	14,121	1.48
Vavuniya		15,720	18,512	1.65
Ampara		-	16,213	
Trincomalee		40,592	44,3[illegible]	0.88
Kuliyapitiya		5,374	5,79[illegible]	0.76
Puttalam		18,157	21,5[illegible]	1.74
Chilaw		17,508	20,8[illegible]	1.69
Anuradhapura		34,[illegible]34	[illegible]	3.35
Bandarawela		4,410	4,914	1.09
Haputale		3,454	2,437	-3.43
Balangoda		9,269	10,065	0.83
Kegalle		13,305	15,0[illegible]	1.22
Ja-ela		21,717	24,485	1.21
	Sub Total	695,290	804,498	

Town and type of area		[illegible]	[illegible]	Growth Rate (%/annum)
	c/f	695,280	594,498	
Wattala-Mabole		18,32?	19,85?	1.02
Peliyagoda		24,40?	23,45?	0.40
Gampaha		9,964	10,656	0.67
Minuwangoda		-	5,400	
Seeduwa-Katunayake		23,411	31,491	3.01
	Total	771,095	898,488	1.54
Town Councils				
Batteramulle		44,212	56,535	2.49
Kolonnawa		23,018	25,071	0.86
Kotikawatta		43,795	48,252	0.98
Homagama		20,751	25,911	2.25
Piliyandala		5,754	6,547	1.30
Maharagama		41,756	49,765	1.77
Wadduwa		13,426	15,507	1.45
Katugama		10,201	11,971	1.61
Kesbewa		28,955	33,979	1.59
Alutgama		5,430	6,513	1.84
Dharga Town		8,707	9,968	1.36
Agalawatte		2,475	2,509	0.13
Pussellawa		2,474	2,913	1.65
Teldeniya		2,305	2,695	1.58
Galewela		2,124	2,396	1.21
Dambulla		3,147	3,755	1.78
Rattota		2,187	2,205	0.08
Pundaloya		1,817	1,874	0.31
Akangama		8,537	8,419	-0.14
Dodanduwa		5,355	5,605	0.46
Elpitiya		10,939	11,535	1.49
Bentota		10,210	11,572	1.35
Balapitiya		15,010	15,189	0.11
Hikkaduwa		3,240	4,252	2.75
Watugedera		16,999	17,292	0.17
Devinuwara (Dondra)		7,353	7,724	0.49
Akuressa		5,878	5,962	1.55
Beliatta		3,208	3,459	0.75
Walasmulla		1,898	2,313	2.01
Ambalantota		8,192	11,083	3.07
Tissamaharama		4,343	6,404	3.96
Kilinochchi		7,704	15,336	7.13
Neeliyaddi		12,524	13,925	1.07
Kankasanturai		11,590	14,543	2.30
Chunakam		14,192	16,118	1.28
Chankanai		6,269	7,435	1.72
Pandatharippu		8,745	10,429	1.79
[illegible]		6,573	[illegible]	1.55
[illegible]		11,5[illegible]	[illegible]	[illegible]
Kayts		3,73?	[illegible]	0.[illegible]5
[illegible]		11,0[illegible]	[illegible]	[illegible]
[illegible]ttankudy		15,8[illegible]	17,51[illegible]	1.09
[illegible]avur		16,9[illegible]9	19,93?	[illegible]
[illegible]vanturai		12,7[illegible]0	14,29?	1.08
[illegible]lmunai		19,190	22,829	1.75
[illegible]tur		11,682	15,722	3.02
	Sub Total	593,368	626,83?	

Town and type of area		1971	1981	Growth Rate (%/annum)
	c/f	533,353	826,827	
Kantalai		4,585	7,295	4.75
Kinniya		15,380	15,402	0.01
Polgahawela		5,973	6,200	0.52
Alawwa		2,229	3,042	3.09
Narammala		1,904	2,153	1.26
Madampe		5,284	5,525	0.45
Wennappuwa		2,250	2,436	0.80
Dankotuwa		2,750	3,154	1.34
Nattandiya		2,479	2,773	1.16
Kalpitiya		3,884	5,444	3.43
Kekirawa		4,099	5,411	2.84
Polonnaruwa		9,694	11,036	1.85
Hingurakgoda		6,603	8,859	2.98
Hali-ela		2,615	2,692	0.29
Passara		3,081	3,218	0.44
Lunugala		3,955	2,791	-3.45
Welimada		2,372	2,471	0.41
Moneragala		5,132	6,920	1.61
Kahawatte		2,865	3,716	2.63
Pelmadulla		5,489	6,149	1.14
Rakwana		1,696	1,786	0.52
Rambukkana		4,809	5,958	2.18
Yatiyantota		1,970	2,208	1.15
Warakapola		3,873	4,920	2.42
Ruwanwella		4,453	4,839	0.83
Mawanella		11,009	12,935	1.55
Dehiowita		6,660	6,975	0.46
Hendala		29,660	35,927	2.22
Veyangoda		3,823	3,903	0.21
Kochchikade		9,642	9,642	1.19
Dalugama		42,564	47,722	1.15
Kelaniya		32,657	35,738	1.18
Kandana		18,930	21,552	1.33
Ragama		17,421	22,238	2.47
Welisara		20,800	26,770	2.56
Mirigama		2,597	3,522	3.09
Kallativu		4,908	7,192	3.89
Wawathagama		2,417	-	
Bandaragama		6,575	-	
Minuwangoda		5,841	-	
	Total	857,339	989,177	1.44

ANNEX - D

AVERAGE BILLING RATE

AVERAGE BILLING RATE

The average billing rate (ABR) for domestic consumption in a water scheme is a useful statistic for projecting the future revenues from water schemes, and in assessing peoples' ability to pay for water.

It is defined as:

$$\text{ABR (Rs/m}^3\text{)} = \frac{\text{Total domestic billing (Rs)}}{\text{Total domestic consumption (m}^3\text{)}}$$

over a specified time period, usually 1 month.

Whereas the ABR for non-domestic consumption will remain constant due to the fixed tariff (Rs.0.8 for standpost, Rs.5.5 for government/commercial, Rs.9 for industrial, etc.), the ABR for domestic consumption varies due to the variable tariff which depends on the amount of monthly consumption (See Table D.1 and Figure D.1).

Because of this stepped domestic tariff, it is not correct to project future revenues from the basis of average design consumption, which has been the NWSDB practice in the past. This method would only be correct if all households consumed exactly the average amount, leading to an infinitely narrow consumption pattern (see A, Fig.D.2). These 'theoretical' average billing rates can be calculated depending on the number of persons per house and per capita consumption, and examples are shown in Table D.2.

e.g. A household of 5 persons at 160 lpcd would use 24.33 m^3/month.

Therefore, theoretical average is = Rs.23.00
and theoretical average billing rate is 23.00/24.33 = 0.95 Rs/m^3

In actual practice, consumption patterns differ scheme by scheme and in most cases are fairly broad, with a proportion of households in each consumption range, i.e. 0-10 m^3, 11-20 m^3, 21-30 m^3, etc. The wider the distribution (spread), the higher will be the average billing rate. This is due to the effect of the skew tariff. (see Figure D.3).

The effect of this consumption distribution on ABR is shown in Figure D.2. The lower range of values corresponds to the theoretical narrow distributions, whereas the higher range shows the effect of wide consumption distributions.

For a realistic projection of domestic revenues it is recommended that a middle range value of ABR be assumed.

e.g. In the example above:

Average consumption	=	24.33
Assumed realistic ABR from graph	=	1.3 Rs/m^3
Increase over theoretical ABR	=	1.3/0.95 = 1.37 times.

<u>Conclusion:</u> The realised projected domestic revenue would in this case be 37% more than theoretical revenue by this method.

Table D.1

NWSDB TARIFF (June 1988)

CUSTOMER CATEGORY	DESCRIPTION	TARIFF Rs./m^3
10	Domestic, house connections	
	1 - 10 m^3/month	Free
	11 - 20 m^3/month	1.00
	21 - 30 m^2/month	3.00
	> 30 m^3/month	5.50
51	Standposts	0.80
60	Government	5.50
70	Commercial	5.50
71	Tourist Hotels (reduced from 15.00 as of March 1988)	9.00
72	Shipping	15.00
73	Industries	9.00
80	Private Schools	Domestic Rate
	Govt. Schools	Domestic Rate with 100% rebate.
81	Religious and Govt. approved Charity	Domestic Rate with 90% rebate.

Table D.2

THEORETICAL AVERAGE BILLING RATES

Persons/ house	Per Capita Cosumption (L/day)	120.00	140.00	160.00	180.00	185.00
5	Av. Consumption(m^3/mo)	18.25	21.29	24.33	27.38	28.14
	Theoretical Av. Bill (Rs.)	8.25	13.88	23.00	32.13	34.42
	Av. Billing Rate(Rs/m^3)	0.45	0.65	0.95	1.17	1.22
5.5	Av. Consumption(m^3/mo)	20.08	23.42	26.77	30.11	30.95
	Theoretical Av. Bill (Rs.)	10.22	20.26	30.30	40.62	45.23
	Av. Billing Rate(Rs/m^3)	0.51	0.87	1.13	1.35	1.46
6	Av. Consumption(m^3/mo)	21.90	25.55	29.20	32.85	33.77
	Theoretical Av. Bill (Rs.)	15.70	26.65	37.60	55.68	60.74
	Av. Billing Rate(Rs/mo)	0.72	1.04	1.29	1.69	1.80

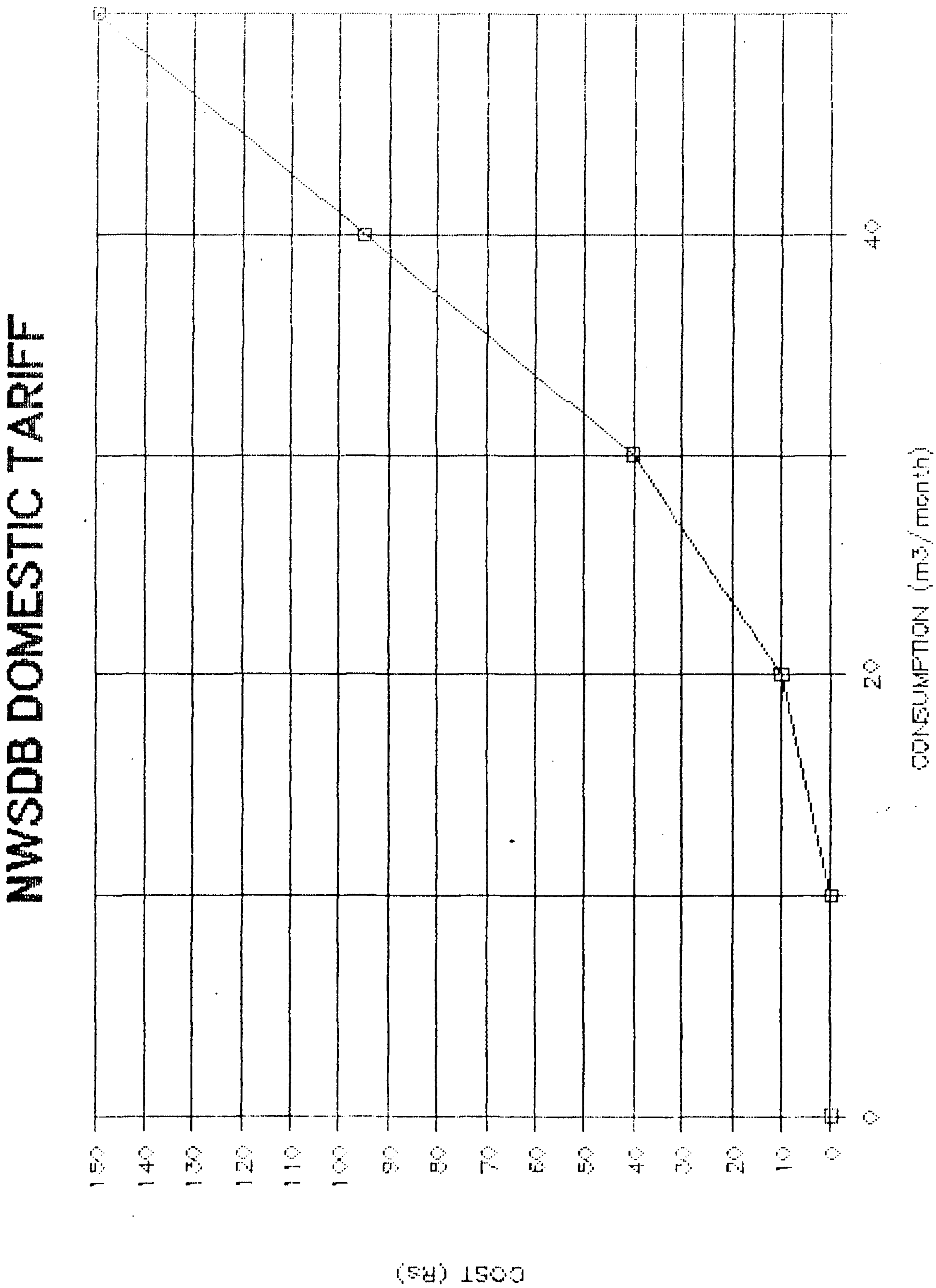
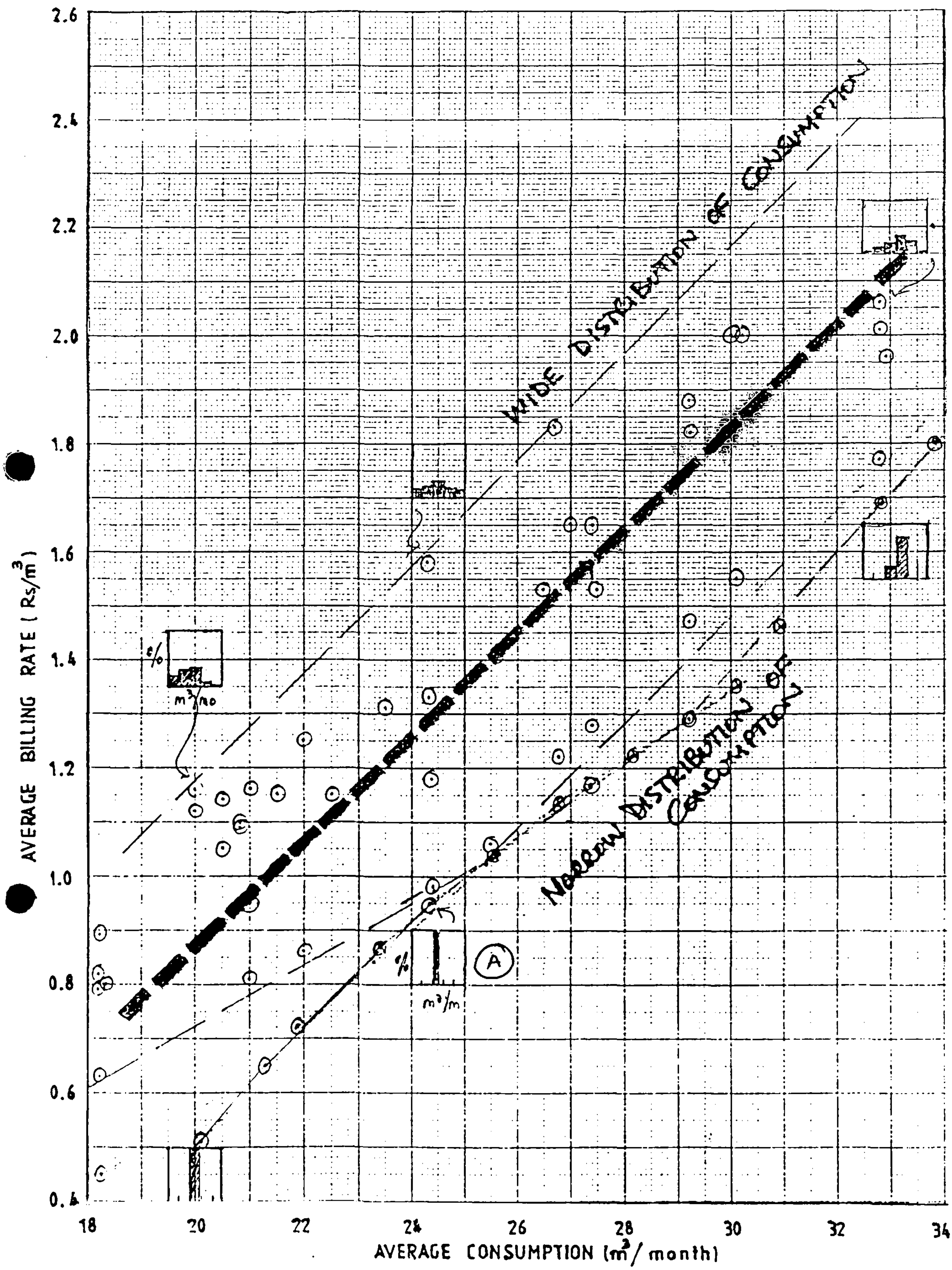
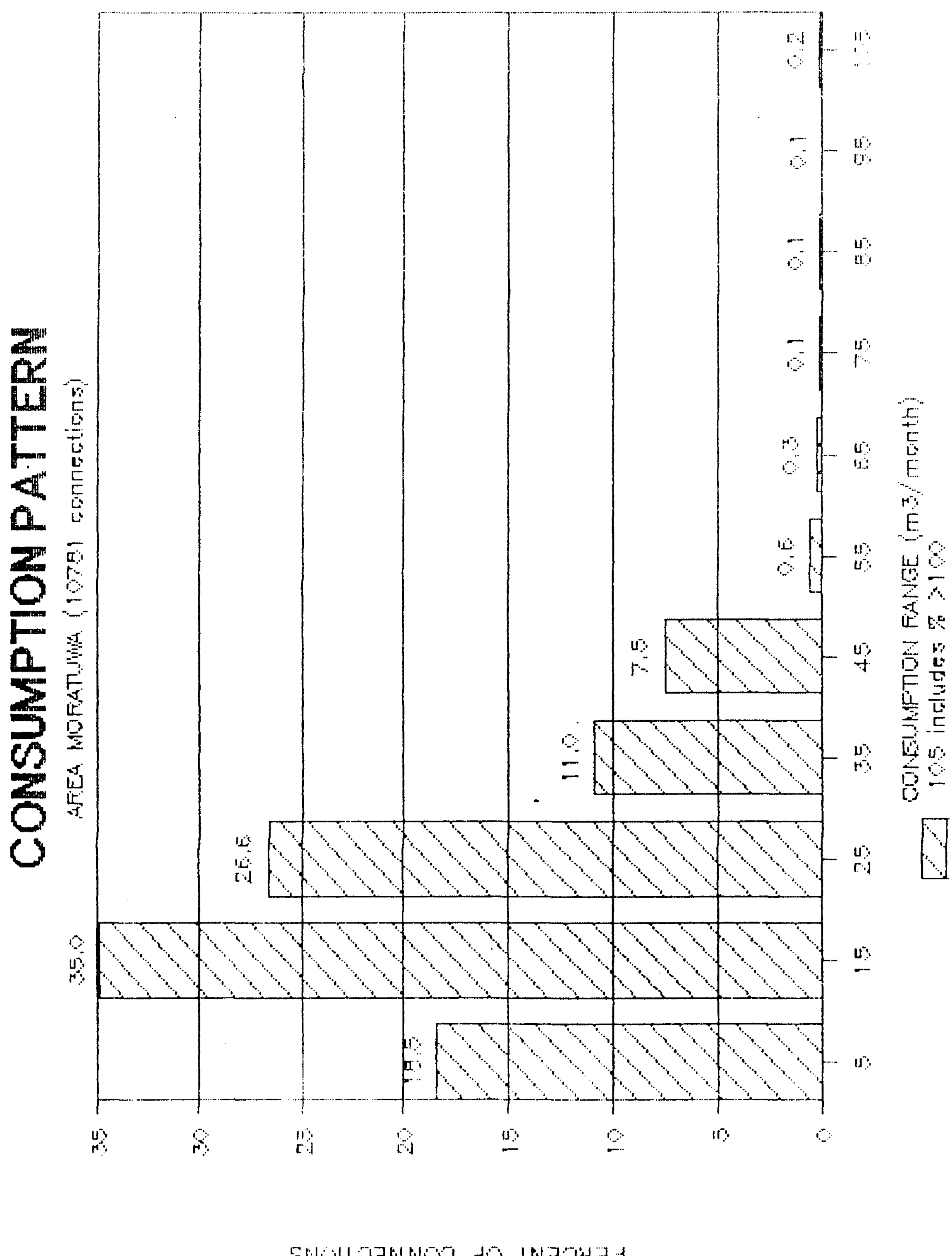

NWSDB DOMESTIC TARIFF
COST (Rs)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
0
20
40
CONSUMPTION (m3/month)

FIGURE - D.1



SUGGESTED GUIDE LINES FOR SELECTION OF AVERAGE BILLING RATE

FIGURE D.2



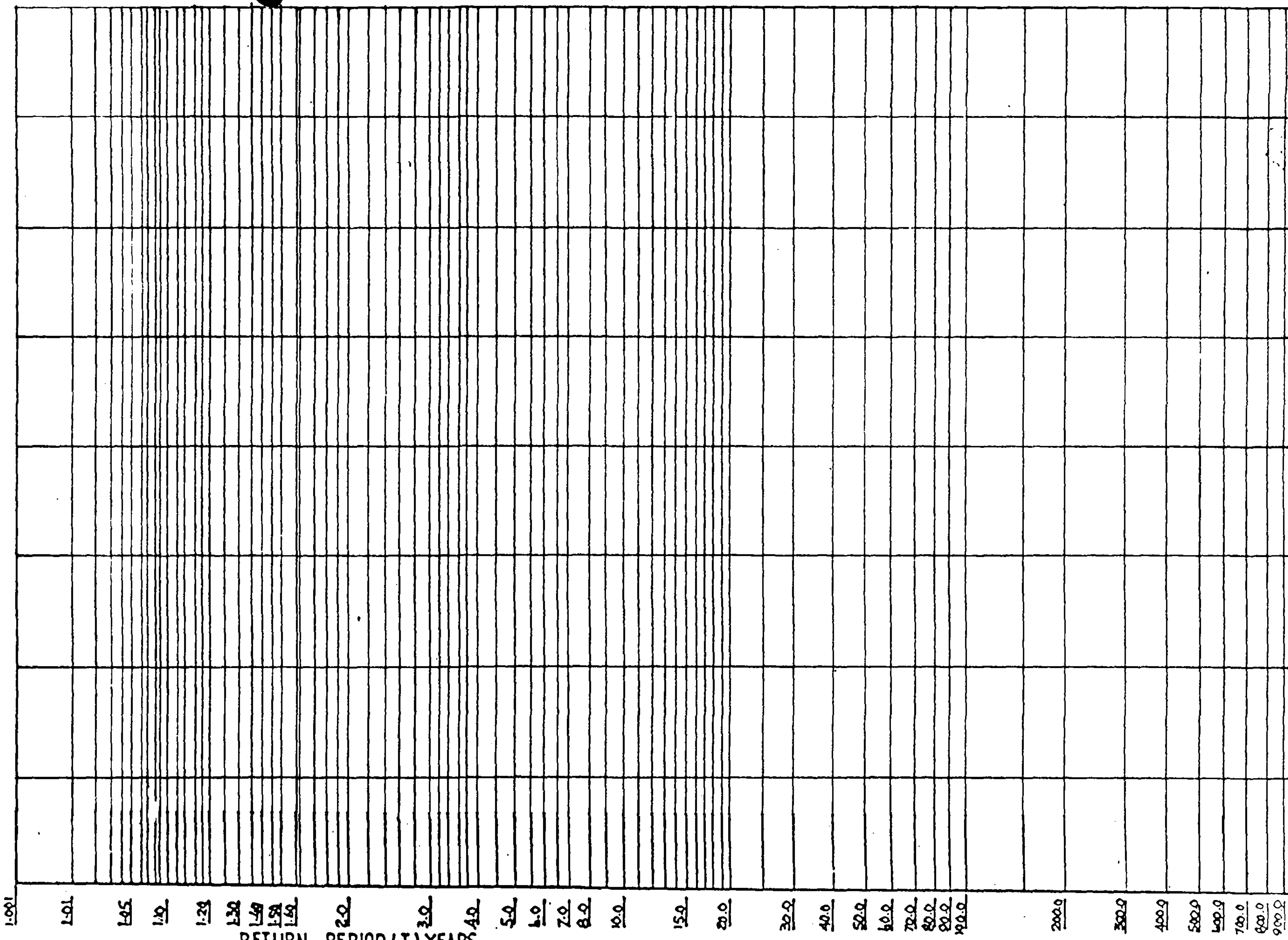
CONSUMPTION PATTERN
AREA MORATUWA (10781 connections)
35.0
26.6
11.9
7.5
0.6
0.3
0.1
0.1
0.1
0.2
5
15
25
35
45
55
65
75
85
95
105
0
5
10
15
20
25
30
35
CONSUMPTION RANGE (m3/month)
105 includes % >100
PERCENT OF CONNECTIONS

