WRC WATER RESEARCH CENTRE

ER 744 March 1980 65/27990

THE EFFECTS OF FLUSHING AT THE CONSUMER'S TAP TO REDUCE DRINKING WATER LEAD LEVELS

1. Introduction

1.1 This report has been prepared for the Lead in Potable Water Sub-Committee of STACWQ, to summarise the data available from WRC studies on the effectiveness of flushing as a means of reducing drinking water lead levels.

2. Summary

2.1 From the available data it is concluded that flushing at the consumer's tap could be an effective, low cost means of reducing drinking water lead levels.

3. Effectiveness of flushing

3.1 High drinking water lead levels can arise where water has stood in contact with lead pipes.

3.2 Using data on water lead levels from the Regional Heart Study, flushing has been shown to reduce water lead levels at the consumer's tap. This can be seen in the comparisons of flushed, random daytime and first draw samples taken from properties with lead supply pipes in the eight towns for which data is currently available. (figs 1(a) to 1(i) and Table 1).

3.3 In each case, flushing was carried out in a manner that would comply with the suggestions in this paper, with a considerable safety margin.

3.4 In some cases flushing was effective in reducing lead concentrations to less than 100 µg/l.

3.5 Water supplied to those towns for which data are presented include soft upland, hard groundwater and moderately soft river sources.

4. Suggested rules for flushing

4.1 The effectiveness of flushing depends upon the interrelated variables of the volume of water flushed, and the flow rate used. The volume of water flushed is conveniently considered in terms of the number of pipe volumes.

4.2 Limited experiments have been carried out in a simulated plumbing system in which changes of conductivity were used to indicate the relative mix of 'fresh' and 'standing' water discharged from pipes during flushing at

Registered Office:
45 Station Road,
Henley-on-Thames,
Oxfordshire, RG9 1BW

Medmenham Laboratory,
Medmenham, P.O. Box 16,
Marlow, Bucks, SL7 2HD
049 166 531

various flow rates. Typical results are given in Fig 2.

4.3 The rate of flushing also determines the steady state lead level achieved and results from field experiments are given in Fig 3.

4.4 Considering the data presented in Figs 2 and 3 together, it can be seen that this experimental evidence would suggest that an effective flushing policy, allowing a small margin of safety, would be to flush 1.5 pipe volumes at a rate of between 3 l/min and 10 l/min.

4.5 Flushing smaller volumes would run the risk of achieving little benefit (Fig 2), and using higher flow rates would run the risk of lead levels beginning to increase, perhaps due to disturbance of pipe deposits (Fig 3).

4.6 The flow rate and volume suggested in para 4.4 above would need to be expressed to the consumer in descriptive rather than numerical terms.

4.7 The flow rate of 3 l/min to 10 l/min could perhaps, be described as "a fairly fast rate, but not so fast that excessive splashing occurs".

4.8 The interpretation and description of 1.5 pipe volumes is not so straightforward. Data from 23 large towns in the Regional Heart Study indicate that the average volume of water contained in a ½" pipe between the main and the kitchen tap would be about 4.3 litres (approx 1 gallon or half a washing-up bowl full) and that 95% of such pipes would contain 11.7 litres or less (approx 2½ gallons or a washing-up bowl full). This is consistent with data gathered by the Expert Advisory Group on Costs.

4.9 Clearly, it would be for the water authority to decide upon a recommended flushing volume in any particular area, according to local circumstances.

4.10 Data from stagnation curves for lead pipes indicate that relatively high concentrations of lead are produced by leaving the water in contact with the pipe for even relatively short periods of time. Therefore, when flushing is recommended it is suggested that the consumer should be advised to flush every time water is taken for drinking, cooking or babies' bottles.

4.11 If a flow rate of 10 l/min is used the flushing time would be about ½ minute to be effective in the average case, and about 1¼ minutes to be effective in 95% of cases.

5.9 A comparison of the costs of flushing with other methods of reducing lead levels for a small supply area forming one of the WRC Case Studies is given in Table 3.

6. Conclusions

6.1 Flushing can be an effective means of reducing drinking water lead levels where the kitchen tap is fed directly from the rising main.

6.2 In some cases it is likely to be effective in reducing lead levels to less than 100 µg/1.

6.3 The available evidence suggests that about 4.3 litre (≈ 1 gallon) of water would need to be flushed in the average case, and that flushing 11.7 litres (≈ 2½ gallons) would be effective in 95% of cases.

6.4 Flushing should be carried out at a rate between 3 l/min and 10 l/min.

6.5 To be effective flushing would need to be carried out every time water is drawn for drinking, babies bottles, or cooking.

6.6 Where a water authority decided to implement a flushing policy the advice to the consumer might be "To flush half a washing up bowl-full (for the average case, or a washing up bowl-full to cover 95% of cases) of water at a fairly fast rate but not so fast that excessive splashing occurs".