FIGURE - D.3

ANNEX - E

SAMPLE OF GUMBEL PROBABILITY PAPER

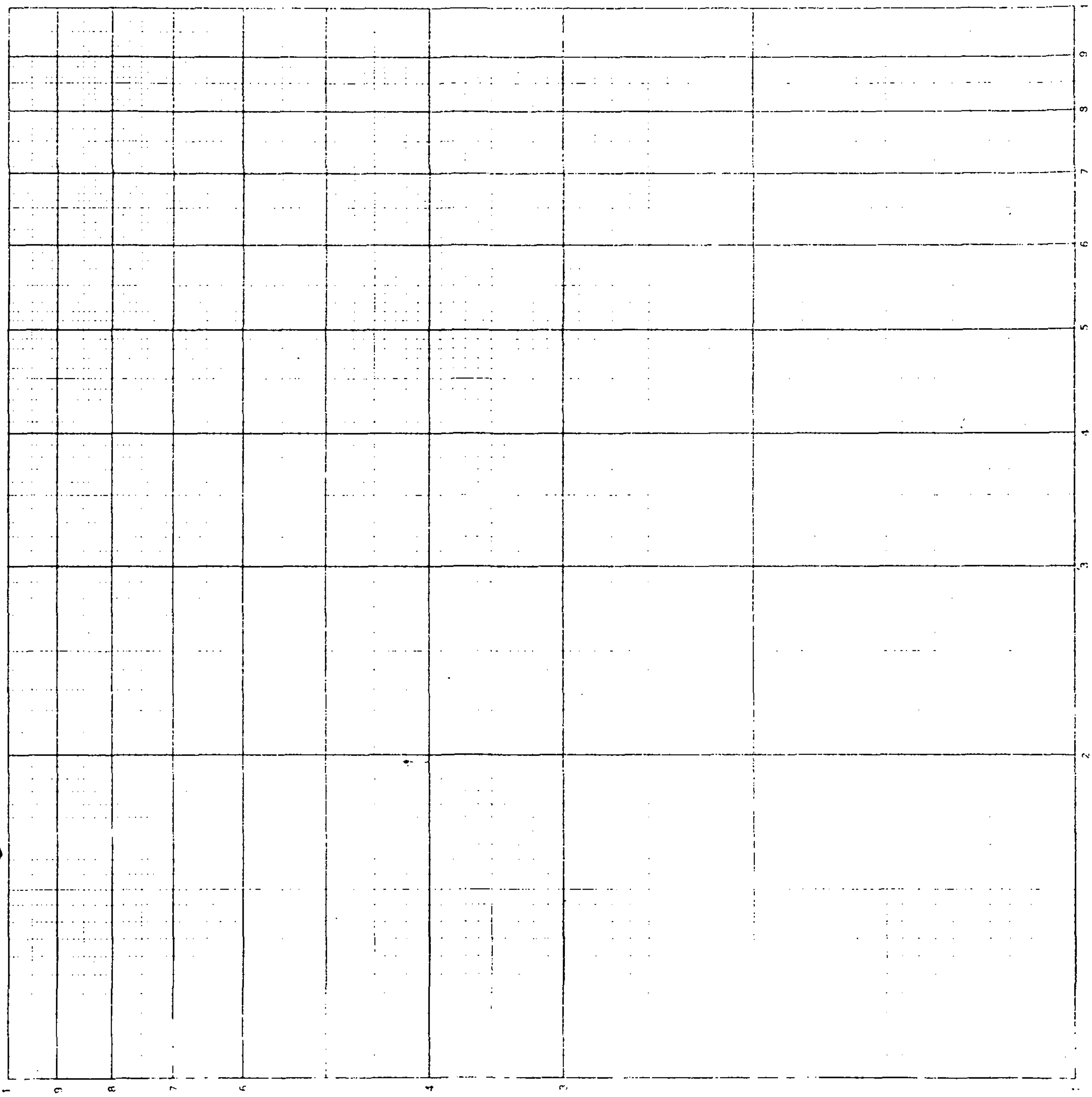
& OTHER LOG PAPERS

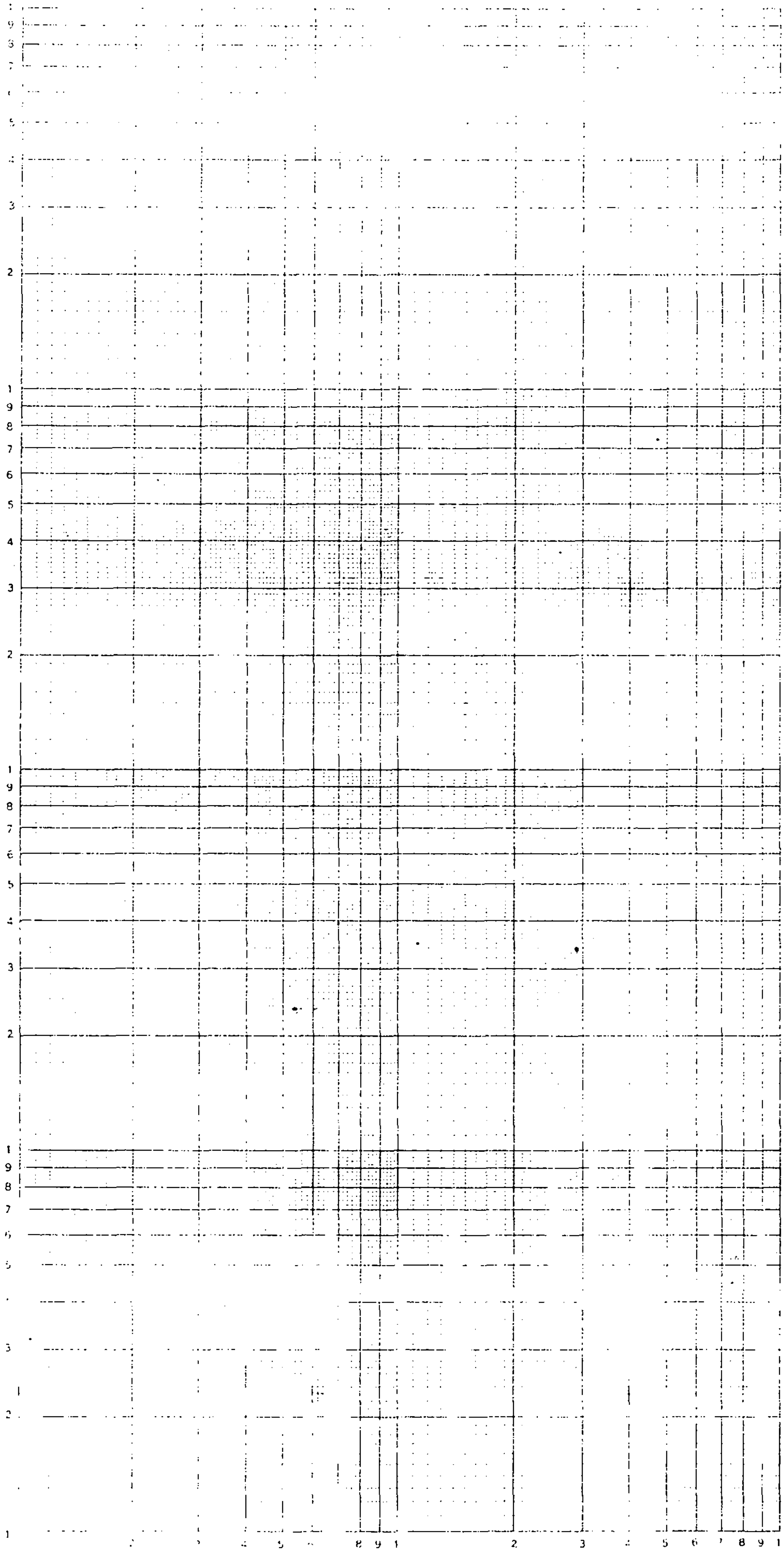


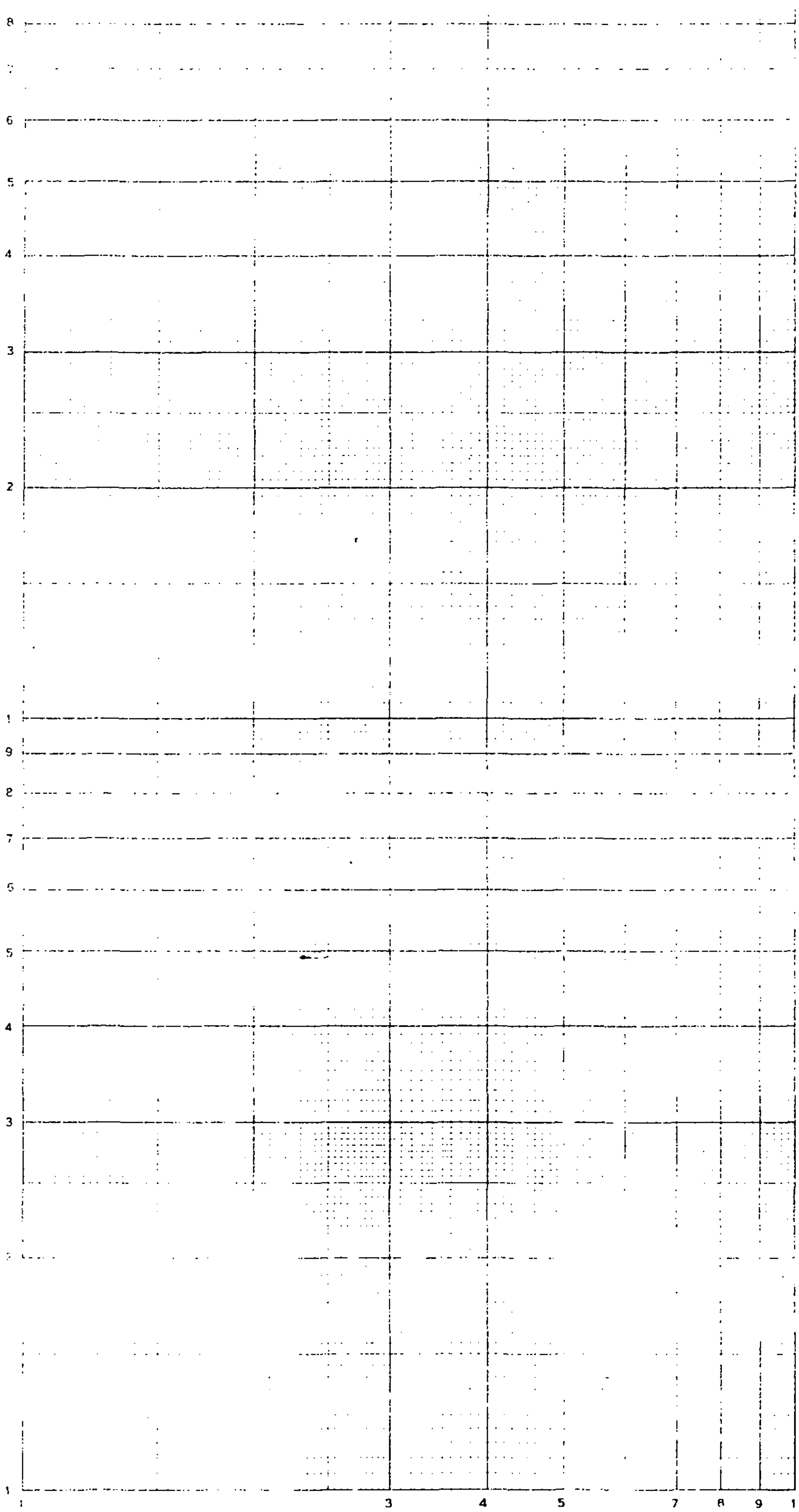
SAMPLE OF GUMBEL PROBABILITY PAPER

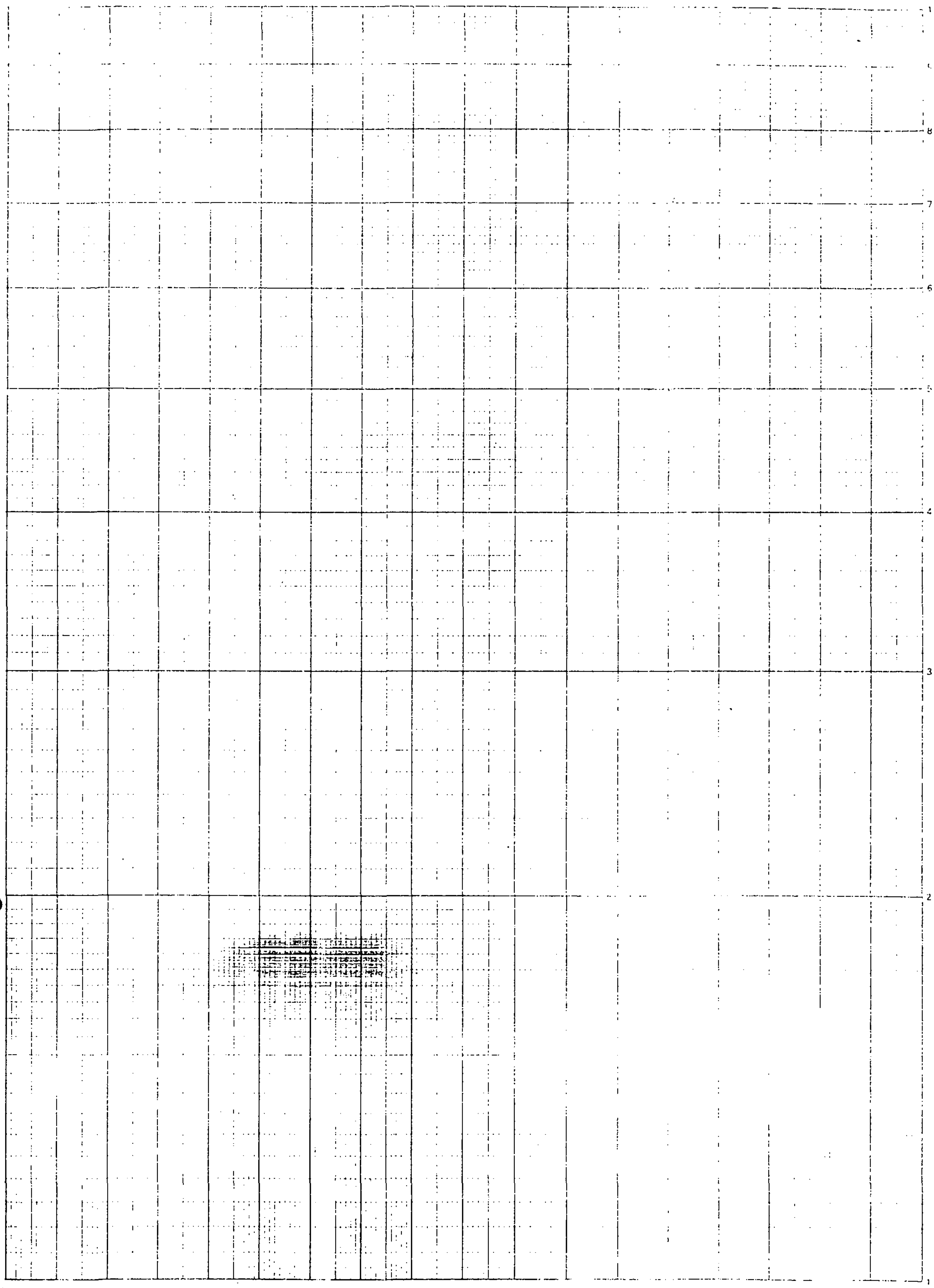
ANNEX E

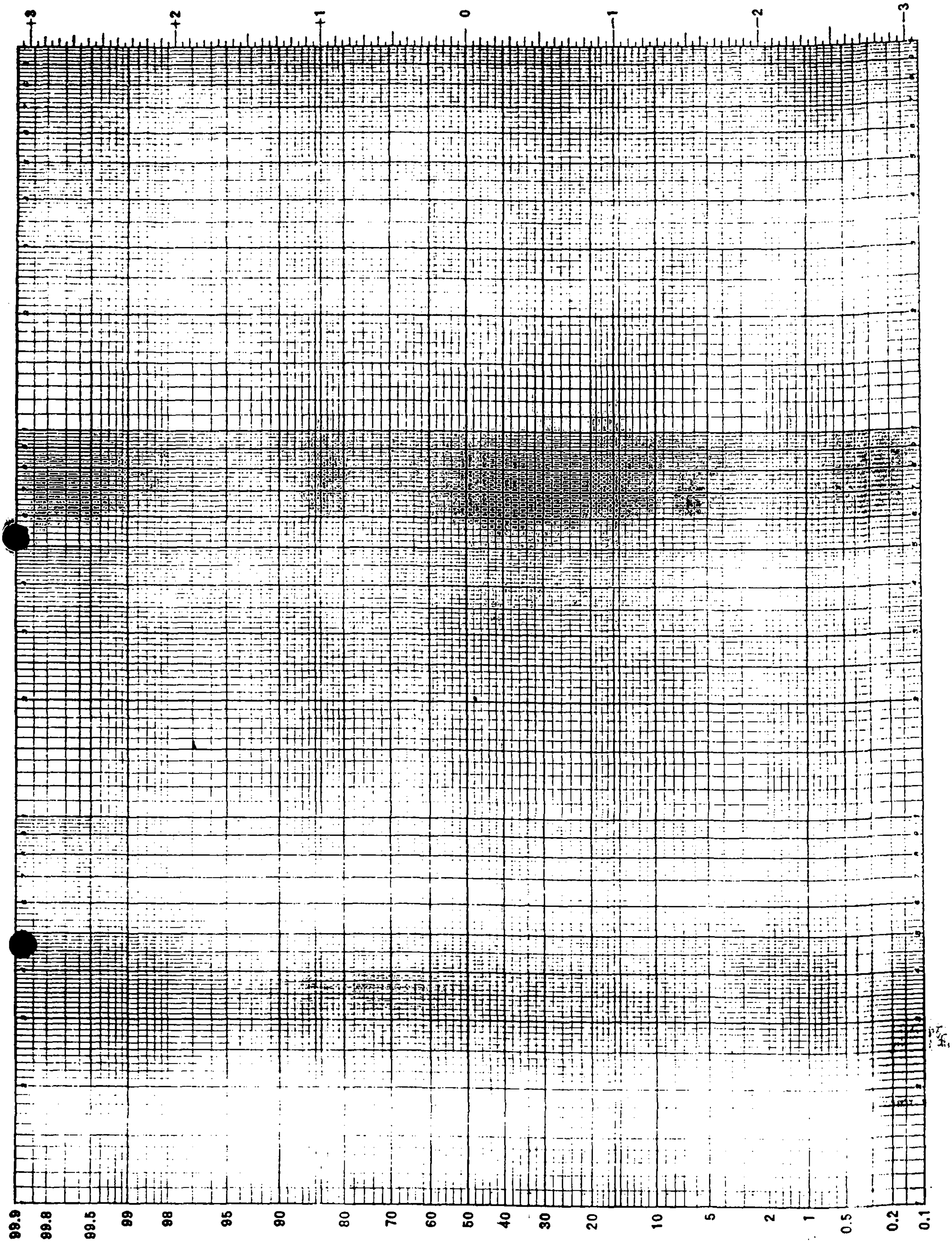
5
4
3
2
1
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
1








1
8
7
6
5
4
3
2
1


+3
+2
+1
0
-1
-2
-3
99.9
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1

ANNEX - F

RAINFALL INTENSITY
DURATION-FREQUENCY CURVES FOR SRI LANKA

ANNEX - F

HYDROLOGICAL STATIONS AND ZONES

Scale 24 Miles to One inch.

SELECTED HYDROLOGICAL STATIONS ▲

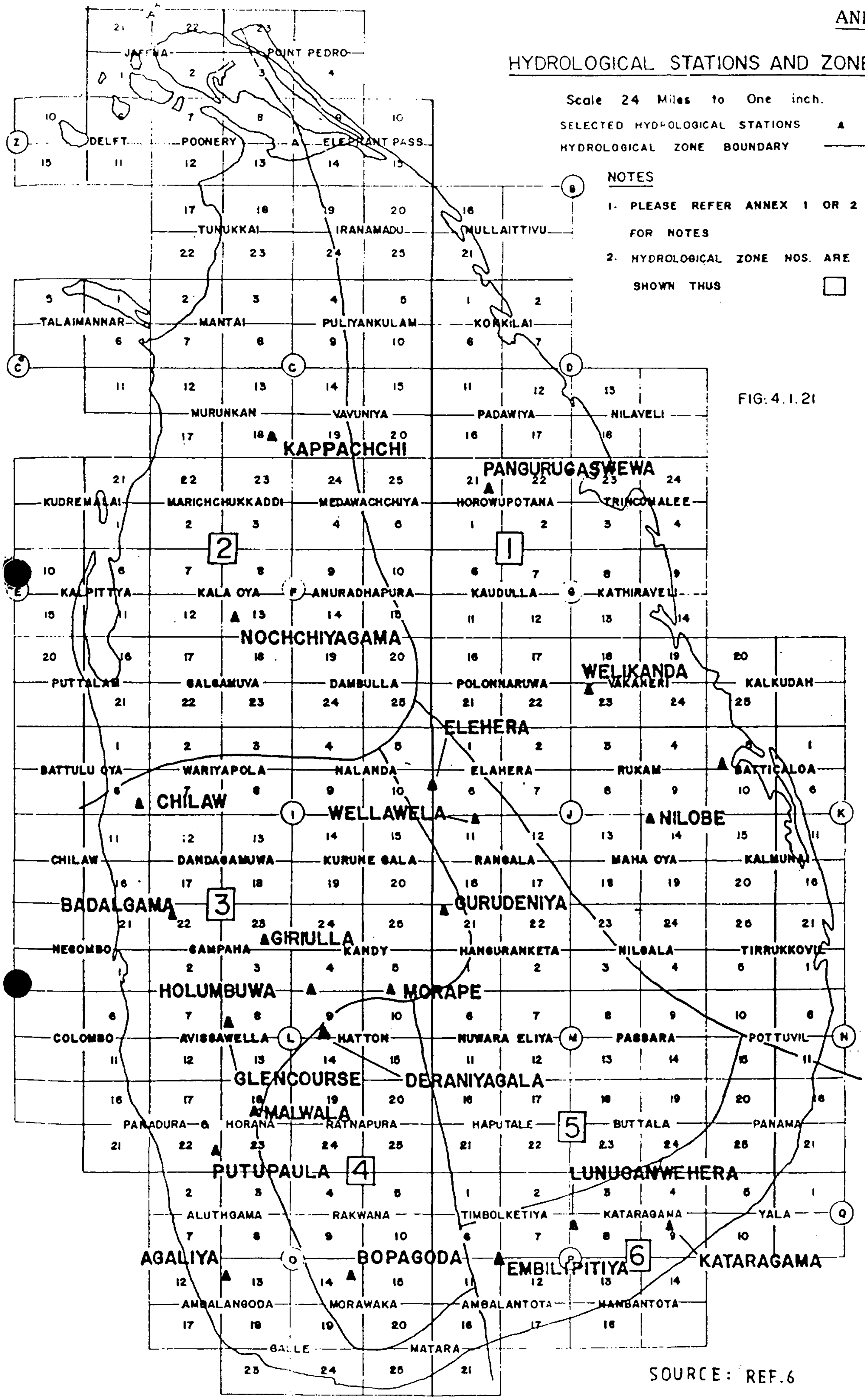
HYDROLOGICAL ZONE BOUNDARY ———

NOTES

1. PLEASE REFER ANNEX 1 OR 2 FOR NOTES

2. HYDROLOGICAL ZONE NOS. ARE SHOWN THUS ☐

FIG: 4.1.21



SOURCE: REF.6

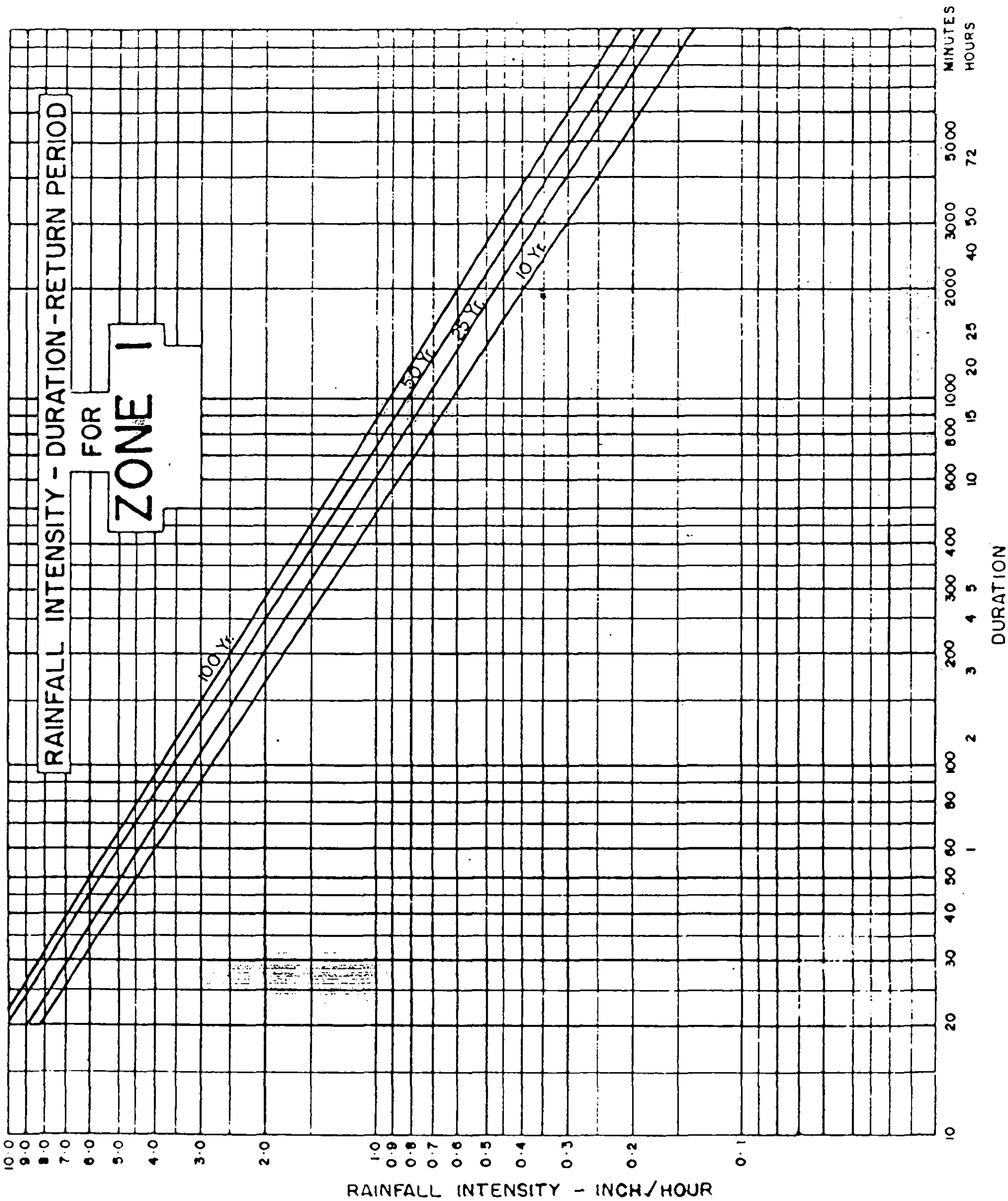

RAINFALL INTENSITY - DURATION - RETURN PERIOD
FOR
ZONE I
100 Yr.
50 Yr.
25 Yr.
10 Yr.
RAINFALL INTENSITY - INCH/HOUR
10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1
DURATION
MINUTES
HOURS
10 20 30 40 50 60 80 100 200 300 400 600 800 1000 2000 3000 5000
1 2 3 4 5 10 15 20 25 40 50 72

FIGURE - F.1

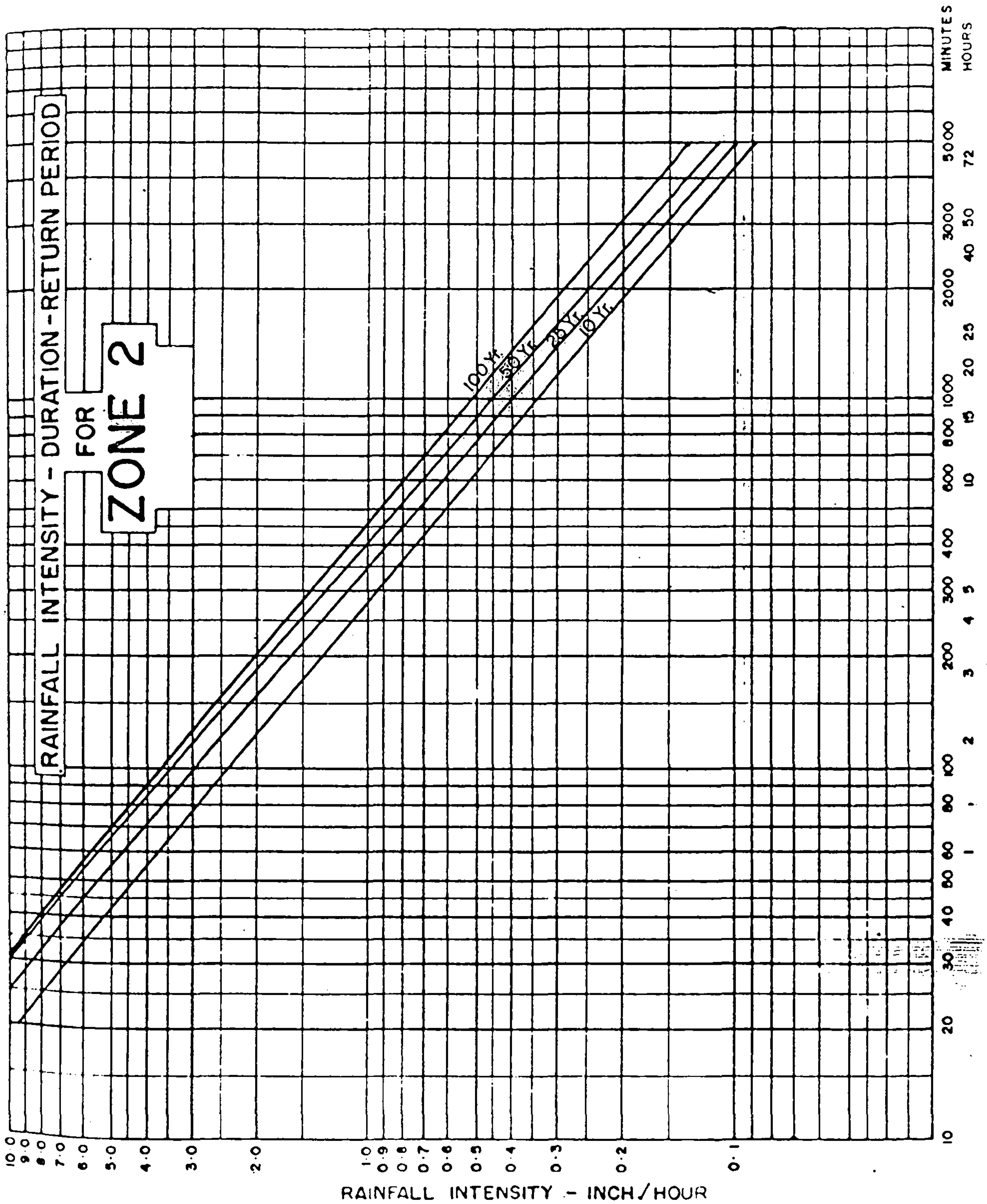

RAINFALL INTENSITY - DURATION - RETURN PERIOD
FOR
ZONE 2
100 Yr.
50 Yr.
25 Yr.
10 Yr.
MINUTES
HOURS
DURATION
10
20
30
40
50
60
80
100
200
300
400
600
800
1000
2000
3000
5000
1
2
3
4
5
10
15
20
25
40
50
72
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
RAINFALL INTENSITY - INCH/HOUR

FIGURE - F.2

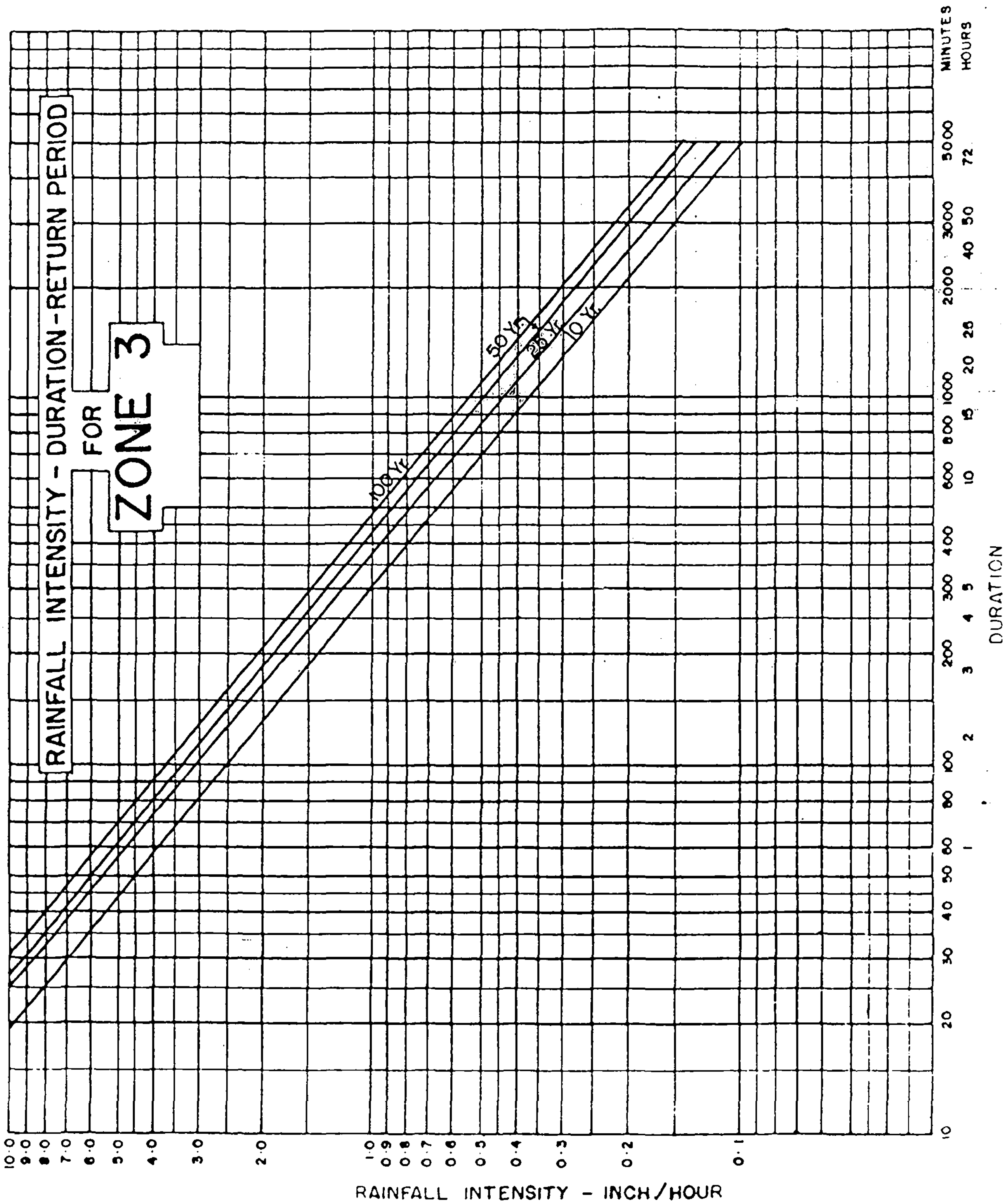

RAINFALL INTENSITY - DURATION - RETURN PERIOD
FOR
ZONE 3
100 Yr.
50 Yr.
25 Yr.
10 Yr.
MINUTES
HOURS
DURATION
RAINFALL INTENSITY - INCH/HOUR

FIGURE - F.3

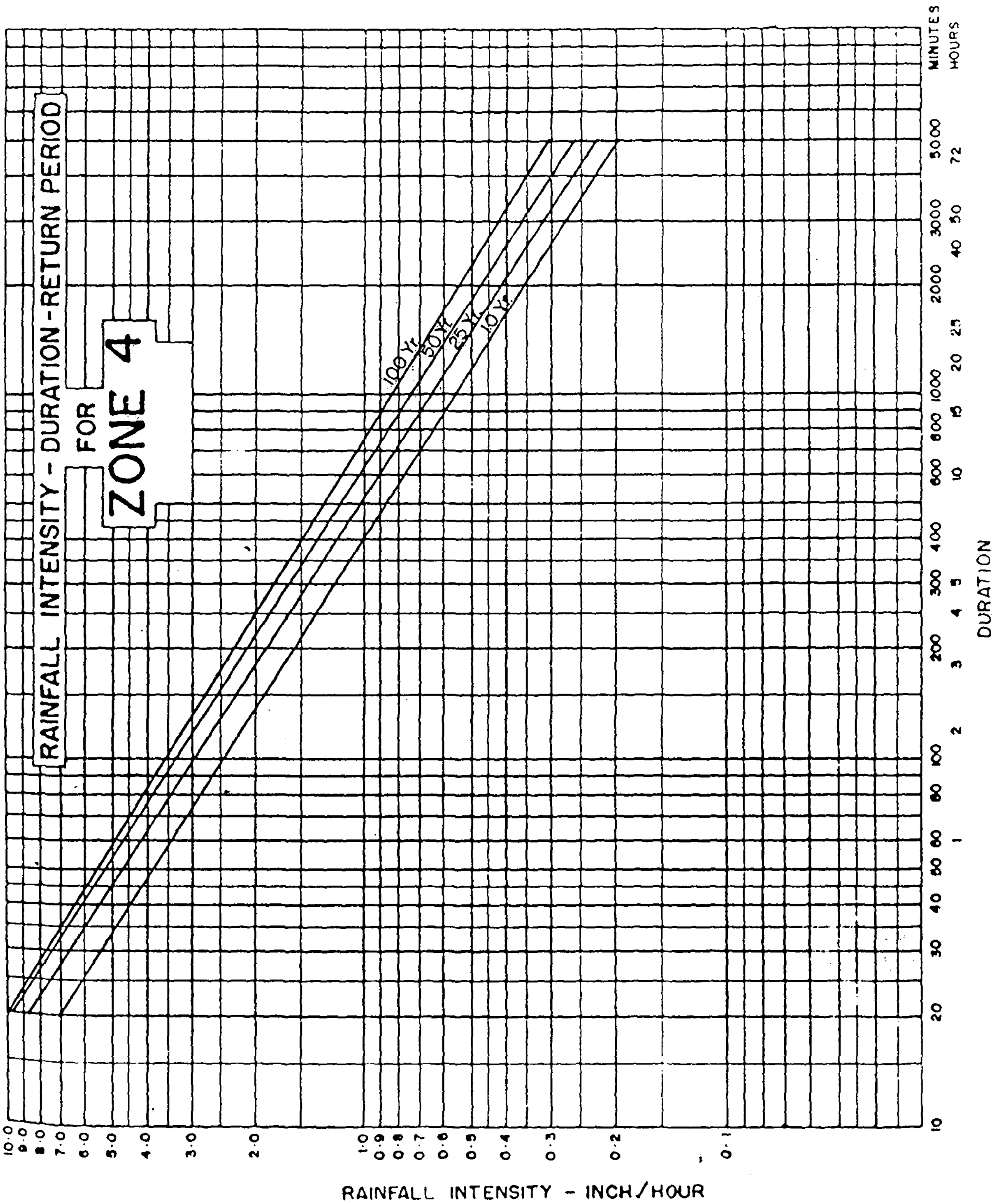

RAINFALL INTENSITY - DURATION - RETURN PERIOD
FOR
ZONE 4
100 Yr.
50 Yr.
25 Yr.
10 Yr.
10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1
RAINFALL INTENSITY - INCH/HOUR
MINUTES 10 20 30 40 50 60 80 100 200 300 400 600 800 1000 2000 3000 5000
HOURS 1 2 3 4 5 10 15 20 25 40 50 72
DURATION

FIGURE - F.4

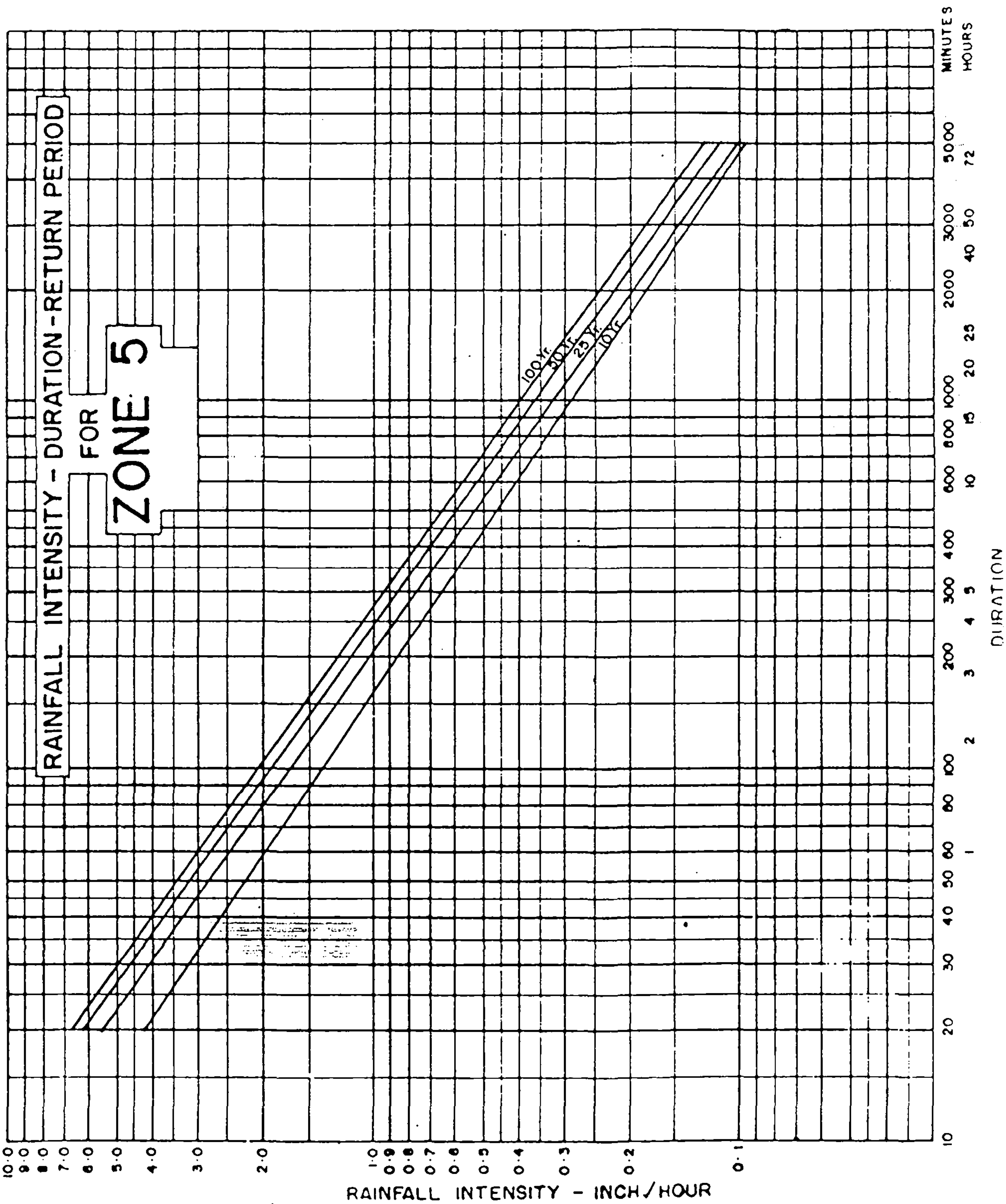
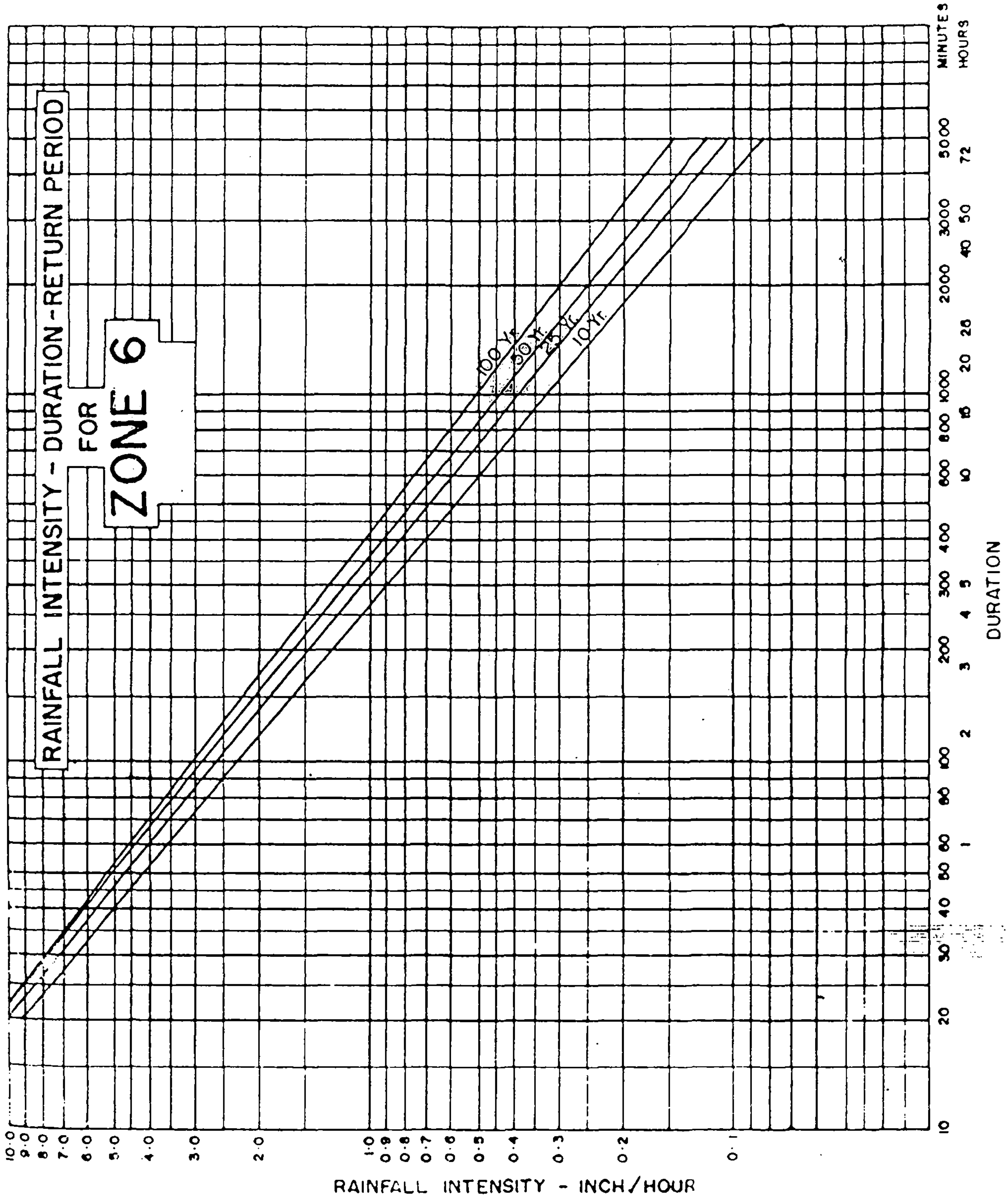

RAINFALL INTENSITY - DURATION - RETURN PERIOD
FOR
ZONE 5
100 Yr.
50 Yr.
25 Yr.
10 Yr.
RAINFALL INTENSITY - INCH/HOUR
DURATION
MINUTES
HOURS

FIGURE - F.5



RAINFALL INTENSITY - DURATION - RETURN PERIOD
FOR
ZONE 6
100 Yr.
50 Yr.
25 Yr.
10 Yr.
MINUTES
HOURS
DURATION
RAINFALL INTENSITY - INCH/HOUR