6.7 Even if the water used in flushing is allowed to run to waste the increase in demand created by a flushing policy would be relatively small for all sizes of supply area. However any increase is likely to be mostly imposed at times of peak demand and there may be operational difficulties in some areas.

6.8 Provided existing installations can meet the small increase in demand, the cost of a flushing policy is very small compared to that of water treatment or pipe replacement.

4.12 Flushing will not reduce lead levels at a kitchen tap which is not fed directly from the rising main.

5. Operational and costs aspects

5.1 The following estimates have been made for a flushing policy that might reduce lead levels effectively in the average case. Estimates of increased water usage and costs would have to be multiplied by a factor of 2.7 to implement a flushing policy that might be effective in 95% of cases.

5.2 Assuming nine flushes per day are required (this is generously consistent with data from the WRC survey of drinking water habits in the UK), this represents 38.7 litres per household/day.

5.3 If this water were all used for some useful purpose for which water would otherwise have been drawn, then the increased usage and cost would be zero.

5.4 If, instead, all of this water were flushed to waste and the water consumption in the average house were 1000 l/day, the increase in demand would be about 4%.

5.5 It is likely that much of this increased demand would be experienced at times of peak flows, and operational constraints may restrict the implementation of a flushing policy.

5.6 Further, if the average production cost of water is $1.5p/m^3$ and all the water used for flushing was wasted, the cost would be about £0.21/household/year.

5.7 Assuming that none of the water used for flushing is used for any other useful purpose the increased water demands and costs for various sizes of supply areas are given in Table 2, together with the likely range of capital and operating costs for water treatment as an alternative means of reducing lead levels.

5.8 It can be seen that in all cases the estimated annual costs of flushing, even if followed by all houses in the supply area, is less than the estimated annual operating costs of water treatment.

TABLE 1. COMPARISON OF FLUSHED, FIRST DRAW AND RANDOM DAYTIME SAMPLES IN VARIOUS TOWNS.

TOWN	SAMPLING RESULTS (only from properties with lead pipes)																	
	FIRST DRAW						RANDOM DAYTIME						FLUSHED					
	No. of Proper-ties	Mean Lead Conc. (µg/l)	Median Lead Conc. (µg/l)	Standard devia-tion (µg/l)	Max. Conc. (µg/l)	No. Props with Pb $\geq$ 100 µg/l	No. of Proper-ties	Mean Lead Conc. (µg/l)	Median Lead Conc. (µg/l)	Standard devia-tion (µg/l)	Max. Conc. (µg/l)	No. Props with Pb $\geq$ 100 µg/l	No. of Proper-ties	Mean Lead Conc. (µg/l)	Median Lead Conc. (µg/l)	Standard devia-tion (µg/l)	Max. Conc. (µg/l)	No. Props with Pb $\geq$ 100 µg/l
A	28	22.0	3.5	35.6	130	2	28	15.2	3.5	22.1	88	0	28	5,6	1	12.1	64	0
B	16	9.0	6	9,0	27	0	16	4.0	1.5	6.7	27	0	16	1.7	1	1.3	5	0
C	15	41.8	40	25,6	91	0	16	31.1	20,5	27.8	101	1	16	23.5	10.0	46.1	193	1
D	12	65.5	7	139,5	490	2	12	8.3	2.5	17.4	63	0	12	1.2	1	0.6	3	0
E	33	30.2	19	31.1	120	1	33	18.2	11	21.9	110	1	31	13.8	5	33.4	150	2
F	33	24.0	17	21.2	73	0	29	12.4	8	15.2	58	0	31	4.4	2	5.5	23	0
G	28	25.5	18	20.8	79	0	29	19.8	11	24.4	120	1	28	4.9	4	3	13	0
H	17	559.0	260	700.6	2660	14	16	305.1	210	400.0	1650	12	16	147,1	128	138.8	490	10

Table 2:

WATER CONSUMPTION IN AREA (Ml/d)	ESTIMATED No. OF DWELLINGS	ESTIMATED No. OF DWELLINGS WITH LEAD PIPES	FLUSHING						POSSIBLE WATER TREATMENT COSTS (£'000)			
			ALL HOUSES			LEAD ONLY HOUSES			SOFT WATER		HARD WATER	
			ANNUAL COST (£'000)		INCREASED DEMAND (Ml/d)	ANNUAL COST (£'000)		INCREASED DEMAND (Ml/d)				
			CAPITAL	OPERATING		CAPITAL	OPERATING		CAPITAL*	OPERATING*	CAPITAL†	OPERATING†
1	1,000	500	None	0.21	0.04	None	0.11	0.02	30 to 60	3.3 to 6.6	10 to 110	1 to 20
5	5,000	2,500	None	1.05	0,2	None	0,53	0.1	50 to 115	10.1 to 13.9	30 to 160	4 to 80
10	10,000	5,000	None	2.1	0.4	None	1.1	0.2	60 to 130	11.2 to 16.1	50 to 200	6 to 150
50	50,000	25,000	None	10.5	2.1	None	5,3	1.0	160 to 220	17.1 to 32	70 to 590	13 to 700
100	100,000	50,000	None	21.0	4.2	None	10.5	2.1	200 to 265	21 to 46	80 to 950	20 to 1400

* Range depends on whether alkalinity increase is necessary or not.