FIGURE - F.6

ANNEX - G

EXAMPLE CALCULATION FOR USE OF RATIONAL FORMULA

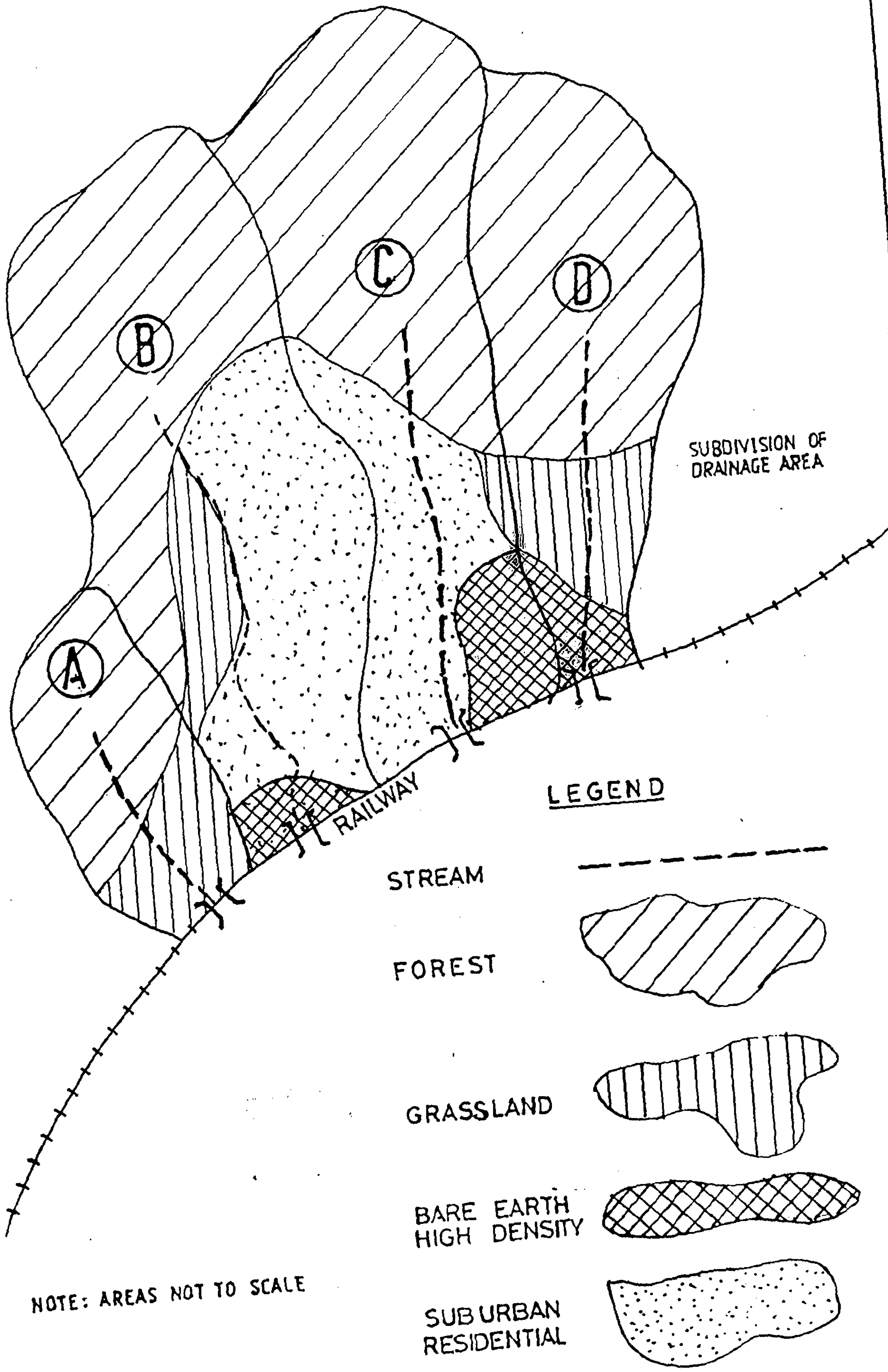
FIG. G.1 EXAMPLE IN USE OF RATIONAL FORMULA FOR ESTIMATION OF FLOOD FLOWS

EXAMPLE CALCULATION FOR USE OF RATIONAL FORMULA

Metric System $Q = CIA/360$ [I (mm/hr), A (ha)] $tc = .0195\ k^{0.77} min$ [$K = \sqrt{L^3}/H$ m]

Drainage Area and Surface Type	Area A (ha)	Coeff. C	A x C (ha)	Length L (m)	Elevation Up Stream (m)	Elevation Down Stream (m)	Difference H (m)	Time of Concentration Formula k	Time of Concentration Formula tc (min)	Rain* Inten. I (mm/h)	Peak Flow Q (m^3/s)
A. Forest	3.97	.15	0.60								
Grassland	2.51	.30	0.75								
Total	6.48		1.35	910	106	71	10	8681	21.0	203	0.76
B. Suburban Res.	19.72	.50	9.86								
Forest	25.78	.15	3.87								
Grassland	6.47	.30	1.94								
Bare Earth + High Density	2.03	.65	1.32								
Total	54.00		16.99	1800	131	72	31	13716	29.9	160	7.55
C. Suburban Res.	14.50	.50	7.25								
Forest	12.53	.15	1.88								
Grassland	0.62	.30	0.19								
Bare Earth High Density	4.46	.65	2.90								
Total	32.11		12.22	1935	134	72	32	15047	32.1	152	5.16
D. Forest	18.03	.15	2.70								
Grassland	6.00	.30	1.80								
Bare Earth + High Density	3.14	.65	2.04								
Total	27.17		6.54	1515	134	72	28	11144	25.5	178	3.23
Project Area	119.76										

* Given from 10-year frequency, intensity duration curves for Zone 1



Example in use of Rational Formula for estimation of flood flows

FIGURE G1

ANNEX - H

PUMP STATION DESIGN CRITERIA

PUMP STATION DESIGN CRITERIA

(To be completed with assistance of Mechanical Engineer)

1.0 Project Name ______________________ Job No. ______________

Location ______________________ Pump Station Name ______________

	STAGE	I	II	III
2.0	**Design Data**			
2.1	Design period ending (yr)	____	____	____
2.2	Design Population	____	____	____
2.3	Average daily demand per Capita (l/cap.d)	____	____	____
2.4	Average daily demand (m^3/d)	____	____	____
2.5	Maximum daily demand (m^3/d)	____	____	____
2.6	Peak hourly demand (m^3/d)	____	____	____
2.7	Maximum fire protection flow (m^3/d)	____	____	____
3.0	**Design Flows**			
3.1	When storage is available, design flow equal to maximum daily demand (m^3/d)	____	____	____
3.2	When storage is not available, design flow equal to peak hourly demand or to sum of maximum daily demand plus fire flow, whichever is greater (m^3/d)	____	____	____
4.0	**Pump Design Parameters**			
4.1	Hydraulic Parameters			
°	Static head (m)	____	____	____
°	Friction losses at design flow (m)	____	____	____
°	Station losses at design flow (m)	____	____	____
°	Total dynamic head at design flow (m) (See attached system head curve)	____	____	____
°	Variations in water surface elevation at wet well (m)	____	____	____
4.2	Pump Selection			
°	Number of duty pumps	____	____	____
°	Number of standby pumps	____	____	____
°	Pump position (horizontal dry pit, vertical dry or wet pit etc.)	____	____	____
°	Type of coupling (threaded, flanged, flexible, spacer)	____	____	____
°	Pump size (suction, discharge) (mm)	____	____	____
°	Type of operation (constant or variable speed)	____	____	____
°	Pump Arrangement (parallel or series)	____	____	____
°	Bearing lubrication (grease, oil, water flushed)	____	____	____
°	Packing box (water seal, grease seal)	____	____	____
°	Pump Speed (max.) (rpm)	____	____	____

STAGE	I	II	III
4.3 Impeller Selection			
° Maximum capacity (m^3/s) and power (kW) for minimum operating head	________	________	________
° Minimum capacity and Power (kW) for maximum head for each pump	________	________	________
° Efficiency range (%) for each pump	________	________	________
° For variable speed, minimum speed for minimum capacity	________	________	________
° kW required at minimum speed	________	________	________
° Shut off head (m)	________	________	________
° Minimum NPSH available (m)	________	________	________
° Specific speed	________	________	________
° Type impeller (open, semi-open, closed)	________	________	________
° Minimum required submergency (for vertical pumps (m)	________	________	________
° Selected impeller trim and maximum dia. available (m)	________	________	________
° Minimum pump operating cycle (minutes)	________	________	________
° Maximum retention time in wet well (minutes)	________	________	________
° Flywheel effect of pump	________	________	________
5.0 Pump Drive and Controls			
5.1 Type of drive (motor and/or engine)	________	________	________
5.2 Motor speed			
° Constant speed (rpm)	________	________	________
° Variable speed (rpm)	________	________	________
5.3 Motor frame	________	________	________
5.4 Voltage (Volts)	________	________	________
5.5 Power rating (kW)	________	________	________
5.6 Number of phases	________	________	________
5.7 Frequency (Hz)	________	________	________
5.8 Ambient temperature (Degrees C)	________	________	________
5.9 Insulation class	________	________	________
5.10 Full load current (Amperes)	________	________	________
5.11 Service factor	________	________	________
5.12 Motor dimensions			
° Diameter (mm)	________	________	________
° Height (mm) (or maximum length) (mm)	________	________	________
5.13 Internal combustion engine drive			
° Type (heavy duty, light duty)	________	________	________
° Fuel	________	________	________

	STAGE	I	II	III
5.14	Transmission			
	° Speed ratio	______	______	______
	° Connection (direct, angle gear)	______	______	______
5.15	Variable speed drive (representative manufacturer)			
	° Hydraulic coupling	______	______	______
	a) Hydrokinetic	______	______	______
	b) Hydroviscous	______	______	______
	° Magnetic (eddy current drive)	______	______	______
	° Variable voltage	______	______	______
	° Variable frequency	______	______	______
	° Wound rotor			
	a) Energy recovery	______	______	______
	b) Variable resistance	______	______	______
	c) Liquid rheostat	______	______	______
5.16	Level sensing system			
	° Bubbler (pneumatic backpressure)	______	______	______
	° Float	______	______	______
	° Electronic probe	______	______	______
5.17	Pump sequence control			
	° Elevation Low Water Level (m)	______	______	______
	° Elev. Start level Lead Pump	______	______	______
	° Elev. Start level Lag Pump 1	______	______	______
	° Elev. Start level Lag Pump 2	______	______	______
	° Elev. Start level Lag Pump 3	______	______	______
	° Elev. Start level Lag Pump 4	______	______	______
	° Elev. Alarm Water level	______	______	______
	° Elev. Stop level Lag Pump 4	______	______	______
	° Elev. Stop level Lag Pump 3	______	______	______
	° Elev. Stop level Lag Pump 2	______	______	______
	° Elev. Stop level Lag Pump 1	______	______	______
	° Elev. Stop level Lead Pump	______	______	______
5.18	Pump control			
	° Manual sequence selection ? YES/NO	______	______	______
	° Automatic lead-lag alternation ? YES/NO	______	______	______
	° Automatic start of standby pump ? YES/NO (If NO explain)	______	______	______
	° Remote alarm ? YES/NO	______	______	______
	° Backup for level sensing ? (CO_2 bottle for bubbler etc.)	______	______	______

	STAGE	I	II	III
6.0 Piping and Valves				
6.1 Suction piping				
° Diameter (mm)		______	______	______
° Pipe material and wall thickness (mm)		______	______	______
° Valve type		______	______	______
° Suction fitting (bell, flare)		______	______	______
6.2 Discharge piping				
° Diameter (mm)		______	______	______
° Pipe material and wall thickness (mm)		______	______	______
° Control valve type		______	______	______
° Opening and closing time of control valve (s)		______	______	______
° If future pump to be installed, is the control valve provided ? YES/NO		______	______	______
° Check valve type		______	______	______
6.3 Discharge header				
° Diameter (mm)		______	______	______
° Pipe material and wall thickness (mm)		______	______	______
6.4 Air valves				
° Air and vacuum valve (mm)		______	______	______
° Air release valve (mm)		______	______	______
° Combination air valve (mm)		______	______	______
6.5 Main line				
° Length (m)		______	______	______
° Diameter (mm)		______	______	______
° Material		______	______	______
° Wall thickness (mm)		______	______	______
° Design friction factor (Hazen Williams C coefficient)		______	______	______
6.6 Overall efficiency at maximum speed		______	______	______
6.7 Suction strainer				
° Type		______	______	______
° Diameter (mm)		______	______	______
° Net flow area (mm^2)		______	______	______
° Head loss at maximum flow (m)		______	______	______
6.8 Flowmeter				
° Type		______	______	______
° Size (mm)		______	______	______
° Material		______	______	______

STAGE	I	II	III

7.0 Chlorination Facilities

	I	II	III
7.1 Application range (mg/l)	______	______	______
7.2 Type of control (manual, solenoid, flowpaced, compound loop)	______	______	______
7.3 Type of storage	______	______	______
7.4 Quantity of storage (kg)	______	______	______
7.5 Evaporators YES/NO	______	______	______
7.6 Ejector booster pump			
° Type (centrifugal or turbine)	______	______	______
° Pump capacity (l/s)	______	______	______
° TDH (m)	______	______	______
° Brake horsepower (kW)	______	______	______

8.0 Ventilation

8.1 Type of fan ______________________

8.2 Capacity for pumproom (air changes per hr.) ______________________

8.3 Capacity of motor-room (air changes per hr.) ______________________

8.4 Capacity for chlorination room (air changes per hr.) ______________________

9.0 Pump Station Structural Loads

9.1 Equipment loads

	I	II	III
° Pumps (kg)	______	______	______
° Motors (kg)	______	______	______
° Standby generator (kg)	______	______	______
° Other ______________ (kg)	______	______	______

9.2 Ground water levels

- El. Ground surface ______________________
- El. Bottom pump station ______________________
- El. Ground water (normal and flood) ______________________

10.0 Station Sump Pump

10.1 Sump dimensions (m) ______________________

10.2 Pump size (suct. discharge, impeller) (mm) ______________________

10.3 Pump capacity (m^3/s) ______________________

10.4 TDH (m) ______________________

10.5 Diameter discharge pipe (mm) ______________________

10.6 Minimum required submergency (m) ______________________

10.7 Brake horsepower (kW) ______________________

	STAGE I	II	III

11.0 Hydraulic Transients

11.1 Problem definition

	I	II	III
° Maximum upsurge due to start-up of pump (m)	______	______	______
° Maximum upsurge due to valve closure (m)	______	______	______
° Maximum downsurge following valve closure (m)	______	______	______
° Maximum downsurge due to power failure (m)	______	______	______
° Maximum upsurge following power failure (m)	______	______	______
° Maximum negative pressure (magnitude and location) (m)	______	______	______
° Maximum reverse speed of pump (rpm)	______	______	______

11.2 Surge protection equipment

° Vacuum relief valve

a) Type ______________________

b) Size (mm) ______________________

° Hydraulically controlled air and vacuum valve

a) Type ______________________

b) Size (mm) ______________________

c) Rate of valve closure (s) ______________________

° Surge relief valve

a) Type ______________________

b) Size (mm) ______________________

c) Pressure set point for valve opening (N/m^2) ______________________

d) Rate of valve closure (s) ______________________

° Air chamber

a) Design pressure of vessel (N/m^2) ______________________

b) Total volume of vessel (m^3) ______________________

c) Configuration of tank (vertically or horizontally) ______________________

d) Diameter of vessel (m) ______________________

e) Height (length) of vessel (m) ______________________

f) Initial volume of air (m^3) ______________________

g) Connection line diameter (mm) ______________________

h) Compressor size (kW) ______________________

i) Maximum allowable elevation for top of vessel (m) ______________________

STAGE	I	II	III

° Vented air chamber

a) Design pressure of vessel (N/m^2) __________

b) Total volume of vessel (m^3) __________

c) Configuration of tank (vertically or horizontally) __________

d) Required elevation difference between top of vessel and center line of header (m) __________

e) Diameter of vessel (m) __________

f) Height (length) of vessel (m) __________

g) Connection line diameter (mm) __________

h) Vacuum relief valve size (mm) __________

i) Air release valve size (mm) __________

° Surge tank

a) Tank diameter (m) __________

b) Maximum tank elev. (m) __________

c) Connection line diameter (mm) __________

° One-way surge tank

a) Tank diameter (m) __________

b) Maximum water surface level (m) __________

c) Connection line diameter (mm) __________

d) Check valve diameter (mm) __________

12.0 Standby Power

12.1 Type __________

12.2 Rating (kW) __________

12.3 Fuel __________

12.4 Cooling system __________

12.5 Dimensions

° Length (m) __________

° Width (m) __________

° Height (m) __________

13.0 Crane Bridge

13.1 Type (top running or under running) __________

13.2 Load rating (kg) __________

13.3 Travelling speed (m/min) __________

13.4 Span (m) __________

	STAGE I	II	III

14.0 Trolley Hoist

14.1 Type (electric driven, air driven hand chain) __________

14.2 Load rating (kg) __________

14.3 Hoisting speed (m/min) __________

14.4 Travelling speed (m/min) __________

14.5 Maximum hook travel (m) __________

15.0 Soil data

15.1 Equivalent fluid pressure - active (kg/m^3) __________

15.2 Equivalent fluid pressure - passive (kg/m^3) __________

15.3 Equivalent fluid pressure at rest (kg/m^3) __________

15.4 Specific weight of soil (kg/m^3) __________

15.5 Soil friction

- Uplift __________
- Sliding __________

15.6 Other __________

ANNEX - I

TOTAL PUMPING HEAD

TOTAL PUMPING HEAD

CALCULATIONS FOR TOTAL PUMPING HEAD

Calculations for determining pumping head are best made after the preparation of detailed longitudinal sections of the pumping main. It is important to accurately compute the pumping head in order to minimize the cost of pump installation and ensure reliable operation. Careful attention should be paid to suction conditions related to site elevation and operating water temperature in order to eliminate cavitation problems.

Surge conditions should also be evaluated for all pumping mains in order to select the proper pipe material and provide surge arrestors when necessary. The tables in Annex - J could be used to evaluate surge conditions.

Design Parameters

Q = ________________ m^3/s

d = Pumping main diameter ________________ mm

Pumping main material ________________

C factor = ________________

V = ________________ m/s

$V^2/2g$ = ________________ m

A. Pumping Main Losses in Pipe

L Length of main ________________ m

h Headloss ________________ m/1000

Friction losses in main : $\frac{L}{1000} \times h_f$ = ________________ m

B. Pumping Main Losses in Pipe Fittings

Type and number of Fittings

Type	n = No	K	nK
90° Bend	______	0.6	______
45° Bend	______	0.4	______
22½° Bend	______	0.3	______
Gate Valve	______	0.5	______
Scour Valve Tee	______	0.6	______
Air Valve Tee	______	0.6	______
Ball Valve	______	16	16*
	Total nK		______

Friction losses in pumping main fittings : $nK \frac{v^{2*}}{2g}$ = ________________ m

C. Difference in Pump and Discharge Elevations

Discharge elevation at storage tank ________________ m

Pump discharge elevation ________________ m

Difference in elevation (static head) = ________________ m

---

* The velocity at the particular fitting should be used. This is especially important if the ball valve size is smaller than the pumping main diameter. Annex I.4 shows values of K for various fittings and valves.

D. Pump Discharge Losses

Type	K
Increaser (if needed)	usually negligible
Reflux valve	3.7
Gate valve	0.5
Tee	1.8
Total K	= 6.0

Pump discharge losses $6 \frac{V^2}{2g}$ = ____________ m

E. Water Meter Losses (check manufacturer's catalogue) = ____________ m

TOTAL DISCHARGE HEAD (sum of items A thru E) = ____________ m

F. Suction Losses

Suction pipe diameter ________ mm C factor ________ Length: ________

V_s = ________ m/s $\frac{V_s^2}{2g}$ = ________ m h_{f_s} = ________ m/1000

1. Losses in Pipe

$\frac{L}{1000} \times h_{f_s}$ = ________ m

2. Losses in Fittings

Type	K
Foot valve & strainer	16
Long radius elbow	0.3
Reducer (if needed)	usually negligible
Total K =	16.3

Suction losses in fittings = 16.3 $V_s^2 / 2g$ = ________ m

3. Static Suction Lift

Pump inlet waterline elevation = ________ m

Minimum water elevation in the sump = ________ m

Difference in elevation (static suction lift) ________ m

TOTAL SUCTION* (sum of items 1,2 & 3) ________ m

G. Velocity Head

For centrifugal and booster pumps the velocity head $V^2/2g$ is the difference between the velocity heads at the suction and discharge flanges of the pump and is usually negligible. For vertical turbine and submersible pumps the velocity head is measured at the discharge flange.

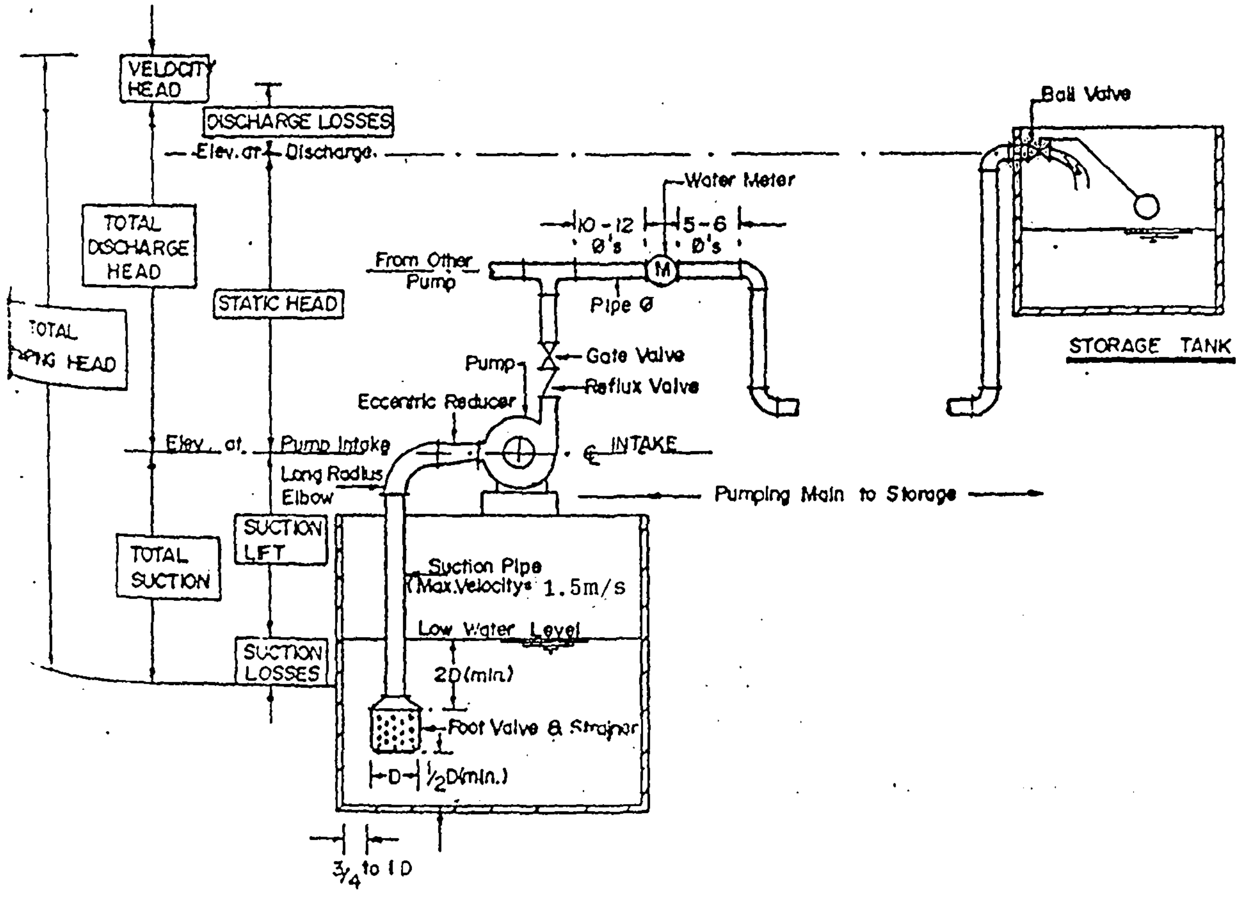
---

* Total suction is the sum of the static lift and losses in the suction piping and fittings. For proper pump operation the total pump suction should not exceed the figures given in Annex I.2 . Total suction varies with the site elevation, the water temperature and the speed of the pump.

H. Total Pumping Head

Total pumping head is the sum of total discharge head, suction lift, total suction losses and velocity head. (see sketch below)

Total discharge head	________	m
Total suction	________	m
Velocity head (usually negligible)	________	
Total pumping head	________	m



PUMP SUMP DESIGN
(not to scale)

FIGURE - I.1

TABLE - I.1

I.2 FACTORS AFFECTING SUCTION HEAD

Pumps with not too high a speed, liquid temperatures up to 20°C and situated at low altitude, can lift up to 6.4 metres. At higher temperatures and at higher altitudes, this figure is reduced.

The following table indicates the total suction lift in relation to the temperature of the liquid, the number of revolutions per min. and the altitudes of the site of the pump.

Water Temperature °C	10	20	30	40	50
Total Suction* in m					
1450 rpm	6.4	6.3	5.8	5	4
2900 rpm	4.6	4.3	3.8	3.1	2

* Altitude Correction Multiplier

Altitude in m	0-450	915	1370	1830
Multiplier	1.0	0.9	0.79	0.7

For altitudes above 450 m the suction lift must be multiplied by the correction multiplier.

---

* Includes static suction lift from minimum water level to pump inlet centerline, and losses on suction pipe and fittings.