† Range depends on what treatment process used.

TABLE 3. COMPARISON OF COSTS FOR A CASE STUDY AREA

Works throughput 2.5 ml/d. Total No. of properties in supply area 1744
No. of properties with lead pipes 1395

Treatment Measure	Increase in Water Demand (Ml/d)	Cost (£ '000 - 1978)	
		Capital	Annual Operating
Flush at all properties with lead pipes. (marginal cost basis)	0.08	None	0.3
Flush at all properties (marginal cost basis)	0.1	None	0.4
Replacement of all lead pipes	None	565	-
Corrosion Inhibitors* (assumed cost 40 p/kg and dose 5 mg/l)	None	40	5.3
Chemical Treatment - Installation of alternative or modification of present treatment	None	14.9 to 90.2	7.2 to 23.3

*Effect largely unknown.

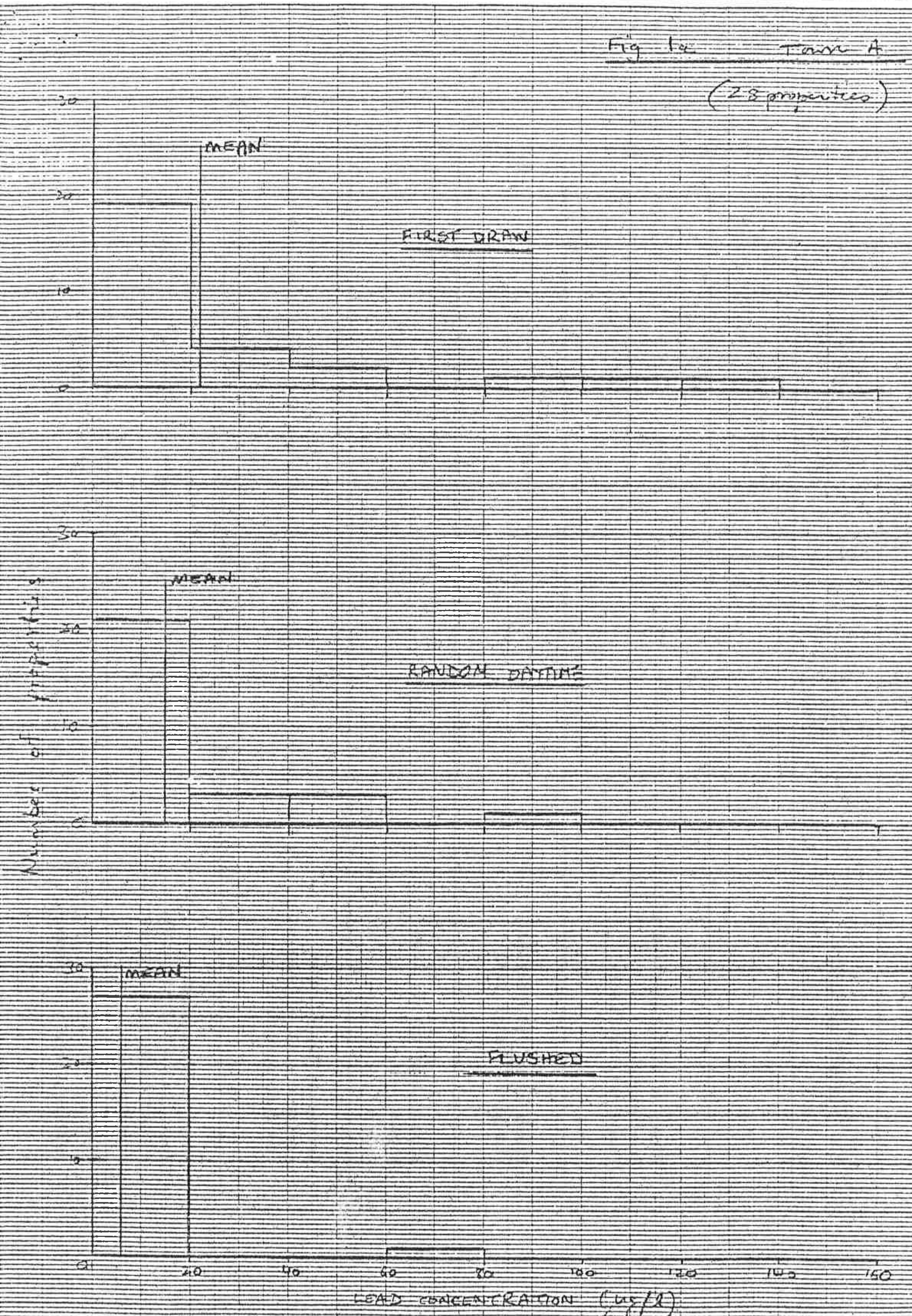


Fig 1a Town A
(28 properties)
MEAN
FIRST DRAW
MEAN
RANDOM DAYTIME
MEAN
FLUSHED
Number of properties
LEAD CONCENTRATION (ug/l)

Fig. 1b TOWN B
(15 properties)

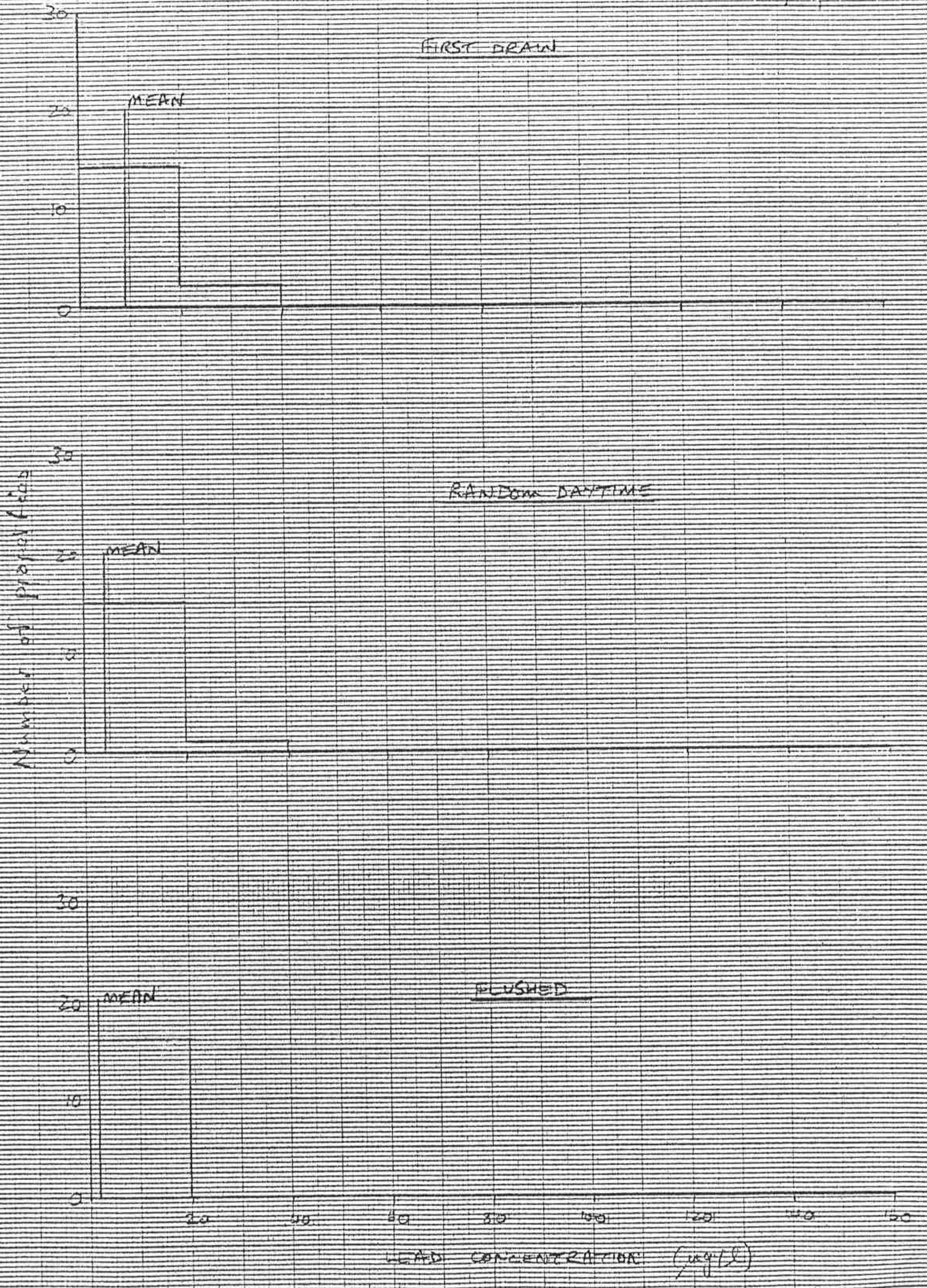


Fig. 1c TOWN C
(16 properties)