TABLE - I.2

I.3 RECOMMENDED MAXIMUM FLOW RATES IN FOOT VALVE WITH STRAINER

Valve Size (mm)	Maximum Flow Rate(m^3/h)
50	7.9
65	14.4
80	21.6
100	43.2
150	108
200	198
250	324
300	468

TABLE - I.3

HEAD LOSSES IN PIPE FITTINGS, VALVES AND OPEN CHANNELS DUE TO TURBULENCE

(Values of K)

	Nature of Resistance	Loss in terms of $V^2/2g$
a.	Swing check valve (fully open)	3.7
b.	Foot valve & strainer	16
c.	Gate valve (fully open)	0.48
d.	Butterfly valve (fully open)	1.2
e.	90° Bend	
	Regular flanged	0.30
	Long radius flanged	0.25
	Short radius screwed	0.90
	Long radius screwed	0.60
f.	45° Bend	
	Regular flanged	0.42
	Long radius flanged	0.20
	Standard screwed	0.42
g.	22½° Bend	use ½ loss for 90° Bend
h.	Wye branches	1.0
i.	Tee	
	Side inlet	1.80
	Side outlet	1.80
	Run of tee	0.6
	Run of tee reduced ½	0.9
	Run of tee reduced ¼	0.75
j.	Reducers (velocity at small end)	0.25
k.	Increasers	$0.25\ (V_1^2/2g - V_2^2/2g)$ where V_1 = velocity in small end
l.	Sudden contraction	
	d/D = ¼	0.42 where d and D are diameters of small and large pipes respectively
	d/D = ½	
	d/D = ¾	0.19
m.	Sudden enlargement	
	d/D = ¼	0.92
	d/D = ½	0.56 Ditto
	d/D = ¾	0.19
n.	Entrance losses:	
	Pipe projecting into tank	1.0
	End of pipe flush with tank (ordinary square edged entry)	0.5
	Slightly rounded	0.23
	Bell- mouthed	0.04
o.	Outlet losses:	
	From pipe with still water or atmosphere	1.0
	From pipe to well	$0.9\ (V_1^2/2g - V_2^2/2g)$ where V_1 = velocity in the pipe

p. Losses in open channels :

Sharp cornered entrance	$0.5\ (V_1^2/2g - V_2^2/2g)$
	where V_1 = velocity downstream
Round cornered entrance	$0.25(V_1^2/2g - V_2^2/2g)$
Bell-mouthed entrance	0.05 "

q. Losses at turns around baffles — 3.3

r. Sudden enlargement or outlet losses due to turbulence:

Sharp cornered outlet	$1.0\ (V_2^2/2g - V_1^2/2g)$
	where V_1 = velocity downstream
Bell-mouthed	$0.1\ (V_2^2/2g - V_1^2/2g)$

ANNEX - J

WATER HAMMER

J.1	TABLES FOR WATER HAMMER EVALUATIONS FOR PUMPING MAINS
TABLE J.1	CLASSIFICATION OF PUMPING MAINS FOR DETERMINING THE COMPLEXITY OF WATER HAMMER PROBLEMS
TABLE J.2	CHECKING FOR DETERMINING THE DEGREE OF WATER HAMMER SEVERITY
J.2	SURGE PRESSURE CALCULATION

J.1 TABLES FOR WATER HAMMER EVALUATIONS FOR PUMPING MAINS

The following two tables could be used to rapidly determine the possibility of a water hammer occurence in pumping main using centrifugal pumps.

Table J.1- Enables the design engineer to ascertain whether the water hammer problem would be a relatively simple or complex one. Simple water hammer problems occur with great frequency in practice. The analyses of complex problems should be done with the assistance of specialists.

Table J.2- Can be used to determine the severity of simple water hammer problems. If any one item is checked in the affirmative, there is cause for concern. If there are two or more affirmative items, the situation is likely to be serious and the degree of severity will be proportional to the number of affirmative items.

Analyses and solutions to various water hammer problems are presented in detail in the following excellent references available in the library:

a) "Pipline Design for Water Engineers" by D. Stephenson Chapter 14

b) "Water Hammer Analysis" by J. Parmakian

Table - J.1

CLASSIFICATION OF PUMPING MAINS FOR DETERMINING THE COMPLEXITY OF WATER HAMMER PROBLEMS

Condition	Simple Water Hammer Problems	Complex* Water Hammer Problems
I. TYPE OF SYSTEM		
a. Single pipeline of uniform size	x	
b. Single pipeline of more than one size		x
c. Two or more parallel lines		x
d. Single or parallel system connected to distribution system		x
II. PROFILE OF SYSTEM		
a. Relatively flat or mild ascending slope	x	
b. Steep slope (length of main (L) less than 20 times pumping head)		x
c. Intermediate high points		x
d. Intermediate reservoir or pumps		x
III. PUMP SUCTION CONDITIONS		
a. Direct suction from suction well	x	
b. Suction conduit in which period (2L/C) is 1 s or less	x	
c. Suction conduit in which period (2L/C) is greater than 1 s		x

* Complex water hammer problems should be referred to specialists in water hammer analysis.

C is pressure wave celerity (speed)

Source: Report of the Task Committee on Engineering Practices in the Design of Pipelines, American Society of Civil Engineers, 1975.

CHECKING FOR DETERMINING THE DEGREE OF WATER HAMMER SEVERITY

Item	Yes	No
1. Critical period* is greater than 1.5		
2. Maximum velocity of flow is greater than 1.2 m/s		
3. Check valve closes in less than critical period		
4. Pump and motor will be damaged if allowed to run backward up to full speed.		
5. Factor of safety of the pipe is less than 3.5 for normal operating pressures.		
6. Pump will be started with discharge valve open		
7. Pump will be shut off before the discharge valve is fully closed		
8. Automatic valves are present in the system.		

* Critical period is $\frac{2L}{C}$ where L is the length of pipe and C is the wave celerity of the pipe material

J.2 SURGE PRESSURE CALCULATION

Assume Q = 30 l/s

Pipe D = 200 mm Pipe Material : AC

For asbestos cement pipe the following applies:

Maximum operating pressure (pump discharge head) + maximum calculated surge pressure at power failure $\leq$ 1.1 x maximum allowable sustained pressure for the class of pipe

Assume pipe pressure including surge recommended in BS Code of Practice is
1.1 times max. allow. sustained pressure = 1.1 x 102 = 112 m

Max. Calculated Surge Pressure

at Water temperature of 50°C,

Pressure wave celerity, $C = \dfrac{1540}{\sqrt{1 + \dfrac{kd}{Et}}}$ m/s $\left(\text{or } \dfrac{5050}{\sqrt{1 + \dfrac{kd}{Et}}} \text{ ft/s} \right)$

Where k = elastic modulus of water = 2.07×10^9 N/m^2 (0.3×10^6 lbf/in^2) at 0°C

or

2.34×10^9 N/m^2 (0.34×10^6 lbf/in^2) at 50°C

d = pipe ID (m)

E = modulus of elasticity of pipe (Young's Modulus)

E = 24×10^9 N/m^2 (3.5×10^6 lbf/in^2) for AC

= 110×10^9 N/m^2 (16×10^6 lbf/in^2) for CI

= 165×10^9 N/m^2 (24×10^6 lbf/in^2) for DI

= 210×10^9 N/m^2 (30.5×10^6 lbf/in^2) for Steel

= 2.7×10^9 N/m^2 (0.4×10^6 lbf/in^2) for PVC

t = Pipe wall thickness (mm)

for 200 mm class 20 AC pipe d = 200 mm, $t \simeq 25$ mm

$$C = \frac{1540}{\sqrt{1 + \left(\dfrac{2.34 \times 10^9 . 0.2}{24 \times 10^9 . 0.025}\right)}} = \underline{1154 \text{ m/s}}$$

$\therefore$ Max. surge pressure, $p_s = \dfrac{Cv}{g}$

Where v = velocity = $\dfrac{Q}{A} = \dfrac{0.03}{.0314}$ = 0.96 m/s

$g = 9.78 \text{ ms}^{-2}$

$Ps = \dfrac{1154.0.96}{9.78} = \underline{113 \text{ m}}$

Assume total pump discharge head	=	90 m
plus max. surge pressure	=	113 m
Total System Pressure	=	203 m
Recommended BS Code 2010 pressure	=	112 m
Excess pressure	=	91 m

ANNEX - K

CEYLON ELECTRICITY BOARD TARIFF

ශ්‍රී ලංකා ප්‍රජාතාන්ත්‍රික සමාජවාදී ජනරජයේ ගැසට් පත්‍රය

අති විශෙෂ

The Gazette of the Democratic Socialist Republic of Sri Lanka

EXTRAORDINARY

අංක 334/5—1985 ජනවාරි 29 වැනි අඟහරුවාදා—1985.01.29

No. 334/5 – TUESDAY, JANUARY 29, 1985

(Published by Authority)

PART I: SECTION (I)—GENERAL

Miscellaneous Departmental Notices

ANNEX I

CEYLON ELECTRICITY BOARD

Tariffs and Charges

NOTICE is hereby given in terms of Section 52(2) of the Ceylon Electricity Board Act. No. 17 of 1969, that it is intended to introduce with effect from 1st March, 1985 the following tariffs and charges for the supply of electrical energy to all direct consumers of the Ceylon Electricity Board who are supplied by the integrated hydro-thermal electrical power system.

K. K. Y. W. PERERA,
Chairman.

25th January, 1985,
Ceylon Electricity Board,
Sir Chittampalam A. Gardiner Mawatha,
Colombo 2.

SECTION 1—DOMESTIC TARIFF

Rate D. 1

1. This rate shall apply to supplies of electricity used for domestic purposes in private residences.

2. The monthly charges for supply under this tariff shall be—

For the first 30 units (1st Block) at a basic rate of 50 cents per unit (exempted from the Fuel Adjustment charge).

For the units in excess of 30 units and up to 150 units (2nd Block) at a basic rate of 90 cts. per unit (exempted from the Fuel Adjustment Charge).

For the units in excess of 150 units and up to 500 units (3rd Block) at a basic rate of Rs. 1.80 per unit plus Fuel Adjustment Charge in accordance with Section 10.

For the units in excess of 500 units (4th Block) at the basic rate of Rs. 2.25 per unit plus Fuel Adjustment Charge in accordance with Section 10.

The above charges shall be subject to a minimum of Rs. 5 in respect of any month.

SECTION 2—RELIGIOUS PREMISES & APPROVED CHARITABLE INSTITUTIONS TARIFF

Rate R. 1

1. This rate shall apply to supplies of electricity to—

(a) Places of public religious worship including a private residence or residences of a priest or priests where such residence or residences are associated with and are within the curtilage of a place of public religious worship, and

(b) Approved charitable institutions.

The installation should not include any buildings used mainly or wholly for commercial purposes.

2. The monthly charge for supply under this tariff shall be at a basic rate of 50 cents per unit (exempted from the Fuel Adjustment Charge).

The above charge shall be subject to a minimum of Rs. 5 in respect of any month.

SECTION 3—STREET LIGHTING TARIFF

1. This rate shall apply to supplies given for the purpose of public street lighting only.

2. The monthly charges for energy supply under this tariff shall be at a basic rate of Rs. 1.60 per unit plus Fuel Adjustment Charge in accordance with Section 10.

SECTION 4—TARIFFS FOR BULK SUPPLY TO LICENSEES

The rates L. 1 and L. 2 set out below shall apply to bulk supplies provided to Licensees within the meaning of the Electricity Act. The " domestic, religious premises and approved charitable institution consumers " mentioned in this section refer to domestic, religious premises and approved charitable institutions consumers of the Licensee.

Rate L. 1

This rate shall apply to supplies delivered and metered at 400/230 volts nominal. The monthly charge under this tariff shall be the sum of the charges (a), (b), and (c) given below :

(a) A maximum demand charge at the rate of Rs. 30 per KVA. of maximum demand made during the month at each individual point of supply for supplies where the contract demand exceeds 50 KVA.

(b) Unit charges for Blocks of energy as follows :—

(i) A basic rate of 40 cts. per unit for the First Block of units equal to 120% of the sum of units used per month by religious premises and approved charitable institution consumers, plus 120% of the sum of units used per month by domestic consumers consuming up to 30 units per month plus 120% of 30 units × number of domestic consumers consuming above 30 units per month

(ii) A basic rate of 70 cts. per unit for the Second Block of units equal to 120% of the sum of units used in excess of 30 units per month by domestic consumers consuming in excess of 30 units and up to 150 units per month, plus 120% of 120 units × number of domestic consumers consuming in excess of 150 units per month.

(iii) A basic rate of Rs. 1.35 per unit for the Third Block of units consisting of all units purchased per month by the Licensee in excess of the sum of units in the First and Second Blocks.

(c) Fuel Adjustment Charge for all units in the Third Block in (b) above, in accordance with Section 10.

For the purpose of computation of monthly bills by the Ceylon Electricity Board, the Licensee shall provide in the manner requested by the Ceylon Electricity Board the monthly details of consumption of their retail supplies. Until such data is provided to the satisfaction of the Ceylon Electricity Board, the monthly bills shall be worked out on an estimated basis by the Ceylon Electricity Board.

Rate L 2

This rate shall apply to supplies delivered and metered at 11,000 volts mominal and above.

The monthly charge under this tariff shall be the sum of the charges (a), (b) and (c) given below.

(a) A maximum demand charge at the rate of Rs. 25 per KVA, of maximum demand made during the month at each individual point of supply.

(b) Unit charges for Blocks of energy as follows :—

(i) A basic rate of 40 cts. per unit for the First Block of units equal to 120% of the sum of units used per month by religious premises and approved charitable institution consumers plus 120% of the sum of units used per month by domestic consumers consuming up to 30 units per month, plus 120% of 30 units × number of demestic consumers consuming above 30 units per month.,

(ii) A basic rate of 70 cts. per unit for the Second Block of units equal to 120% of the sum of units used in excess of 30 units per month by domestic consumers consuming in excess of 30 units and up to 150 units per month, plus 120% of 120 units × number of domestic consumers consuming in excess of 150 units per month.

(iii) A basic rate of Rs. 1.35 per unit for the Third Block of units consisting of all units purchased per month by the Licensee in excess of the sum of units in the First and Second Blocks.

(c) Fuel Adjustment Charge for all units in the Third Block in (b) above, in accordance with Section 10.

For the purpose of computation of monthly bills by the Ceylon Electricity Board the Licensee shall provide in the manner requested by the Ceylon Electricity Board the monthly details of consumption of their retail supplies. Until such data is provided to the satisfaction of the Ceylon Electricity Board, the monthly bills shall be worked out on an estimated basis by the Ceylon Electricity Board.

SECTION 5—GENERAL PURPOSE TARIFF

The rates G.P. 1, G.P. 2 and G.P. 3 set out below shall be applicable to a supply of electricity to be used in shops, offices, banks, warehouses, public buildings, hospitals, educational establishments, places of entertainment and other premises not covered under any other tariffs in this schedule.

Rate G.P. 1

1. This rate shall apply to supplies at each individual point of supply delivered and metered at 400/230 volts nominal and where the contract demand is less than 50 KVA.

2. The monthly charge under this tariff shall be the sum of charges (a) and (b) given below :—

(a) A basic rate of Rs. 1.70 per unit plus Fuel Adjustment Charge in accordance with Section 10.

(b) Fixed charge of Rs. 20 for contract demands up to 10 KVA. Fixed charge of Rs. 100 for contract demands in excess of 10 KVA. but less than 50 KVA.

Rate G.P. 2.

1. This rate shall apply to supplies at each individual point of supply delivered and metered at 400/230 volts nominal and where the contract demand is equal to or exceeds 50 K.V.A

2. The monthly charge for supplies under this tariff shall be the sum of the charges (a), (b) and (c) given below :

(a) A maximum demand charge at the rate of Rs. 125 per KVA. of— the maximum demand made during the month.

(b) A unit charge at the basic rate of Rs. 1.60 per unit plus Fuel Adjustment Charge in accordance with Section 10.

(c) Fixed charge of Rs. 200.

Rate G.P. 3

(1) This rate shall apply to supplies at each individual point of supply delivered and metered at 11,000 volts nominal and above.

2. The monthly charge for supplies under this traiff shall be the sum of the charges (a), (b) and (c) given below :—

(a) A maximum demand charge at the rate of Rs. 115 per KVA. of the maximum demand made during the month.

(b) A unit charge at the basic rate of Rs. 1.50 per unit plus Fuel Adjustment Charge in accordance with Section 10.

(c) A fixed charge of Rs. 200.

SECTION 6—INDUSTRIAL TARIFF

The rates I. 1., I.2 and I.3 set out below shall be applicable to a supply of electricity used wholly or mainly for motive power or for electrochemical processes in factories, workshops, foundries, oil mills, spinning and weaving mills, pumping stational port and dock installations and other similar industrial installations, but shall not be applicable to a supply of electricity covered under Section 8 of this schedule.

Rate I.1.

(1) This rate shall apply to supplies at each individual point of supply, delivered and metered at 400/230 volts nominal and where the contract demand is less than 50 KVA.

The monthly charge for supplies under this tariff shall be the sum of charges (a) and (b) given below :—

(a) A unit charge at the basic rate of Rs. 1.55 per unit plus Fuel Adjustment Charge in accordance with Section 10.

(b) A fixed charge of Rs. 20 for contract demand upto 10 KVA. A fixed charge of Rs. 100 for contract demand in excess of 10 KVA. but below 50 KVA.

Rate I.2

1. This rate shall apply to supplies at each individual point of supply, delivered and metered at 400/230 volts nominal and where the contract demand is equal to or exceeds 50 KVA.

2. The monthly charge for supplies under this tariff shall be the sum of the charges (a), (b) and (c) given below :

(a) A maximum demand charge at the rate of Rs. 100 per KVA. of the maximum demand made during the month.

(b) A unit charge at the basic rate of Rs. 1.45 per unit, plus Fuel Adjustment Charge in accordance with Section 10

(c) A Fixed Charge of Rs. 200.

Rate I.3

1. This rate shall apply to supplies at each individual point of supply delivered and metered at 11,000 volts nominal and above.

2. The monthly charge for supplies under this Tariff shall be the sum of the charges (a), (b) and (c) given below :

(a) A maximum demand charge at the rate of Rs. 90 per KVA. of the maximum demand made during the month.

(b) A unit charge at the basic rate of Rs. 1.25 per unit, plus Fuel Adjustment Charge in accordance with Section 10.

(c) A Fixed Charge of Rs. 200.

SECTION 7—HOTELS TARIFF

The Rates Hotels 1, Hotels 2 and Hotels 3 set-out below shall be applicable to a supply of electricity to be used in Hotels Restaurants, Cafes and other similar premises, but shall not be applicable to a supply of electricity covered under Section 8 of this Schedule.

Rate Hotels 1

1. This rate shall apply to supplies at each individual point of supply delivered and metered at 400/230 volts nominal and where the contract demand is less than 50 KVA

2. The monthly charge under this Tariff shall be the sum of the charges (a) and (b) given below :

(a) A unit charge at the basic rate of Rs. 1.70 per unit, plus Fuel Adjustment Charge in accordance with Section 10

(b) A fixed Charge of Rs. 20 for contract demand up to 10 KVA. A Fixed Charge of Rs. 100 for contract demand in excess of 10 KVA. but less than 50 KVA.

Rate Hotels 2

1. This rate shall apply to supplies at each individual point of supply delivered and metered at 400/230 volts nominal and where the contract demand is equal to or exceeds 50 KVA.

2. The monthly charge under this Tariff shall be the sum of the charges (a), (b) and (c) given below:

(a) A maximum demand charge at the rate of Rs. 150 per KVA. of the maximum demand made during the month

(b) A unit charge at a basic rate of Rs. 1.60 per unit, plus Fuel Adjustment Charge in accordance with Section 10.

(c) A fixed Charge of Rs. 200.

Rate Hotels 3

1. This rate shall apply to supplies at each individual point of supply delivered and metered at 11,000 volts nominal and above.

2. The monthly charge under this Tariff shall be the sum of the charges (a), (b) and (c) given below :

(a) A maximum demand charge at the rate of Rs. 140 per KVA. of the maximum demand made during the month

(b) A unit charge at a basic rate of Rs. 1.50 per unit, plus Fuel Adjustment Charge in accordance with Section 10.

(c) A fixed charge of Rs. 200.

SECTION 8—TARIFF FOR INTERRUPTIBLE, SEASONAL, TEMPORARY, STANDBY AND OPTIONAL TIME OF DAY SUPPLIES

The rates for supplies given on Interruptible, Seasonal, Temporary or Standby basis shall be determined by the General Manager, Ceylon Electricity Board in each case.

It is intended to introduce on a trial basis a Time of Day tariff for Industrial and Hotel Consumers. Changes to metering and other equipment would be required to implement this Tariff. The tariff would initially be intrduced on a trial basis. This tariff would be applicable only to supplies of electricity where the Ceylon Electricity Board and the consumer mutually agree to the supply of electricity at this proposed Time of Day Tariff. The date the new tariff comes into force for each supply of electricity would be determined by the General Manager, Ceylon Electricity Board taking into consideration the availability of equipment and other factors.

The optional Time of Day rates I.2 (T.D.) I.3 (T.D.) Hotel 2 (T.D.) and Hotel 3 (T.D.) set out below, shall be applicable to a supply of electricity for Industrial and Hotel consumers where the Ceylon Electricity Board and consumer mutually agree to one of these optional rates in lieu of the corresponding rates I.2. I.3 in Section 6 and Hotel 2, Hotel 3 in Section 7 of this notice. The General Manager, Ceylon Electricity Board shall, taking into consideration the time taken for procurement of suitable metering equipment and other factors, determine at his discretion the date from which the relevant rate shall be applicable to each supply of electricity on a case by case basis.

Industrial-Time of Day

The rates I.2 (T.D.) and I.3. (T.D.) set-out below shall be applicable to a supply of electricity at each individual point of supply used wholly or mainly for motive power or for electro-chemical porcesses in factories, workshops, foundries, oil mills, spinning and weaving mills, pumping stations, port and dock installations and other similar industrial installations.

Rate I.2 (T.D.)

1. This rate shall apply to supplies delivered and metered at 400/230 volts nominal and where the contract demand is equal to or exceeds 50 KVA.

The monthly charge for supplies under this tariff shall be the sum of the charges (a), (b). (c) and (d) given below :

(a) A maximum demand charge at the rate of Rs. 50 per KVA of the maximum demand made during the month

(b) A unit charge at the basic rate of Rs. 1.35 per unit for units consumed within the hours from 9.00 p.m. to 6.00 p.m. the following day, plus Feul Adjustment Charge in accordance with Section 10.

(c) A unit charge at the basic rate of Rs. 1.90 per unit for units consumed in the hours from 6.00 p.m. to 9.00 p.m. each day, plus Fuel Adjustment Charge in accordance with Section 10.

(d) A fixed charge of Rs. 200.

Rate I.3 (T.D.)

1. This rate shall apply to supplies at each individual point of suppiy, delivered and metered at 11,000 volts nominal and above. The monthly charge for supplies under this tariff shall be the sum of charges (a) (b) (c) and (d) given below :

(a) A maximum demand charge at the rate of Rs. 45 per KVA. of the maximum demand made during the month.

(b) A unit charge at the basic rate of Rs. 1.20 per unit for units consumed within the hours from 9.00 p.m. to 6.00 p.m. the following day, plus Fuel Adjustment charge in accordance with section 10.

(c) A unit charge at the basic rate of Rs. 1.75 per unit for units consumed within the hours from 6.00 p.m.to 9.00 p.m. each day plus Fuel Adjustment Charge in accordance with Section 10.

(d) A fixed charge of Rs. 200.

Hotels—Time of Day.—The rates Hotel 2 (T.D.) and Hotel 3 (T.D.) set out below shall be applicable to a supply of Electricity at each individual point of supply used in Hotels, Restaurants, Cafes and other Similar Premises.

Rate Hotel 2 (T.D.).—(1) This rate shall apply to supplies delivered and metered at 400/230 Volts nominal and where the assessed demand is equal to or exceeds 50 KVA.

(2) The monthly charge for supplies under this traiff shall be the sum of the charges (a), (b), (c) and (d) given below :

(a) A maximum demand charge at the rate of Rs. 50 per KVA of the maximum demand made during the month.

(b) A unit charge at the basic rate of Rs. 1.35 per unit for units consumed within the hours 9.00 p.m. to 6.00 p.m. the following day, plus Fuel Adjustment Charge in accordance with Section 10.

(c) A unit charge at the basic rate of Rs. 1.90 per unit for units consumed within the hours 6.00 p.m. to 9.00 p.m each day plus, Fuel Adjustment Charge in accordance with Section 10.

(d) A fixed charge of Rs. 200.

Rate Hotel 3 (T.D.).—This rate shall apply to supplies delivered and metered at 11,000 volts nominal and above.

The monthly charge for supplies under this trariff shall be the sum of the charges (a), (b), (c) and (d) given below :

(a) A maximum demand charge at the rate of Rs. 45 per KVA of the maximum demand made during the month.

(b) A unit charge at the basic rate of Rs. 1.20 per unit for units consumed within the hours 9.00 p.m. to 6.00 p.m. the following day, plus Fuel Adjustment Charge in accordance with Section 10.

(c) A unit charge at the basic rate of Rs. 1.75 per unit for units consumed within the hours 6.00 p.m. to 9.00 p.m. each day, plus Fuel adjustment charge in accordance with Section 10.

(d) A fixed charge of Rs. 200.

SECTION 9—DEPOSIT AGAINST ELECTRICITY CONSUMPTION

The Ceylon Electricity Board shall obtain from all its consumers a deposit equal to the assessed cost of electricity consumption for three months, against electricity consumed.

SECTION 10—FUEL ADJUSTMENT CHARGE

The expenses incurred on account of fuel in the generation of electricity with the use of petroleum fuel or coal or petroleum gas shall be recovered from consumers, by way of a Fuel Adjustment Charge levied on the units consumed, except where specifically exempted.

Except in cases where specifically exempted, an averaged Fuel adjustment Charge on the units shall be levied monthly in addition to the charges at the given basic rates per unit. The estimated Fuel Adjustment Charge is zero percent for the next 12 months.

At the end of the year, the actual fuel cost will be compared and if any modification is necessary, this will be made in the Fuel Adjustment Charge percentage for the next year, or if necessary more frequent modification will be made.

At the beginning of each subsequent year or as found necessary, the estimated Fuel Adjustment Charge percentage applicable for that year or period will be announced by the Ceylon Electricity Board.

DEFINITIONS AND CLARIFICATIONS

(1) The 'Monthly Charge' and 'Fuel Adjustment Charge' shall be based on the routine meter readings which shall be taken at approximately 30 day intervals. Where such readings have not been taken, assessments of the consumption shall be made by the General Manager of the Ceylon Electricity Board and used for computation of the monthly charge and Fuel Adjustment Charge.

(2) When the date of commencement of supply is other than the normal routine meter reading date, the unit charge shall remain as before, while the maximum demand charge shall be levied on a pro-rata basis depending on the period after connection of supply.

(3) The maximum demand in Kilovolt-amperes (KVA) for any month shall, depending on the instrument used, be—

(a) The highest number of amperes registered by the demand indicator multiplied by the current transformer ratio and the declared Voltage and divided by 1000.

OR

(b) The highest demand in Kilovolt-amperes recorded in the month as measured over successive periods of not less than 15 minutes.

In case the recorded maximum demand in KVA is not a whole number, the maximum demand chargeable shall be the next higher whole number in KVA.

(4) The expression 'Contract Demand' in Kilovolt amperes means the total service capacity required by the consumer as declared in the original agreement or as subsequently varied, such contract demand being not less than the actual maximum demand made or likely to be made from time to time. The contract demand shall not be reduced from the agreed value until after the expiry of 12 months from the date of such agreement.

(5) The 'unit' used in the context of energy charges shall be a Kilowatt-hour (KWH).

MISCELLANEOUS CHARGES

(1) *Installation Testing*—

(a) First testing of new installation and extensions to installation .. .. Free

(b) Each additional testing, if first testing is unsatisfactory—

Single phase installation .. .. Rs. 50

Three phase installation .. .. Rs. 150

(2) *Meter Testing*—

Testing meter at consumer's request (if the inaccuracy of the meter exceeds plus or minus 2½ percent, the fee will be refunded) .. Rs. 100

(3) *Charges for Delays in Payment*—

In the event of a consumer being in arrears of his electricity bill for a period exceeding two months a disconnection order is issued. In the event of an issue of a disconnection order, a surcharge of 10% of the outstanding amount will be applied together with a charge of Rs. 100/- for reconnection of supply.

(4) *Charges for Breach of Regulations*—

If a consumer violates any of the regulations or conditions under which supply has been provided (for example, tampering with meters, breaking of cut-out seals or meter seals etc.) a charge of Rs. 2,000/- will be levied in addition to the installation being liable for disconnection. Further, any unmetered consumption will be assessed and recovered from the consumer on a basis of assessment to be determined by the General Manager, Ceylon Electricity Board. The period and method of assessment shall be at the discretion of the General Manager, Ceylon Electricity Board.

(5) *Reconnection Fee after Disconnection at Consumer's Request*—

Reconnecting the supply after supply had been disconnected at the request of the same consumer.. Rs. 100

Tariffs, charges and fees published in any previous notices applying to consumers fed from the national grid are hereby revoked.

2-255

PRINTED AT THE DEPARTMENT OF GOVERNMENT PRINTING, SRI LANKA

ANNEX - L

PIPELINE DESIGN EXAMPLES

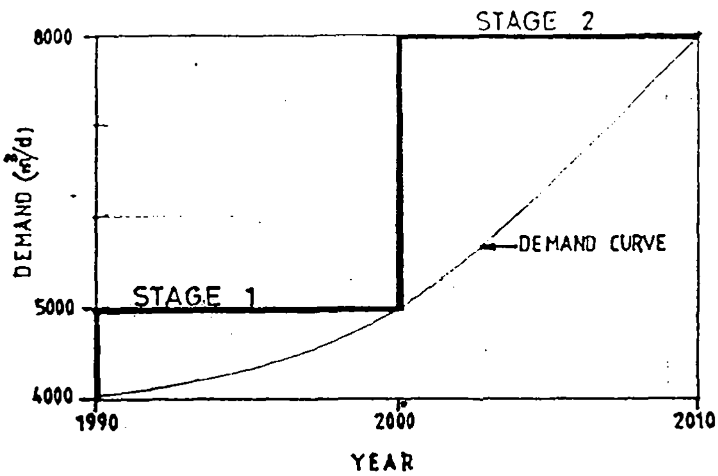
EXAMPLE	1	DUAL OR SINGLE PIPELINE
	2	MOST ECONOMICAL PUMPING MAIN
TABLE - L.1		EXAMPLE 2. CALCULATIONS

PIPELINE DESIGN EXAMPLES

Example 1 Dual or Single Pipeline

Decision required whether to construct gravity pipeline in single phase now for 8000 m^3/d or in 2 stages as shown.

Projected maximum day demand curve:



Basic Assumptions

1. Complete cost of DI pipeline

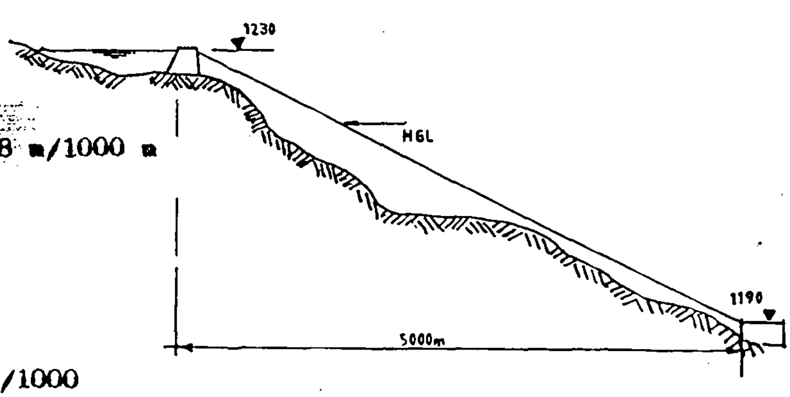
225 mm	Rs.3100/m
250 mm	3500/m
300 mm	4400/m

2. Range in possible interest (discount) rates 8% - 15% p.a.

3. Hazen-Williams C-value = 120

Hydraulic Gradient

Available Head = 40 m
Pipeline length = 5000 m
Available H_L = 40/5000 = 8 m/1000 m



Allow 10% for minor losses
Net available H_L = 0.9 x 8 = 7.2 m/1000

Alternative 1 Single pipe 1990 for 8000 m^3/d (93 l/s)

		Capacity	Velocity
Try	250 mm	61 l/s	1.24 m/s
	300 mm	98 l/s	1.39 m/s
	350 mm	148 l/s	1.53 m/s

Therefore select 300 mm pipe

Check for low initial flow rate:

At 4000 m^3/d (46 l/s) V = 0.65 m/s. (above minimum of 0.6 m/s)

Alternative 2 1st stage 1990 for 5000 m^3/d (58 l/s)
2nd stage 2000 for 3000 m^3/d (35 l/s)

		Capacity	Velocity
1st stage			
Try	225 mm	46 l/s	1.16 m/s
	250 mm	61 l/s	1.24 m/s

Therefore select 250 mm pipe

2nd stage

Try	200 mm	34 l/s	1.08 m/s
	225 mm	46 l/s	1.16 m/s

Therefore select 225 mm pipe.

Present Value

Expenditure

Alternative 1			Alternative 2	
Year	Item	Amount (Rs.million)	Item	Amount (Rs.million)
1990	5000 m of 300 mm	22.0	5000 m of 250 mm	17.5
2000			5000 m of 225 mm	15.5
	Total expenditure	22.0		33.0
	Present value PV_1 =	22.0	$PV_2 = 17.5 + \frac{15.5}{(1+r)^n}$ (where r = 0.08 to 0.15 and n = 10 years) PV_2 (8% pa) = 24.68; PV_2 (10% pa) = 23.48; PV_2 (12% pa) = 22.49; PV_2 (15% pa) = 21.33	

Conclusions

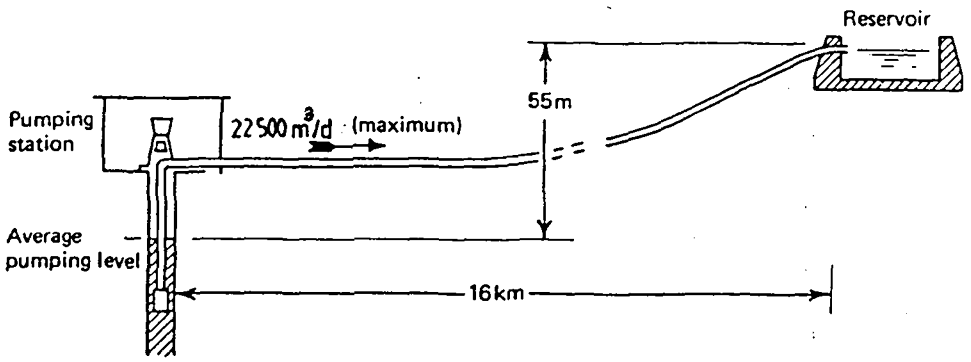
Assuming discount rate is below 13% the least cost solution is for single phase construction.

Other factors to consider:

- o route may be difficult or congested to lay 2 pipelines;
- o dual pipelines will allow shut-down for pipeline maintenance without interruption of supply;
- o dual pipeline will (in this case) give 9% more flow;
- o demand forecast may change - reduction in demand would favour staged approach.

Example 2 Most Economical Pumping Main

(Source: Adapted from Twort, Water Supply)



Find the most economic pumping main for a maximum flow of 22500 m^3/d and an average flow of 20,000 m^3/d for a static of 55 m through 16 km of main. Use the following data:

cost of pipeline = Rs.300 per m per 25 mm diameter
cost of pumps = Rs.50,000 per kW installed power
cost of power (all in) = Rs.1.90 per kWh
annual charges on capital = 12%
total installed power = 150% of required power (i.e.50% standby)

Calculations for various sizes of mains can be tabulated as shown on Table L.1.

Table L.1

Example 2. Calculations

	Trial Diameter of main (mm)			Notes
	525	600	675	
Method 1				
Static lift (m)	55	55	55	
Friction (approximate) (m)(C = 120)	50	26	15	
Total head on pumps (m)	105	81	70	
Installed power of pumps (water horsepower) for maximum flow rate + 50% standby (kW)	402	310	268	(1)
Power used at average rate x 0.73 efficiency x 0.85 power factor (kW)	383	296	256	(2),(3)
Cost of main (Rs.million)	100.8	115.2	129.6	
Cost of pumps (Rs.million)	24.1	18.6	16.1	
Total capital	124.9	133.8	145.7	
Annual charges on capital at 12%	14.99	16.06	17.48	
Annual power charges at Rs.1.90 per kWh	6.37	4.93	4.26	
Total annual cost	21.36	20.99	21.74	
Method 2				
By discounting at 12% for 40 years:				
Cost of main	100.80	115.20	129.60	
Cost of pumps	24.10	18.60	16.10	
Renewal of pumps after 20 years (discount factor = 0.1037)	2.50	1.93	1.67	
Power charges for 40 years (discount factor = 8.24)	52.49	40.60	35.10	
Total net present cost	179.89	176.33	182.47	

Notes:

(1) 1 kW = 0.1134 QH where Q is in m^3/d and h is in metres. (Note: 1 kgwt x 1 m/s = 9.81 watts).

(2) Pump efficiency 81%; Motor efficiency 90%; Overall efficiency 73%.

(3) 1/0.73 x 1/0.85 x 0.1134 QH where Q is average flow of 20000 m^3/d

(4) Power against note (3) x 24 hours x 365 days x Rs.1.90

(5) Discount factors (See Tables L.2 to L.5)

The 600 mm diameter pipe is shown to be the most favourable by both methods. It will be noted, however, that the discounting method does not show the actual amount of the extra cost per annum in choosing one pipe in preference to another. For a 675 mm pipe the extra cost per annum is Rs.750,000 and it might be thought it is worth shouldering this extra annual payment to have the largest sized main, in case a greater demand than expected occurs or in case the friction increases more than expeted. However, this must be viewed in the light of the extra capital cost for the larger main.

Once a first calculation of this nature has been made, then a closer examination of the problem in detail must be carried out because there will be some assumptions which must be rectified. Amongst the factors which will need to be examined are the following:

(1) Will the different pressures on the 525, 600, and 675 mm mains require one main to be of a stronger class than another? If so, we cannot apply a rule of thumb price related to their diameter, but must price the lines individually taking into account the more expensive pipes required for the higher pressure.

(2) What will be the effect of the first 10 or 20 years life of the main giving a higher coefficient of friction C in the Hazen-Williams formula and therefore a lesser friction head?

(3) What is the effect of possible increases in the cost of power?

(4) What is the effect of different discount rates?

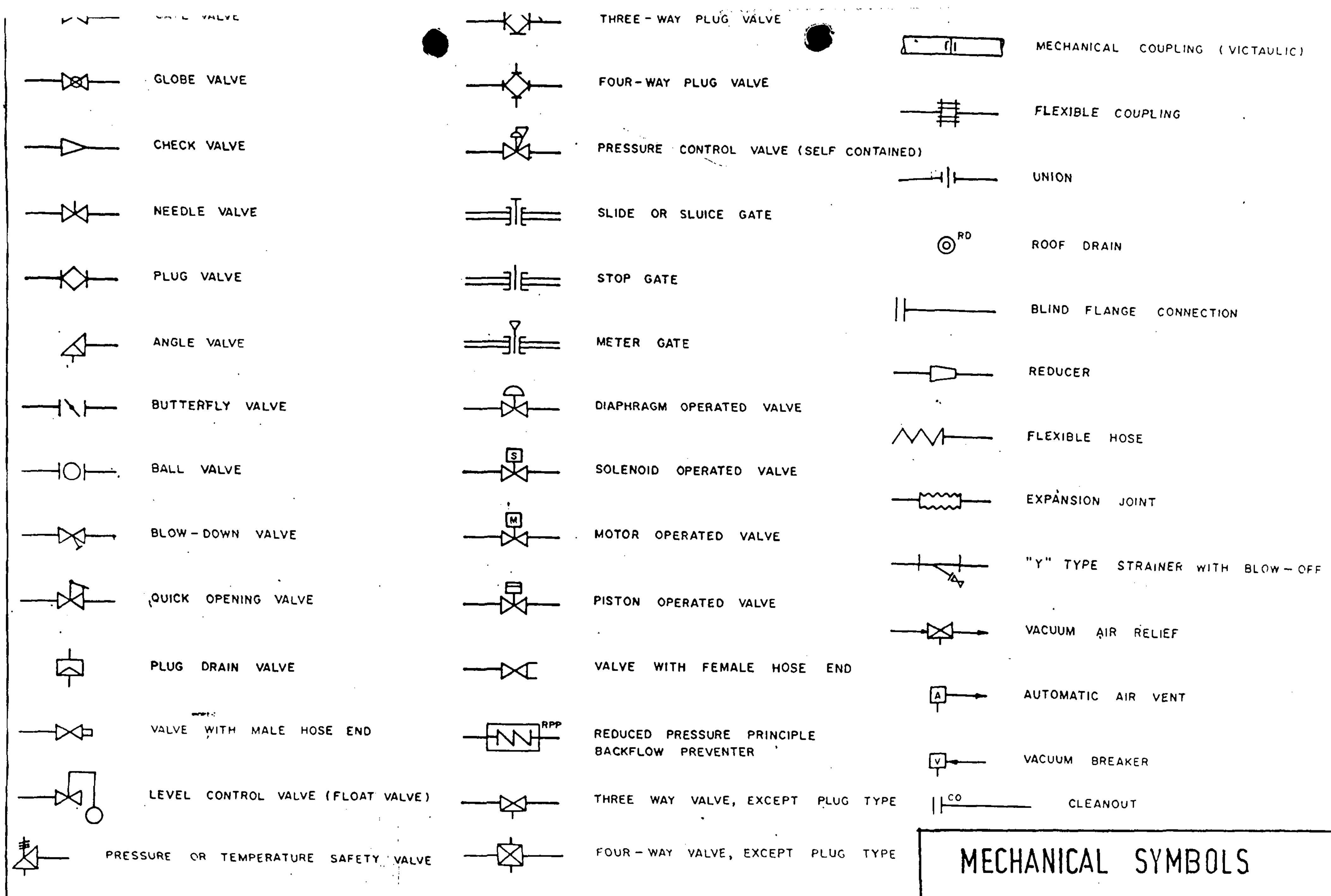
(5) What is the effect of an output which starts at, say 5000 m^3/d and increases year by year at the rate of 3000 m^3/d per annum until the maximum average output of 20,000 m^3/d is reached and maintained?

(6) What is the likely further development when the demand exceeds the output of the source? Will the pipeline be required to carry more water from an additional source for the whole or part of its length?

ANNEX - M

MECHANICAL SYMBOLS

MECHANICAL SYMBOLS



ANNEX - N

ECONOMIC ANALYSIS - PRESENT VALUE CALCULATION

TABLE	N.1	TERMINAL VALUE OF A SINGLE SUM AT COMPUND INTEREST
TABLE	N.2	PRESENT VALUE OF A SINGLE SUM
TABLE	N.3	PRESENT VALUE OF AN ANNUITY
TABLE	N.4	SINKING FUND

ECONOMIC ANALYSIS - PRESENT VALUE CALCULATION

Assume:

a. Initial cost of pumps, C = Rs. 100,000/-

b. Service life of pumps, n_1 = 15 years

c. Annual O&M costs:

c.1 Labour L = Rs. 10,000/-

c.2 Electric power, P = Rs. 12,000/- initially, Rs. 20,000/- at design year

d. Discount rate, r = 9%

e. Design period, n_2 = 20 years

$$\text{Present Value,} \quad PV = \frac{C}{(1+r)^n}$$

Solution:

a. Present Worth of Capital Cost

Initial Cost	Rs.	100,000
Present value of pumps replaced in 15 years:		
Replacement Cost PV $= \frac{100,000}{(1+0.09)^{15}}$	=	27,450
Present value of Capital Investment	Rs.	127,450
Less present value of pumps salvaged at end of design period:		
Salvage value $= \frac{\text{Rs. } 100,000}{15 \text{ years}}$. (5 yrs)	= Rs.	33,330
Present value of salvage value $= \frac{33,330}{(1+0.09)^{20}}$	= Rs.	5,950
Net Present value of Capital Investment	= Rs.	121,500

b. Present Value of O&M Cost

Present value of labour $PV = L \times \frac{(1+r)^n - 1}{r(1+r)^n} = \text{Rs. } 10,000 \times \frac{(1+0.09)^{20} - 1}{(0.09)(1+0.09)^{20}}$

= Rs. 91,280

Present value of electrical power includes uniform cost of power at Rs. 12,000/yr. and gradient cost ofRs. 400/yr.

Present value of uniform power cost = Rs. 12,000 (9.128) = Rs. 109,540

Present value of gradient power cost, $G = \frac{G}{r(1+r)^n} \cdot \left(\frac{((1+r)^n - 1)}{r} - 20 \right)$

$$= \frac{\text{Rs. } 400}{(0.09)(1+0.09)^{20}} \left(\left(\frac{(1+0.09)^{20} - 1}{0.09} \right) - 20 \right) = \text{Rs. } 24,710$$

Present value of O&M	Rs.225,530
Total Present value of Capital and O&M	Rs. 347,030

TABLE N .1

TABLE 1. TERMINAL VALUE OF A SINGLE SUM AT COMPOUND INTEREST

The amount to which £1 will increase in n years with interest rate r per annum $= (1+r)^n$. (See note A)

Interest % (=100r)

n (years)	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5
1	1·0100	1·0150	1·0200	1·0250	1·0300	1·0350	1·0400	1·0450	1·0500	1·0550
2	1·0201	1·0302	1·0404	1·0506	1·0609	1·0712	1·0816	1·0920	1·1025	1·1130
3	1·0303	1·0457	1·0612	1·0769	1·0927	1·1087	1·1249	1·1412	1·1576	1·1742
4	1·0406	1·0614	1·0824	1·1038	1·1255	1·1475	1·1699	1·1925	1·2155	1·2388
5	1·0510	1·0773	1·1041	1·1314	1·1593	1·1877	1·2167	1·2462	1·2763	1·3070
6	1·0615	1·0934	1·1262	1·1597	1·1941	1·2293	1·2653	1·3023	1·3401	1·3788
7	1·0721	1·1098	1·1487	1·1887	1·2299	1·2723	1·3159	1·3609	1·4071	1·4547
8	1·0829	1·1265	1·1717	1·2184	1·2668	1·3168	1·3686	1·4221	1·4775	1·5347
9	1·0937	1·1434	1·1951	1·2489	1·3048	1·3629	1·4233	1·4861	1·5513	1·6191
10	1·1046	1·1605	1·2190	1·2801	1·3439	1·4106	1·4802	1·5530	1·6289	1·7081
11	1·1157	1·1779	1·2434	1·3121	1·3842	1·4600	1·5395	1·6229	1·7103	1·8021
12	1·1268	1·1956	1·2682	1·3449	1·4258	1·5111	1·6010	1·6959	1·7959	1·9012
13	1·1381	1·2136	1·2936	1·3785	1·4685	1·5640	1·6651	1·7722	1·8856	2·0058
14	1·1495	1·2318	1·3195	1·4130	1·5126	1·6187	1·7317	1·8519	1·9799	2·1161
15	1·1610	1·2502	1·3459	1·4483	1·5580	1·6753	1·8009	1·9353	2·0789	2·2325
16	1·1726	1·2690	1·3728	1·4845	1·6047	1·7340	1·8730	2·0224	2·1829	2·3553
17	1·1843	1·2880	1·4002	1·5216	1·6528	1·7947	1·9479	2·1134	2·2920	2·4848
18	1·1961	1·3073	1·4282	1·5597	1·7024	1·8575	2·0258	2·2085	2·4066	2·6215
19	1·2081	1·3270	1·4568	1·5986	1·7535	1·9225	2·1068	2·3079	2·5269	2·7656
20	1·2202	1·3469	1·4859	1·6386	1·8061	1·9898	2·1911	2·4117	2·6533	2·9178
25	1·2824	1·4509	1·6406	1·8539	2·0938	2·3632	2·6658	3·0054	3·3864	3·8134
30	1·3478	1·5631	1·8114	2·0976	2·4273	2·8068	3·2434	3·7453	4·3219	4·9840
35	1·4166	1·6839	1·9999	2·3732	2·8139	3·3336	3·9461	4·6673	5·5160	6·5138
40	1·4889	1·8140	2·2080	2·6851	3·2620	3·9593	4·8010	5·8164	7·0400	8·5133
45	1·5648	1·9542	2·4379	3·0379	3·7816	4·7024	5·8412	7·2482	8·9850	11·127
50	1·6446	2·1052	2·6916	3·4371	4·3839	5·5849	7·1067	9·0326	11·467	14·542
55	1·7286	2·2679	2·9717	3·8888	5·0821	6·6331	8·6464	11·256	14·636	19·006
60	1·8167	2·4432	3·2810	4·3998	5·8916	7·8781	10·519	14·027	18·679	24·840