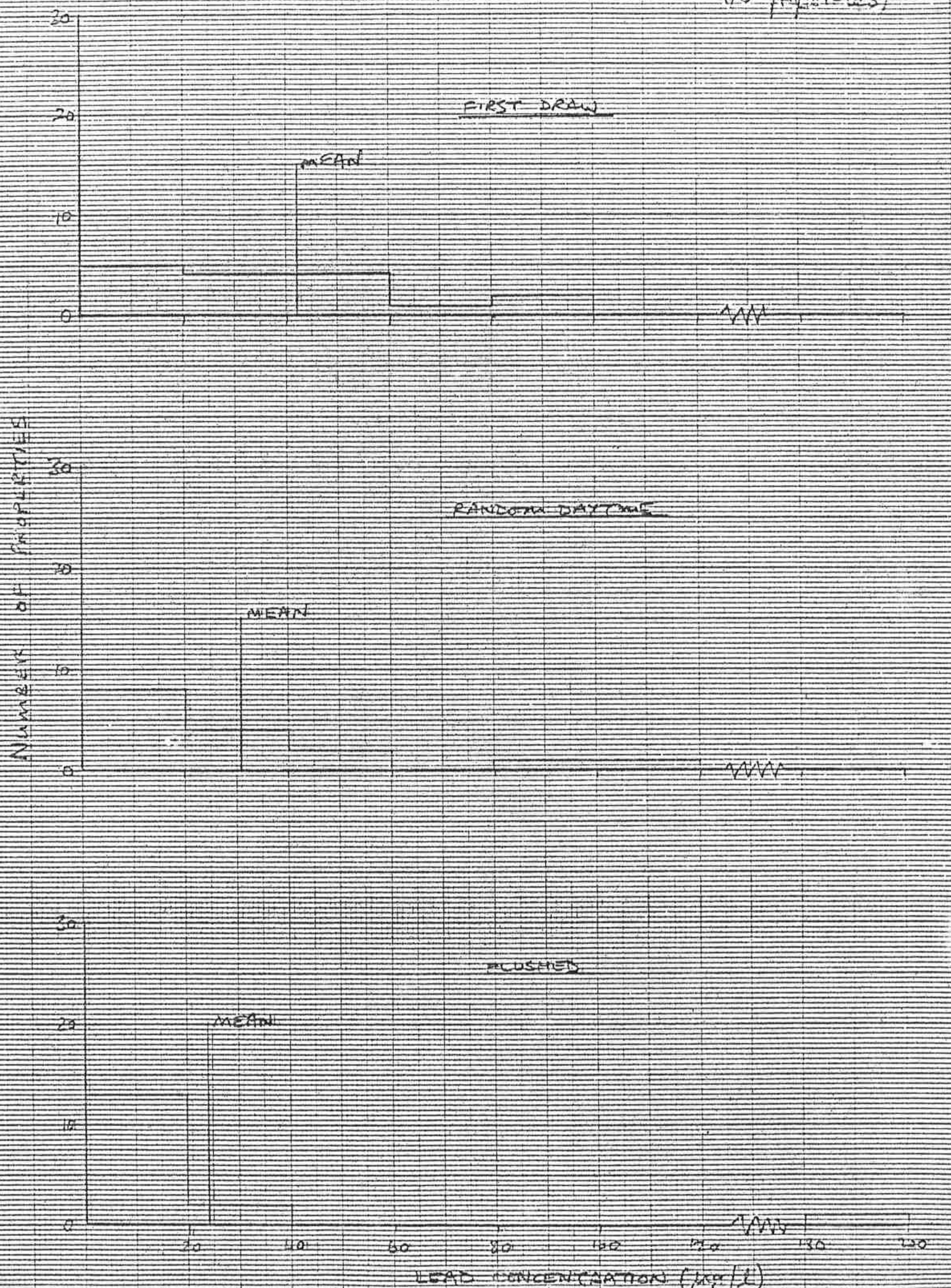


Fig 1d TOWN D
(12 properties)