Interest % (=100r)

n (years)	6·0	6·5	7·0	7·5	8·0	9·0	10·0	12·0	15·0	20·0
1	1·0600	1·0650	1·0700	1·0750	1·0800	1·0900	1·1000	1·1200	1·1500	1·2000
2	1·1236	1·1342	1·1449	1·1556	1·1664	1·1881	1·2100	1·2544	1·3225	1·4400
3	1·1910	1·2079	1·2250	1·2423	1·2597	1·2950	1·3310	1·4049	1·5209	1·7280
4	1·2625	1·2865	1·3108	1·3355	1·3605	1·4116	1·4641	1·5735	1·7490	2·0736
5	1·3382	1·3701	1·4026	1·4356	1·4693	1·5386	1·6105	1·7623	2·0114	2·4883
6	1·4185	1·4591	1·5007	1·5433	1·5869	1·6771	1·7716	1·9738	2·3131	2·9860
7	1·5036	1·5540	1·6058	1·6590	1·7138	1·8280	1·9487	2·2107	2·6600	3·5832
8	1·5938	1·6550	1·7182	1·7835	1·8509	1·9926	2·1436	2·4760	3·0590	4·2998
9	1·6895	1·7626	1·8385	1·9172	1·9990	2·1719	2·3579	2·7731	3·5179	5·1598
10	1·7908	1·8771	1·9672	2·0610	2·1589	2·3674	2·5937	3·1058	4·0456	6·1917
11	1·8983	1·9992	2·1049	2·2156	2·3316	2·5804	2·8531	3·4785	4·6524	7·4301
12	2·0122	2·1291	2·2522	2·3818	2·5182	2·8127	3·1384	3·8960	5·3502	8·9161
13	2·1329	2·2675	2·4098	2·5604	2·7196	3·0658	3·4523	4·3635	6·1528	10·699
14	2·2609	2·4149	2·5785	2·7524	2·9372	3·3417	3·7975	4·8871	7·0757	12·839
15	2·3966	2·5718	2·7590	2·9589	3·1722	3·6425	4·1772	5·4736	8·1371	15·407
16	2·5404	2·7390	2·9522	3·1808	3·4259	3·9703	4·5950	6·1304	9·3576	18·488
17	2·6928	2·9170	3·1588	3·4194	3·7000	4·3276	5·0545	6·8660	10·761	22·186
18	2·8543	3·1067	3·3799	3·6758	3·9960	4·7171	5·5599	7·6900	12·375	26·623
19	3·0256	3·3086	3·6165	3·9515	4·3157	5·1417	6·1159	8·6128	14·232	31·948
20	3·2071	3·5236	3·8697	4·2479	4·6610	5·6044	6·7275	9·6463	16·367	38·338
25	4·2919	4·8277	5·4274	6·0983	6·8485	8·6231	10·835	17·000	32·919	95·396
30	5·7435	6·6144	7·6123	8·7550	10·063	13·268	17·449	29·960	66·212	237·38
35	7·6861	9·0623	10·677	12·569	14·785	20·414	28·102	52·800	133·18	590·67
40	10·286	12·416	14·974	18·044	21·725	31·409	45·259	93·051	267·86	1469·8
45	13·765	17·011	21·002	25·905	31·920	48·327	72·890	163·99	538·77	3657·3
50	18·420	23·307	29·457	37·190	46·902	74·358	117·39	289·00	1083·7	9100·4
55	24·650	31·932	41·315	53·391	68·914	114·41	189·06	509·32	2179·7	22644
60	32·988	43·750	57·946	76·649	101·26	176·03	304·50	897·59	4384·1	56346

SOURCE, TABLES 1-4 AN INTRODUCTION TO ENGINEERING ECONOMICS, ICE, 1969

TABLE N.2

TABLE 2. PRESENT VALUE OF A SINGLE SUM

The present value of £1 n years hence, when discounted at interest rate r per annum $= (1+r)^{-n}$. (See note B)

Interest % (=100r)

n (years)	1	1·5	2	2·5	3	3·5	4	4·5	5	5·5
1	0·99010	0·98522	0·98039	0·97561	0·97087	0·96618	0·96154	0·95694	0·95238	0·94787
2	0·98030	0·97066	0·96117	0·95181	0·94260	0·93351	0·92456	0·91573	0·90703	0·89845
3	0·97059	0·95632	0·94232	0·92860	0·91514	0·90194	0·88900	0·87630	0·86384	0·85161
4	0·96098	0·94218	0·92385	0·90595	0·88849	0·87144	0·85480	0·83856	0·82270	0·80722
5	0·95147	0·92826	0·90573	0·88385	0·86261	0·84197	0·82193	0·80245	0·78353	0·76513
6	0·94205	0·91454	0·88797	0·86230	0·83748	0·81350	0·79031	0·76790	0·74622	0·72525
7	0·93272	0·90103	0·87056	0·84127	0·81309	0·78599	0·75992	0·73483	0·71068	0·68744
8	0·92348	0·88771	0·85349	0·82075	0·78941	0·75941	0·73069	0·70319	0·67684	0·65160
9	0·91434	0·87459	0·83676	0·80073	0·76642	0·73373	0·70259	0·67290	0·64461	0·61763
10	0·90529	0·86167	0·82035	0·78120	0·74409	0·70892	0·67556	0·64393	0·61391	0·58543
11	0·89632	0·84893	0·80426	0·76214	0·72242	0·68495	0·64958	0·61620	0·58468	0·55491
12	0·88745	0·83639	0·78849	0·74356	0·70138	0·66178	0·62460	0·58966	0·55684	0·52598
13	0·87866	0·82403	0·77303	0·72542	0·68095	0·63940	0·60057	0·56427	0·53032	0·49856
14	0·86996	0·81185	0·75788	0·70773	0·66112	0·61778	0·57748	0·53997	0·50507	0·47257
15	0·86135	0·79985	0·74301	0·69047	0·64186	0·59689	0·55526	0·51672	0·48102	0·44793
16	0·85282	0·78803	0·72845	0·67363	0·62317	0·57671	0·53391	0·49447	0·45811	0·42458
17	0·84438	0·77637	0·71416	0·65720	0·60502	0·55720	0·51337	0·47318	0·43630	0·40245
18	0·83602	0·76491	0·70016	0·64117	0·58739	0·53836	0·49363	0·45280	0·41552	0·38147
19	0·82774	0·75361	0·68643	0·62553	0·57029	0·52016	0·47464	0·43330	0·39573	0·36158
20	0·81954	0·74247	0·67297	0·61027	0·55368	0·50257	0·45639	0·41464	0·37689	0·34273
25	0·77977	0·68921	0·60953	0·53939	0·47761	0·42315	0·37512	0·33273	0·29530	0·26223
30	0·74192	0·63976	0·55207	0·47674	0·41199	0·35628	0·30832	0·26700	0·23138	0·20064
35	0·70591	0·59387	0·50003	0·42137	0·35538	0·29998	0·25342	0·21425	0·18129	0·15352
40	0·67165	0·55126	0·45289	0·37243	0·30656	0·25257	0·20829	0·17193	0·14205	0·11746
45	0·63905	0·51171	0·41020	0·32917	0·26444	0·21266	0·17120	0·13796	0·11130	0·08988
50	0·60804	0·47500	0·37153	0·29094	0·22811	0·17905	0·14071	0·11071	0·08720	0·06877
55	0·57853	0·44093	0·33650	0·25715	0·19677	0·15076	0·11566	0·08884	0·06833	0·05262
60	0·55045	0·40930	0·30478	0·22728	0·16973	0·12693	0·09506	0·07129	0·05354	0·04026

Interest % (=100r)

n (years)	6	6·5	7	7·5	8	9	10	12	15	20
1	0·94340	0·93897	0·93458	0·93023	0·92593	0·91743	0·90909	0·89286	0·86957	0·83333
2	0·89000	0·88166	0·87344	0·86533	0·85734	0·84168	0·82645	0·79719	0·75614	0·69444
3	0·83962	0·82785	0·81630	0·80496	0·79383	0·77218	0·75131	0·71178	0·65752	0·57870
4	0·79209	0·77732	0·76290	0·74480	0·73503	0·70843	0·68301	0·63552	0·57175	0·48225
5	0·74726	0·72988	0·71299	0·69656	0·68058	0·64993	0·62092	0·56743	0·49718	0·40188
6	0·70496	0·68533	0·66634	0·64796	0·63017	0·59627	0·56447	0·50663	0·43233	0·33490
7	0·66506	0·64351	0·62275	0·60275	0·58349	0·54703	0·51316	0·45235	0·37594	0·27908
8	0·62741	0·60423	0·58201	0·56070	0·54027	0·50187	0·46651	0·40388	0·32690	0·23257
9	0·59190	0·56735	0·54393	0·52158	0·50025	0·46043	0·42410	0·36061	0·28426	0·19381
10	0·55839	0·53273	0·50835	0·48519	0·46319	0·42241	0·38554	0·32197	0·24718	0·16151
11	0·52679	0·50021	0·47509	0·45134	0·42888	0·38753	0·35049	0·28748	0·21494	0·13459
12	0·49697	0·46968	0·44401	0·41985	0·39711	0·35553	0·31863	0·25668	0·18691	0·11216
13	0·46884	0·44102	0·41496	0·39056	0·36770	0·32618	0·28966	0·22917	0·16253	0·09346
14	0·44230	0·41410	0·38782	0·36331	0·34046	0·29925	0·26333	0·20462	0·14133	0·07789
15	0·41727	0·38883	0·36245	0·33797	0·31524	0·27454	0·23939	0·18270	0·12289	0·06491
16	0·39365	0·36510	0·33873	0·31439	0·29189	0·25187	0·21763	0·16312	0·10686	0·05409
17	0·37136	0·34281	0·31657	0·29245	0·27027	0·23107	0·19784	0·14564	0·09293	0·04507
18	0·35034	0·32189	0·29586	0·27205	0·25025	0·21199	0·17986	0·13004	0·08081	0·03756
19	0·33051	0·30224	0·27651	0·25307	0·23171	0·19449	0·16351	0·11611	0·07027	0·03130
20	0·31180	0·28380	0·25842	0·23541	0·21455	0·17843	0·14864	0·10367	0·06110	0·02608
25	0·23300	0·20714	0·18425	0·16398	0·14602	0·11597	0·09230	0·05882	0·03038	0·01048
30	0·17411	0·15119	0·13137	0·11422	0·09938	0·07537	0·05731	0·03338	0·01510	0·00421
35	0·13011	0·11035	0·09366	0·07956	0·06763	0·04899	0·03558	0·01894	0·00751	0·00169
40	0·09722	0·08054	0·06678	0·05542	0·04603	0·03184	0·02209	0·01075	0·00373	0·00068
45	0·07265	0·05879	0·04761	0·03860	0·03133	0·02069	0·01372	0·00610	0·00186	0·00027
50	0·05429	0·04291	0·03395	0·02689	0·02132	0·01345	0·00852	0·00346	0·00092	0·00011
55	0·04057	0·03132	0·02420	0·01873	0·01451	0·00874	0·00529	0·00196	0·00044	0·00004
60	0·03031	0·02286	0·01726	0·01305	0·00988	0·00568	0·00328	0·00111	0·00023	0·00002

TABLE N.3

TABLE 3. PRESENT VALUE OF AN ANNUITY

The present value of £1 per annum for n years when discounted at interest rate r per annum $=\{(1-(1+r)^{-n})/r\}$. (See note C)
The amount per annum to redeem a loan of £1 at the end of n years and provide interest on the outstanding balance at r per annum can be determined from the reciprocals of values in this table. (See note D)

Interest % (=100r)

n (years)	1	1·5	2	2·5	3	3·5	4	4·5	5	5·5
1	0·9901	0·9852	0·9804	0·9756	0·9709	0·9662	0·9615	0·9569	0·9524	0·9479
2	1·9704	1·9559	1·9416	1·9274	1·9135	1·8997	1·8861	1·8727	1·8594	1·8463
3	2·9410	2·9122	2·8839	2·8560	2·8286	2·8016	2·7751	2·7490	2·7232	2·6979
4	3·9020	3·8544	3·8077	3·7620	3·7171	3·6731	3·6299	3·5875	3·5460	3·5052
5	4·8534	4·7826	4·7135	4·6458	4·5797	4·5151	4·4518	4·3900	4·3295	4·2703
6	5·7955	5·6972	5·6014	5·5081	5·4172	5·3286	5·2421	5·1579	5·0757	4·9955
7	6·7282	6·5982	6·4720	6·3494	6·2303	6·1145	6·0021	5·8927	5·7864	5·6830
8	7·6517	7·4859	7·3255	7·1701	7·0197	6·8740	6·7327	6·5959	6·4632	6·3346
9	8·5660	8·3605	8·1622	7·9709	7·7861	7·6077	7·4353	7·2688	7·1078	6·9522
10	9·4713	9·2222	8·9826	8·7521	8·5302	8·3166	8·1109	7·9127	7·7217	7·5376
11	10·3676	10·0711	9·7868	9·5142	9·2526	9·0015	8·7605	8·5289	8·3064	8·0925
12	11·2551	10·9075	10·5753	10·2578	9·9540	9·6633	9·3851	9·1186	8·8633	8·6185
13	12·1337	11·7315	11·3484	10·9832	10·6350	10·3027	9·9856	9·6829	9·3936	9·1171
14	13·0037	12·5434	12·1062	11·6909	11·2961	10·9205	10·5631	10·2228	9·8986	9·5896
15	13·8650	13·3432	12·8493	12·3814	11·9379	11·5174	11·1184	10·7395	10·3797	10·0376
16	14·7179	14·1313	13·5777	13·0550	12·5611	12·0941	11·6523	11·2340	10·8378	10·4622
17	15·5622	14·9076	14·2919	13·7122	13·1661	12·6513	12·1657	11·7072	11·2741	10·8646
18	16·3983	15·6725	14·9920	14·3534	13·7535	13·1897	12·6593	12·1600	11·6896	11·2461
19	17·2260	16·4262	15·6785	14·9789	14·3238	13·7098	13·1339	12·5933	12·0853	11·6077
20	18·0455	17·1686	16·3514	15·5892	14·8775	14·2124	13·5903	13·0079	12·4622	11·9504
25	22·0231	20·7196	19·5234	18·4244	17·4131	16·4815	15·6221	14·8282	14·0939	13·4139
30	25·8077	24·0158	22·3964	20·9303	19·6004	18·3920	17·2920	16·2889	15·3725	14·5337
35	29·4086	27·0756	24·9986	23·1452	21·4872	20·0007	18·6646	17·4610	16·3742	15·3906
40	32·8347	29·9158	27·3555	25·1028	23·1148	21·3551	19·7928	18·4016	17·1591	16·0461
45	36·0945	32·5523	29·4902	26·8330	24·5187	22·4954	20·7200	19·1563	17·7741	16·5477
50	39·1961	34·9997	31·4236	28·3623	25·7298	23·4556	21·4822	19·7620	18·2559	16·9315
55	42·1472	37·2715	33·1748	29·7140	26·7744	24·2641	22·1086	20·2480	18·6335	17·2252
60	44·9550	39·3803	34·7609	30·9087	27·6756	24·9447	22·6235	20·6380	18·9293	17·4500

Interest % (=100r)

n (years)	6	6·5	7	7·5	8	9	10	12	15	20
1	0·9434	0·9390	0·9346	0·9302	0·9259	0·9174	0·9091	0·8929	0·8696	0·8333
2	1·8334	1·8206	1·8080	1·7956	1·7833	1·7591	1·7355	1·6901	1·6257	1·5278
3	2·6730	2·6485	2·6243	2·6005	2·5771	2·5313	2·4869	2·4018	2·2832	2·1065
4	3·4651	3·4258	3·3872	3·3493	3·3121	3·2397	3·1699	3·0373	2·8550	2·5887
5	4·2124	4·1557	4·1002	4·0459	3·9927	3·8897	3·7908	3·6048	3·3522	2·9906
6	4·9173	4·8410	4·7665	4·6938	4·6229	4·4859	4·3553	4·1114	3·7845	3·3255
7	5·5824	5·4845	5·3893	5·2966	5·2064	5·0330	4·8684	4·5638	4·1604	3·6046
8	6·2098	6·0888	5·9713	5·8573	5·7466	5·5348	5·3349	4·9676	4·4873	3·8372
9	6·8017	6·6561	6·5152	6·3789	6·2469	5·9952	5·7590	5·3282	4·7716	4·0310
10	7·3601	7·1888	7·0236	6·8641	6·7101	6·4177	6·1446	5·6502	5·0188	4·1925
11	7·8869	7·6890	7·4987	7·3154	7·1390	6·8052	6·4951	5·9377	5·2337	4·3271
12	8·3838	8·1587	7·9427	7·7353	7·5361	7·1607	6·8137	6·1944	5·4206	4·4392
13	8·8527	8·5997	8·3577	8·1258	7·9038	7·4869	7·1034	6·4235	5·5831	4·5327
14	9·2950	9·0138	8·7455	8·4892	8·2442	7·7862	7·3667	6·6282	5·7245	4·6106
15	9·7122	9·4027	9·1079	8·8271	8·5595	8·0607	7·6061	6·8109	5·8474	4·6755
16	10·1059	9·7678	9·4466	9·1415	8·8514	8·3126	7·8237	6·9740	5·9542	4·7296
17	10·4773	10·1106	9·7632	9·4340	9·1216	8·5436	8·0216	7·1196	6·0472	4·7746
18	10·8276	10·4325	10·0591	9·7060	9·3719	8·7556	8·2014	7·2497	6·1280	4·8122
19	11·1581	10·7347	10·3356	9·9591	9·6036	8·9501	8·3649	7·3658	6·1982	4·8435
20	11·4699	11·0185	10·5940	10·1945	9·8181	9·1285	8·5136	7·4694	6·2593	4·8696
25	12·7834	12·1979	11·6536	11·1469	10·6748	9·8226	9·0770	7·8431	6·4641	4·9476
30	13·7648	13·0587	12·4090	11·8104	11·2578	10·2737	9·4269	8·0552	6·5660	4·9789
35	14·4982	13·6870	12·9477	12·2725	11·6546	10·5668	9·6442	8·1755	6·6166	4·9915
40	15·0463	14·1455	13·3317	12·5944	11·9246	10·7574	9·7791	8·2438	6·6418	4·9966
45	15·4558	14·4802	13·6055	12·8186	12·1084	10·8812	9·8628	8·2825	6·6543	4·9986
50	15·7619	14·7245	13·8007	12·9748	12·2335	10·9617	9·9148	8·3045	6·6605	4·9995
55	15·9905	14·9028	13·9400	13·0836	12·3186					
60	16·1614	15·0330	14·0392	13·1594	12·3766					

TABLE N.4

TABLE 4. SINKING FUND

The amount per annum for n years at interest rate r per annum needed to accumulate to £1 $= \{r/((1+r)^n-1)\}$. (See note E)
The amount to which £1 per annum will increase in n years when accumulated at interest rate r per annum can be determined from the reciprocals of values in this table. (See note E)

Interest % (= 100r)

n (years)	1	1·5	2	2·5	3	3·5	4	4·5	5	5·5
1	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000
2	0·49751	0·49628	0·49505	0·49383	0·49261	0·49140	0·49020	0·48900	0·48780	0·48662
3	0·33002	0·32838	0·32675	0·32514	0·32353	0·32193	0·32035	0·31877	0·31721	0·31565
4	0·24628	0·24444	0·24262	0·24082	0·23903	0·23725	0·23549	0·23374	0·23201	0·23029
5	0·19604	0·19409	0·19216	0·19025	0·18835	0·18648	0·18463	0·18279	0·18097	0·17918
6	0·16255	0·16053	0·15853	0·15655	0·15460	0·15267	0·15076	0·14888	0·14702	0·14518
7	0·13863	0·13656	0·13451	0·13250	0·13051	0·12854	0·12661	0·12470	0·12282	0·12096
8	0·12069	0·11858	0·11651	0·11447	0·11246	0·11048	0·10853	0·10661	0·10472	0·10286
9	0·10674	0·10461	0·10252	0·10046	0·09843	0·09645	0·09449	0·09257	0·09069	0·08884
10	0·09558	0·09343	0·09133	0·08926	0·08723	0·08524	0·08329	0·08138	0·07950	0·07767
11	0·08645	0·08429	0·08218	0·08011	0·07808	0·07609	0·07415	0·07225	0·07039	0·06857
12	0·07885	0·07668	0·07456	0·07249	0·07046	0·06848	0·06655	0·06467	0·06283	0·06103
13	0·07241	0·07024	0·06812	0·06605	0·06403	0·06206	0·06014	0·05828	0·05646	0·05468
14	0·06690	0·06472	0·06260	0·06054	0·05853	0·05657	0·05467	0·05282	0·05102	0·04928
15	0·06212	0·05994	0·05783	0·05577	0·05377	0·05183	0·04994	0·04811	0·04634	0·04463
16	0·05794	0·05577	0·05365	0·05160	0·04961	0·04768	0·04582	0·04402	0·04227	0·04058
17	0·05426	0·05208	0·04997	0·04793	0·04595	0·04404	0·04220	0·04042	0·03870	0·03704
18	0·05098	0·04881	0·04670	0·04467	0·04271	0·04082	0·03899	0·03724	0·03555	0·03392
19	0·04805	0·04588	0·04378	0·04176	0·03981	0·03794	0·03614	0·03441	0·03275	0·03115
20	0·04542	0·04325	0·04116	0·03915	0·03722	0·03536	0.03358	0·03188	0·03024	0·02868
25	0·03541	0·03326	0·03122	0·02928	0·02743	0·02567	0·02401	0·02244	0·02095	0·01955
30	0·02875	0·02664	0·02465	0·02278	0·02102	0·01937	0·01783	0·01639	0·01505	0·01381
35	0·02400	0·02193	0·02000	0·01821	0·01654	0·01500	0·01358	0·01227	0·01107	0·00997
40	0·02046	0·01843	0·01656	0·01484	0·01326	0·01183	0·01052	0·00934	0·00828	0·00732
45	0·01771	0·01572	0·01391	0·01227	0·01079	0·00945	0·00826	0·00720	0·00626	0·00543
50	0·01551	0·01357	0·01182	0·01026	0·00887	0·00763	0·00655	0·00560	0·00478	0·00406
55	0·01373	0·01183	0·01014	0·00865	0·00735	0·00621	0·00523	0·00439	0·00367	0·00305
60	0·01224	0·01039	0·00877	0·00735	0·00613	0·00509	0·00420	0·00345	0·00283	0·00231

Interest % (= 100r)

n (years)	6	6·5	7	7·5	8	9	10	12	15	20
1	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000
2	0·48544	0·48426	0·48309	0·48193	0·48077	0·47847	0·47619	0·47170	0·46512	0·45455
3	0·31411	0·31258	0·31105	0·30954	0·30803	0·30505	0·30211	0·29635	0·28798	0·27473
4	0·22859	0·22690	0·22523	0·22357	0·22192	0·21867	0·21547	0·20923	0·20027	0·18629
5	0·17740	0·17563	0·17389	0·17216	0·17046	0·16709	0·16380	0·15741	0·14832	0·13438
6	0·14336	0·14157	0·13980	0·13804	0·13632	0·13292	0·12961	0·12323	0·11424	0·10071
7	0·11914	0·11733	0·11555	0·11380	0·11207	0·10869	0·10541	0·09912	0·09036	0·07742
8	0·10104	0·09924	0·09747	0·09573	0·09401	0·09067	0·08744	0·08130	0·07285	0·06061
9	0·08702	0·08524	0·08349	0·08177	0·08008	0·07680	0·07364	0·06768	0·05957	0·04808
10	0·07587	0·07410	0·07238	0·07069	0·06903	0·06582	0·06275	0·05698	0·04925	0·03852
11	0·06679	0·06506	0·06336	0·06170	0·06008	0·05695	0·05396	0·04842	0·04107	0·03110
12	0·05928	0·05757	0·05590	0·05428	0·05270	0·04965	0·04676	0·04144	0·03448	0·02526
13	0·05296	0·05128	0·04965	0·04806	0·04652	0·04357	0·04078	0·03568	0·02911	0·02062
14	0·04758	0·04594	0·04434	0·04280	0·04130	0·03843	0·03575	0·03087	0·02469	0·01689
15	0·04296	0·04135	0·03979	0·03829	0·03683	0·03406	0·03147	0·02682	0·02102	0·01388
16	0·03895	0·03738	0·03586	0·03439	0·03298	0·03030	0·02782	0·02339	0·01795	0·01144
17	0·03544	0·03391	0·03243	0·03100	0·02963	0·02705	0·02466	0·02046	0·01537	0·00944
18	0·03236	0·03085	0·02941	0·02803	0·02670	0·02421	0·02193	0·01794	0·01319	0·00781
19	0·02962	0·02816	0·02675	0·02541	0·02413	0·02173	0·01955	0·01576	0·01134	0·00646
20	0·02718	0·02576	0·02439	0·02309	0·02185	0·01955	0·01746	0·01388	0·00976	0·00536
25	0·01823	0·01698	0·01581	0·01471	0·01368	0·01181	0·01017	0·00750	0·00470	0·00212
30	0·01265	0·01158	0·01059	0·00967	0·00883	0·00734	0·00608	0·00414	0·00230	8·46 –4*
35	0·00897	0·00806	0·00723	0·00645	0·00580	0·00464	0·00369	0·00232	0·00113	3·39 –4*
40	0·00646	0·00569	0·00501	0·00440	0·00386	0·00296	0·00226	0·00130	5·62 –4*	1·36 –4*
45	0·00470	0·00406	0·00350	0·00301	0·00259	0·00190	0·00139	7·36 –4*	2·79 –4*	5·47 –5*
50	0·00344	0·00291	0·00246	0·00207	0·00174	0·00123	8·59 –4*	4·17 –4*	1·39 –4*	2·20 –5*
55	0·00253	0·00210	0·00174	0·00143	0·00118					
60	0·00187	0·00152	0·00123	0·00010	0·00080					

* The figures –4 or –5 indicate that the figures preceding them should be multiplied by 10^{-4} or 10^{-5}.