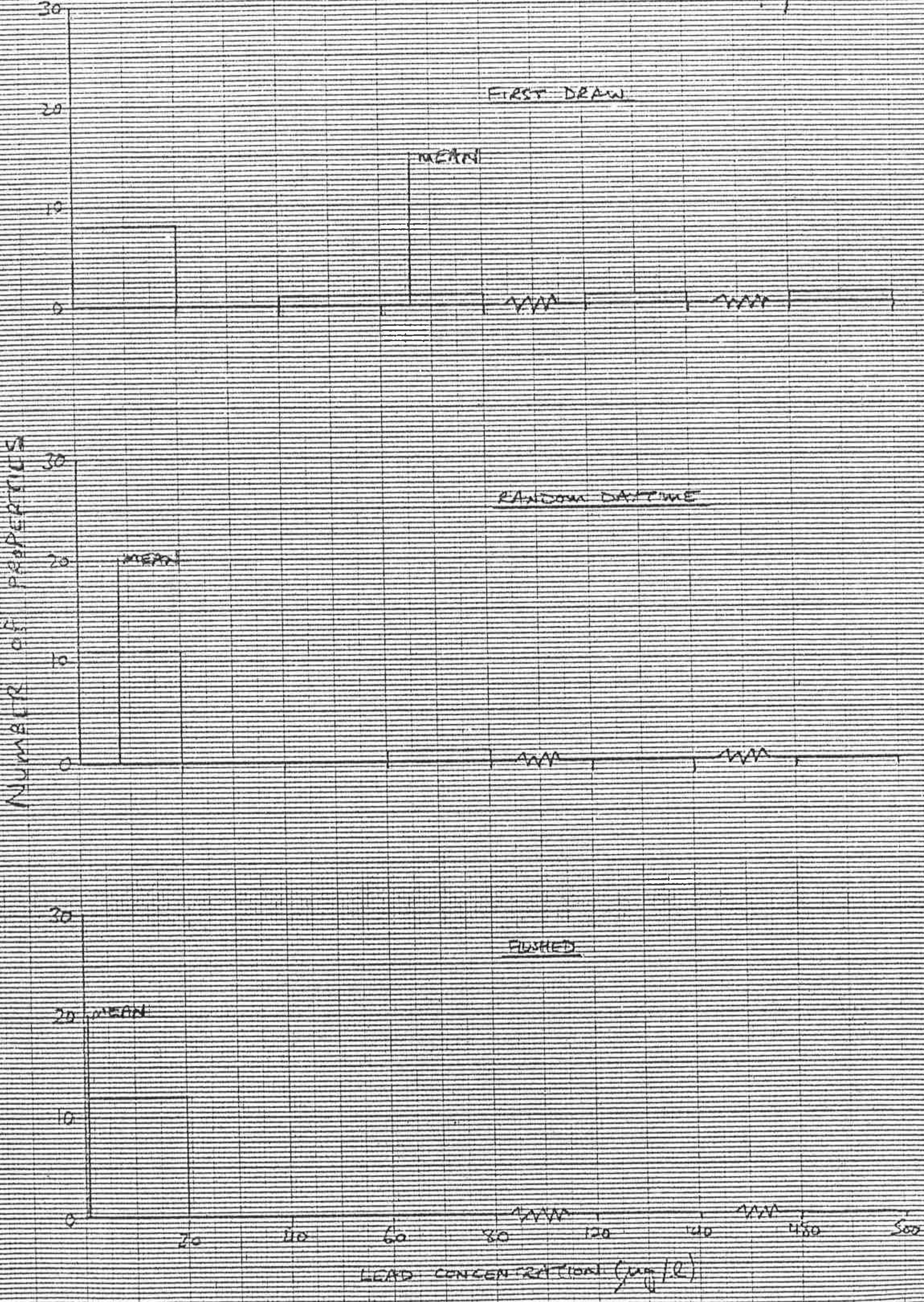


Fig 1e TOWN E
(33 properties)

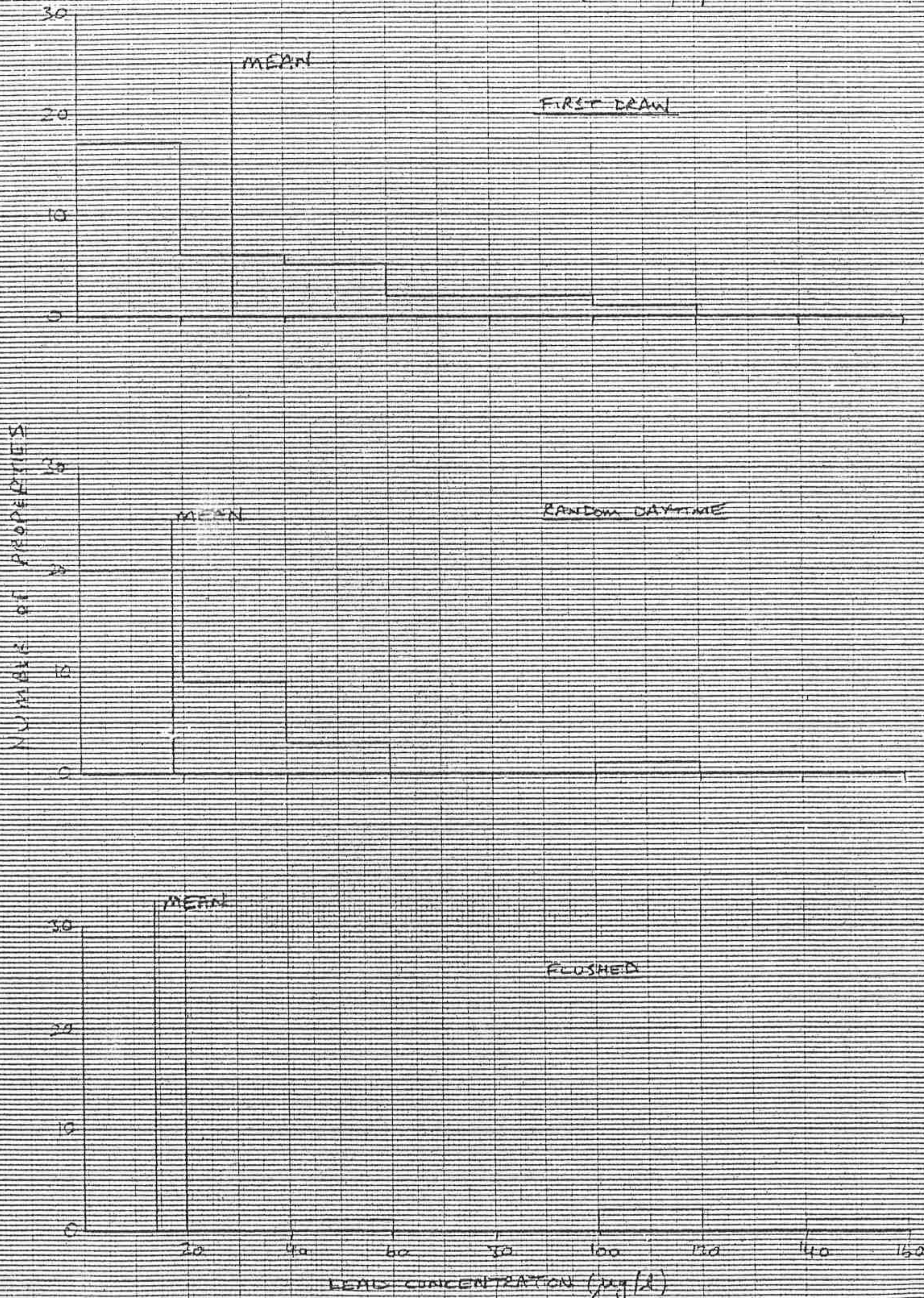
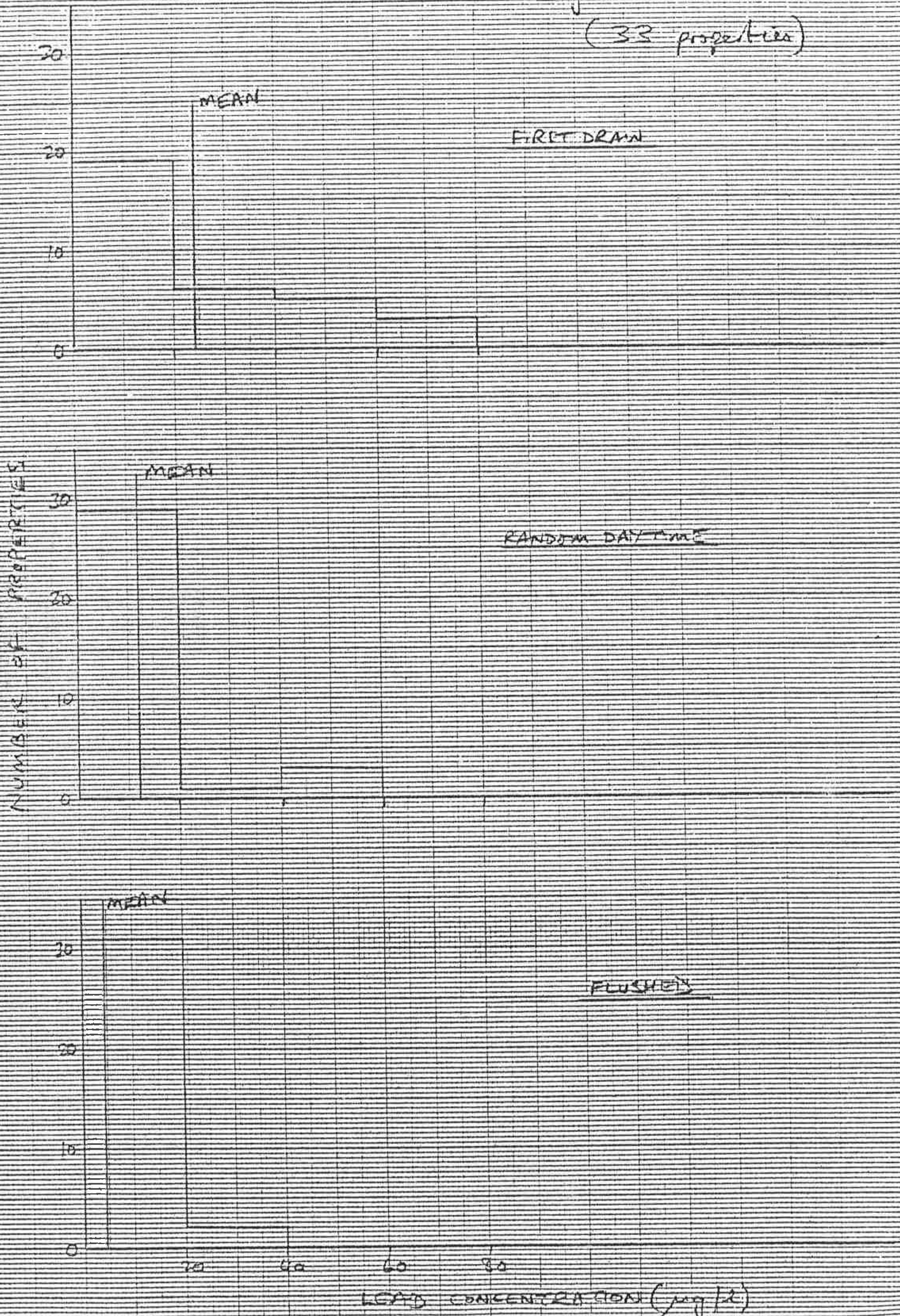