ANNEX - O

METHODS OF LEAKAGE CONTROL

METHODS OF LEAKAGE CONTROL

O.1 GENERAL

Leak detection can take several different forms, each of which requires a greater or lesser input of manpower, materials and equipment; the results, in terms of leakage reduction, should in theory increase with increasing leak detection effort and expenditure.

The first important point to be considered is that for any leakage detection effort to succeed, the resources and incentive must be available to promptly repair all leaks located, or the original effort will have been wasted.

The second important point is that as leak detection effort increases, a point is reached at which the returns, in terms of leakage reduction, start to diminish. This is when detectable leakage has been practically eliminated, with only undetectable leakage remaining.

The next step is to consider ways of tackling the probably substantial portion of leakage that is significant yet does not surface. The methods available are as follows:

- Passive leakage control
- Regular and intensive sounding surveys
- District or sub-system metering
- Waste metering
- Pressure control

Passive leakage control requires the least effort, and does not involve any attempt to locate or detect leakage. Only visible and reported leakage is attended to. This is the system which has been operated by NWSDB in the past. The other methods of leakage control are discussed in the following sections. Reference may also be made to Ref. (26) which includes a comprehensive report on methods of leakage control, the subject of much attention in the U.K. over the past few years.

O.2 SOUNDING SURVEYS

This method involves the systematic sounding, by special crews of technicians, of all mains, valves, hydrants, consumer services and meters. The method is completely flexible and effort can be intensified or reduced as the need of a particular area requires. Instruments are required to locate pipelines so that they can be closely followed, and leak detection is based on electronic or mechanical amplification of the noise of the leak.

Water escaping from an orifice or crack in a pipe under pressure loses energy to the pipe wall and to the surrounding soil, causing sound waves in the audible range to be set up. Characteristically there are three types of sound generated:

- a higher frequency hissing sound due to vibration of the pipe wall, which is transmitted for some distance along the pipe, depending on the material and pipe size;
- a lower frequency sound due to water striking the soil around the pipe; and
- a similar low frequency sound due to circulation of water within a soil cavity adjacent to the leak.

Generally, higher pressure leaks are more audible than those at lower pressure, but the pipe material, soil and degree of water logging and type of crack or orifice have an important bearing on the sound produced; for instance, a leaking collar joint in 50 mm galvanized pipe in sand under a paved surface will generally produce more noise than a blown-out 25 mm cock in a 100 mm PVC line in clay under grass. In larger and non-metallic pipes, listening needs to be at closer intervals than is necessary for small metallic pipe. Background noise can be troublesome and some common sounds (e.g. tyre noise on a road, or wind noise) in the same frequency as leak noise can completely obscure the leak. Generally the position of highest sound intensity will indicate the leak position, but this is not always true. It is also important to remember that some leaks do not produce a detectable noise at all.

Instruments for sounding are as follows:

- sounding rod : a steel bar connected to a mechanical earphone device, used for detecting water leakage by sounding. The end of the bar is held in contact with the water pipe or valve, and any leakage is likely to be heard as a characteristic leak sound in the earphone. These simple instruments have been found to be invaluable in carrying out leakage surveys.

- geophone : this instrument has two sensing heads, which connect by plastic tubing to a small headset like a doctor's stethoscope. Sound vibrations set up by leakage are picked up and amplified by the sensing heads, placed on the ground over the pipeline. Like the electronic leak detector, the instrument is of most use in detecting leaks under paved surfaces.

- electronic leak detector: usually having a rod for direct sounding and weighted diaphragm for indirect sounding with electronic sound amplification.

- leak noise correlator: an electronic sounding device for sensitive location of remote leaks.

The electronic detectors can be useful instruments in trained hands but in many cases the simple mechanical devices perform as well and sometimes better, owing to the extreme sensitivity of the electronic equipment, which can only be used successfully in conditions of very low external noise with no traffic noise and no wind.

For direct sounding surveys on small distribution lines and consumer service connections, the procedure is to go from house to house in the survey area, carrying out the following:

(i) Visually inspect route of main pipe and service pipe for any signs of leakage on surface; sound any valves or hydrants on main pipe.

(ii) Ask consumer to close all house and garden outlets and sound service line with sounding rod.

(iii) Resound service line with meter valve closed; if leak sound is heard in either (i) or (iii) it will then be evident on which side of meter is the leakage.

(iv) If leak is heard, locate exact position if possible by indirect sounding using geophones or electronic detector.

(v) Advise consumer of any leakage on consumer side of meter.

(vi) Report all leaks to supervisor for prompt repair. (see Fig. O.1 for methods)

For direct sounding surveys on trunk mains and main distribution lines, the procedure is as follows:

(i) Visually inspect route of main for any signs of leakage on surface; sound any valves or hydrants.

(ii) Using boring bar, rod down to contact with main at 100 m intervals; sound for leakage using sounding rod.

(iii) If leak is heard, reduce distance between sounding places until location of maximum noise is found.

(iv) If necessary, use geophone or electronic detector to locate leak by indirect sounding.

(v) Report all leaks to supervisor for prompt repair.

(vi) Report any cases of erosion or vandalism.

The frequency of sounding surveys depends upon the need of particular areas and the level of manpower available. It is normally recommended that each pipeline and service connection be sounded annually under a regular sounding program, or twice a year under an intensive sounding program. As records of the surveys are collected and analysed by the Leak Detection Section it should be possible to refine the surveys, particularly under an intensive program to single out areas which are particularly leakage-prone, for more frequent surveys.

0.3 DISTRICT OR SUB-SYSTEM METERING

This method consists of metering flows into districts, usually of 2,000 to 5,000 properties. By reading the district meters weekly or monthly, it is possible to note any increases in flow which may be due to leakage, and to intensify the sounding surveys in those districts.

All flows into and out of each sub-system should be metered and the sub-system supply is usually found by adding or subtracting the flows recorded on several meters. In some cases it may be necessary to close boundary valves between sub-systems.

After a period of metering each sub-system it is possible to know the average daily flow for that sub-system, and to note any seasonal variations. By plotting the monthly or weekly flows on a graph, any undue variation from the average values may indicate a problem.

One major advantage in a fully metered system is that monthly sub-system supplies may be compared directly with monthly sub-system consumptions, for a regular quantitative assessment of the efficiency or losses in each sub-system. This provides a further indication of sub-systems in which more intensive sounding is required.

The meters used should be well maintained and regularly tested for accuracy, and for this purpose a small field crew is required. All meters should be adequately protected in chambers or boxes, locking where necessary. It is advantageous for some meters to have recording capability, to enable the diurnal variation in flow to be investigated. Meters should be sized to pass peak flows without undue head loss and, if possible, small enough to register night flows.

0.4 WASTE METERING

This method involves the division of the system into a number of small metered areas, consisting of from 1,000 to 3,000 properties, which can be isolated from the adjoining areas, with flow into the areas measured by a recording meter. Special meters are available for this purpose, accurate at low rates of flow, and are usually referred to as waste meters. The waste meter may be installed permanently on a by-pass, or may be mobile on a trailer, being connected into the system temporarily via hydrants.

The meter is used normally only to measure night flows. Periodically, each waste meter area will be isolated, the meter connected and a recording made of the night flow. The basis of leak detection comprises interpretation of the minimum night flow, usually recorded between 01.00 and 05.00 hours. By comparing the recording with those of previous night flows, any increase, which may indicate leakage, is noted and a closer inspection of the area is called for. This may take the form of a night-time test, in which the approximate leak location is found by a step-by-step closure of subsection valves within the area, at the same time recording flows through the meter. A large reduction in flow rate when a section valve is closed may indicate a leak in that section. Subsequent day-time surveys are necessary to locate the point of leakage. Normally, measurements of night flows in each area are made at intervals of 4 to 6 months.

This method works well in some systems which are well mapped, valved and maintained, and is particularly suited to systems where consumers are not individually metered, for locating leakage or waste inside properties. The method is able to pick up quite small leaks and to locate them between valves. It requires considerable expenditure on waste meters, chambers and bypass piping and valving and in addition, a considerable amount of night-time tests and inspections, but has the advantage when properly carried out of giving quantitative results of the leak detection and repair effort. One disadvantage of the method is that it cannot distinguish between leakage and legitimate night flow as, for instance, for industrial use or in overnight filling of private storage tanks.

There are several reasons why this method is not suitable for use in Sri Lanka:

- with almost all consumers metered the extent of consumer waste or misuse is limited, and consumers will usually take steps to repair or locate leaks on their premises, made evident by increased water bills;
- the sometimes poor records of system piping and valving effectively prevents isolation of areas in many cases;
- many systems shut down at night-time;
- because of poor day-time supplies in some areas, private storage tanks tend to fill continuously during the night;
- the method requires a considerable amount of night work.

0.5 PRESSURE CONTROL

Pressure can affect the level of leakage from a system in several ways:

- an increase in pressure will cause an increase in system leakage, which may be greater than that predicted by the theoretical square root relationship between flow and pressure; this phenomenon has been investigated by the WRC (26);
- an increase in system pressure may cause a temporary increase in the number and frequency of leaks; the reverse is also true;
- an increase in pressure, by increasing leak flow, will usually make individual leaks easier to locate, both visually and by causing increased leak noise. Leak detection by sounding is difficult or even impossible under very low pressures;
- the effects of suddenly increased pressures due to surge and water hammer, caused by starting or stopping of pumps or rapidly operated valves, can be damaging to pipes, joints, bends, thrust blocks, meters and pressure gauges.

In general, therefore, it can be seen to be advantageous to reduce system pressures wherever possible, while at the same time maintaining minimum pressures throughout the system. There are several ways in which this may be done:

i. Pressure zoning: isolating areas supplied by gravity from existing service reservoirs, and preventing flow to lower zones except with pressure reduction or under emergency conditions.

ii. Reduced pumping heads: where booster pumps are pumping to excessive pressures, reduction of pressure should reduce flow and also the cost of pumping. Pumps may be automatically controlled to pump at a lower pressure at night.

iii. Pressure reducing valves: there are a variety of types: outlet pressures may be fixed, may be a proportion of inlet pressure, or may be varied at different times of the day. However, they require regular and specialized maintenance, careful design and siting, and may require an air-valve downstream.

0.6 OTHER METHODS

There are a few other techniques for leak detection, some primitive and some too complex and expensive for widespread use, though they may be useful in specific leakage problems:

i. Wait and see: a leak is known to exist but cannot be located; by waiting it is hoped that the leak will get worse and become detectable.

ii. Trial digging: expose the main at intervals along its length, looking for the presence of water.

iii. Cut and cap: suitable only for a serious leak on a supply main, the main is isolated and metered; then the main is cut in half, capped and the upstream portion metered; the leaking part of the pipe is repeatedly metered, cut and capped until the leaking length is located.

iv. Tracer gas: this method is suitable for use on supply mains, when a leak is known to exist; it is simple in principle but requires equipment for injecting the gas into the line in the correct quantities, and for later detecting the gas. Formerly, nitrous oxide was the main gas used but recent developments by WRC have led to the use of sulphur hexaflouride, injected at about 7mg/l. The leak site is located by boring sampling holes along the length under investigation, about 150 mm deep and 25 mm in diameter and spaced about the same as the pipeline depth. At the leak, the gas comes out of solution returning to gaseous form, and filters through the soil to collect in the sampling holes nearest the leak. A detector is used to check for the presence of gas in each hole. The method is clearly laborious and relatively expensive.

v. Leak noise correlator : a development of the WRC, this instrument is designed to locate the point of leakage by electronically measuring the time required for the leak noise to reach two microphones, placed on the line at either side of the leak. This method is applicable only if a leak is known to exist. Although commercially available in the U.K., the method is probably too complex for widespread application.

0.7 LEAK DETECTION EQUIPMENT

Besides the leak detectors mentioned in Section 0.2, additional equipment is required for effective leak detection, as follows:

- Electronic metal pipe locator: the locator comprises a transmitter and receiver which utilize loop antennas to locate the pipe or cable. It can be used conductively, with the transmitter connected directly to one end of the pipe by means of a clamp and ground plate or inductively where the pipe is not accessible. The locators are fairly simple to use and work well in practice, though it has been found difficult to follow small service pipes in congested areas.

- Valve box locator: the locator is designed specifically for finding buried or paved-over valves and boxes, and will locate any metallic objects. It has a fully submersible search head, visual and audio detection, adjustable shaft length and will detect large objects up to a metre below surface.

- Boring bar: this consists of a long rod with a heavy sliding handle, to drive the rod down into the ground to make direct contact with the pipe, so that the sounding rod may be used to listen for leakage, or pinpoint a leak position. The boring bar works well in soft ground, but in many urban locations the practice of using large rocks as road base effectively prevents its use since it cannot be driven into the ground.

- Underpressure tapping machine: this machine is for drilling and tapping pipe, and inserting ferrules into water mains under pressure and without the necessity of a shut-down. The machine is capable of installing up to 50 mm ferrules into pipes of diameter 150 mm to 900 mm. Saddles are necessary for tapping into PVC or AC pipelines.

- Test meter: this is a single register magnetic drive meter, supplied with a test report, for use as a calibration meter in a large meter test facility. It has high accuracy at low and high rates of flow.

- Water meters and recorders: for sub-system metering, high-capacity in-line helical rotary type meters suitable for bulk metering are required. Desirable features include magnetic drive, sealed register, and removable mechanism. Portable chart recorders are also useful if they can attach to the meters for recording rate of flow when required.

- Pressure recorders: these should be small, compact and designed to connect easily to pipe fittings or hydrants, and able to measure pressures up to 140 m head. They are available with 24-hour or 7-day clocks.

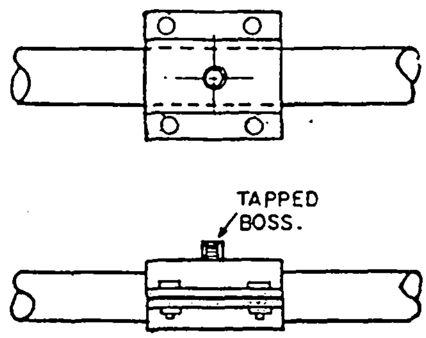
- Deadweight tester: this instrument is used for checking and recalibrating pressure gauges and recorders, and has a range up to 30 kg/cm^2 (300 m head). It consists of an oil reservoir, pump, deadweight column and set of weights.

- Pitometer or insertion flow-meter: for accurate flow measurement by means of a flow velocity profile survey across the pipe diameter.

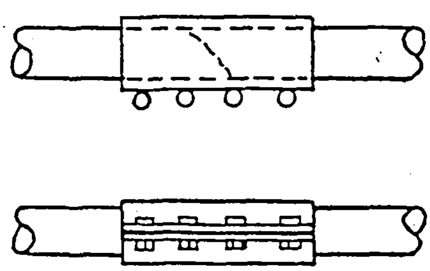
- Pipe cutting tools: steel pipe cutters, pipe reamers, hinged pipe cutters in various sizes, and pipe threading oil.

- Leak repair clamps: these clamps provide for fast, economical repair of pin-holes, punctures, or splits in steel pipe. They may be of band type or wrap-around type. (See Figure 0.1)

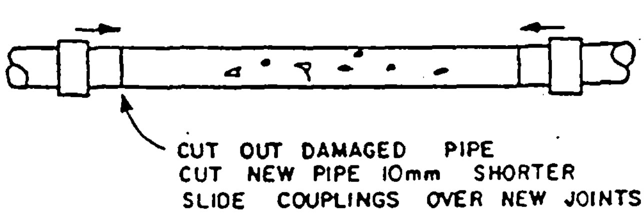
- Pipe Saw: this is an extremely useful tool for rapidly cutting all sizes and types of pipe without the need for pipe cutters or welding torch. It has a 2-cycle motor, and uses 300 mm diameter cutting blades, for either steel or concrete.



DOUBLE STRAP SERVICE SADDLE WITH TAPPED BOSS:
- FOR SERVICE CONNECTION IN PVC
- FOR REPAIR OF BLOWN-OUT SERVICE



STAINLESS STEEL WRAP-AROUND REPAIR CLAMP:
FOR REPAIR OF SHEAR BREAK, SERVICE BLOWOUT, ETC.



DRESSER TYPE COUPLINGS FOR QUICK REPLACEMENT OF DAMAGED PIPE

LEAK REPAIRS

FIGURE 0.1

ANNEX - P

STAFFING FOR OPERATION & MAINTENANCE

NATIONAL WATER SUPPLY AND SANITATION PROJECT SRI LANKA.		TRANSMITTAL REF.No. SHEET No.
TO	Mr. P.U. Gunasinghe - DGM (O&M)	DATE 16/11/1988
FROM	S. de Saram	☐ FOR COMMENTS
SUBJECT	STAFF CADRES FOR SCHEME OPERATION	☐ FOR INFORMATION ☐ FOR CIRCULATION ☐ FOR ACTION

The Operations staff identified here are those staff normally required within the premises of the scheme or pumping section.

Additional operations staff may be required for such situations and locations as:

- Distribution reservoirs with or without pumping facilities
- Operation of valves on distribution systems

Note that casual hired labour should be utilised for those labour intensive activities which need to be performed occasionally; eg. cleaning and replacement of media on slow sand filters. With improved training, greater competance in O&M and better maintained equipment, the staffing cadres could be reduced further. For example the number of Plant Operators at a full treatment plant during the day shift could be reduced from 2 to 1. With a well managed scheme, the number of labourers too could be reduced.

copies to: Dr. R.M. Bradley
Mr. C.H. Tomasides
Mr. G.A. Bridger

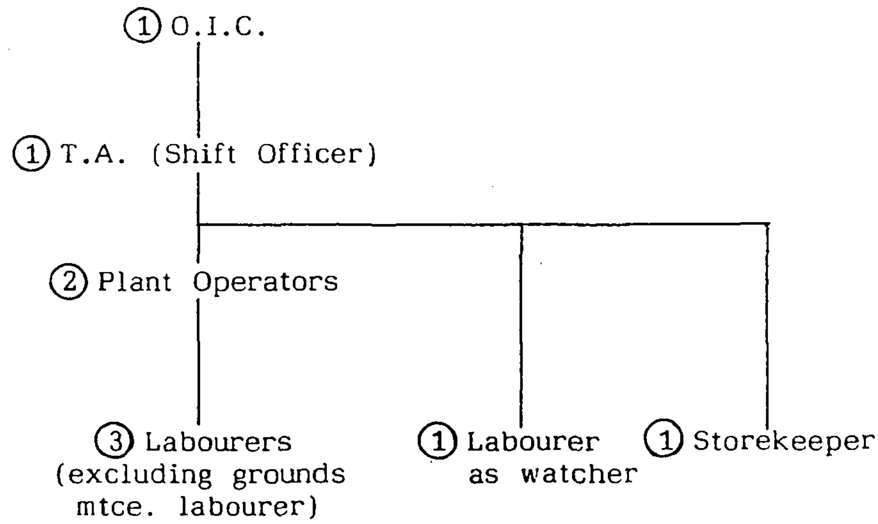
Swastika 1036

OPERATIONS STAFF FOR MAJOR TREATMENT FACILITIES

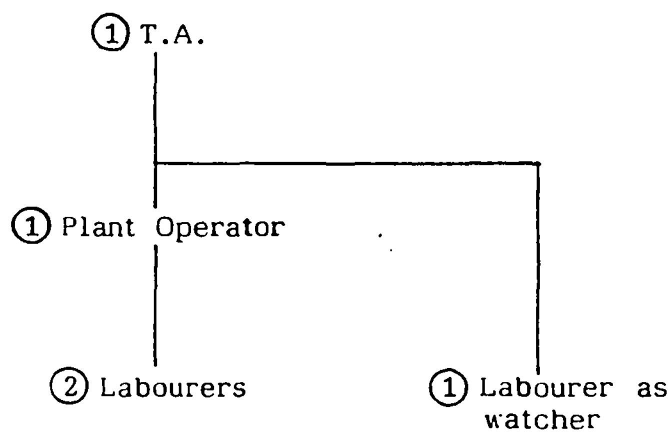
WITH RAW WATER PUMPING STATION CLOSE TO TREATMENT PLANT

eg. Galle, Matara (Nadugala), Kegalle, Tangalle, Negombo

SHIFT 1 (Day Shift)



SHIFTS 2 & 3 (Evening & Night Shifts)



OPERATIONS STAFF FOR MAJOR TREATMENT FACILITIES WITH PUMPING STATION REMOTE FROM TREATMENT PLANT

eg. University (Kandy), Matara (Malimboda), Anuradhapura, Kalutara

SHIFT 1 (Day Shift)

- (1) O.I.C.
  - (1) T.A. (Shift Officer
    - (2) Plant Operators (at Plant)
    - (1) Plant Operator (at RW Pumping Station)
      - (4) Labourers (Distributed between RW Pump Station and Plant as necessity demands) — under both Plant Operator groups above
    - Storekeeper
    - (1) Labourer as Plant watcher

SHIFTS 2 & 3

- (1) T.A.
  - (1) Plant Operator (Treatment Plant)
    - (2) Labourers
  - (1) Plant Operator (RW Pumping Station)
    - (1) Labourer
  - (1) Labourer as Plant watcher

OPERATIONS STAFF FOR LEVEL 2 SCHEMES

(PARTIAL TREATMENT - eg. PUMPING AND CHLORINATION)

WHERE PUMP STATION IS REMOTE FROM CHLORINATION FACILITY

SHIFT 1 (Day Shift)

- (1) O.I.C.
  - (1) T.A. (Shift Officer)
    - (1) Plant Operator (RW Pump Station)
      - (1) Labourer
    - (1) Plant Operator (Chlorination & Storage Facility)
      - (1) Labourer

SHIFTS 2 & 3 (Evening and Night Shift)

- (1) T.A.
  - (1) Plant Operator (If pumps are in Operation)
  - (1) Labourer (If no pumps are in Operation)
  - (1) Labourer At chlorination & storage facility

EXAMPLES OF SHIFT OFFICER'S DUTIES

1. Perform JAR tests to determine optimum values for chemical feeding. Notify plant operator of these values and perform spot checks to ensure that correct dosages are being used.

2. Check correct filling out of Operations forms by plant operators (eg. pump operations, chemical feed, filter, water quality, clarifier etc.).

3. Supervise and if necessary assist in performance of scheduled preventive maintenance, normally executed by plant operators with the assistance of labourers.

4. Spot check - plant operations and inform plant operator of required action. If necessary assist plant operator in performing required tasks.

   eg., ° check pumps/motors for excessive heating, vibration, gland leakage, check filling out of pump operations logs by operators.

   ° Spot check filter operations - are filter records properly filled out by plant operators, occasional check of filter backwash and ensure proper operational procedures are followed.

   ° Check clarifier operation - is the floc settling properly or is it being carried over into filter.

   ° Spot check operation of chlorinators - is dosage correct, are there any leaks, are records being properly maintained.

5. Improve plant O&M with innovative modifications to existing processes, and equipment.

   eg., ° Replace broken flow meters with simple flow measuring devices; improve coagulant mixing using simple weirs; fabricate head loss gauge for measuring filter head loss; install staff gauges to measure filtration rate, filter backwash rate, rate of chemical feed, water levels in tanks etc.

EXAMPLES OF PLANT OPERATORS' DUTIES

1. Pumps and Motors - Maintain pump operations records. Regular checks of pump operation (temp., vibration, gland leakage, pressure, flow, unusual noises, etc.). Report any abnormal condition to shift officer.

2. Filters - Maintain filter operation records. Backwash filters at specified intervals in accordance with standard operation procedures. Observe filter media condition at every backwash and notify shift officer of any abnormal conditions (media cracks, algae growths, etc.).

3. Clarifier - Regular observation of condition of clarifier. Ensure proper clarifier operation in accordance with standard operating procedures.

Report any malfunction (inability to form dense settleable floc. etc.) to shift officer.

4. Chemical Feed - Maintain chemical feed records and ensure correct quantity of chemical is being dosed, check condition of feed pumps (leakage etc.) and report any abnormal condition to shift officer.

5. Chlorination : Ensure chlorine feed rates are being maintained at proper levels.

Maintain chlorine operation records.

6. Perform routine preventive maintenance with the assistance of the shift officer if necessary.

S. de Saram.

Sdes/sh:
17/11/88