Fig 1F TOWN F

(33 properties)



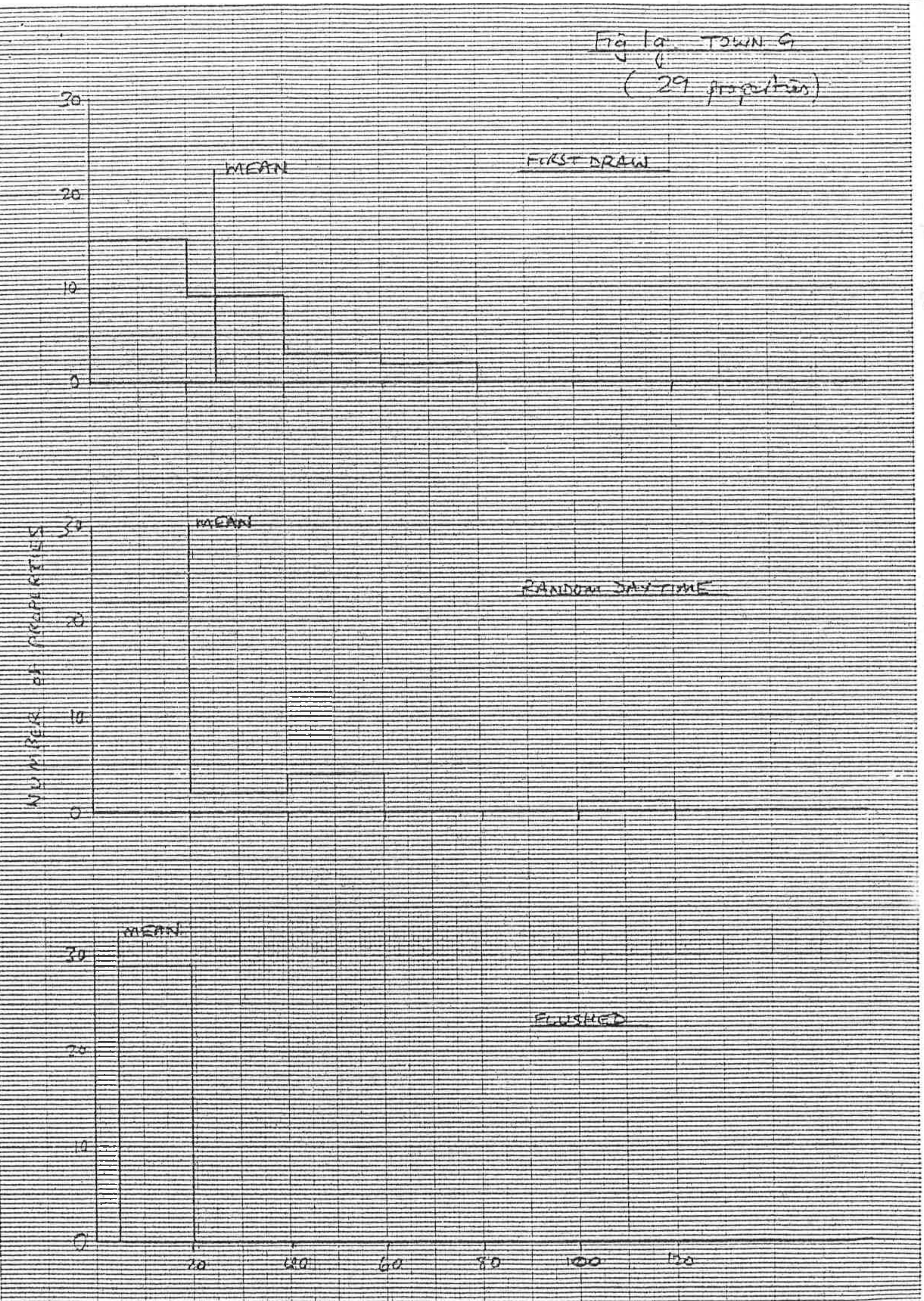


Fig 1a TOWN G
(29 properties)
FIRST DRAW
MEAN
RANDOM DAYTIME
MEAN
FLUSHED
MEAN
NUMBER of PROPERTIES
0
10
20
30
20
40
60
80
100
120

Fig 1h TOWN H
(17 properties)

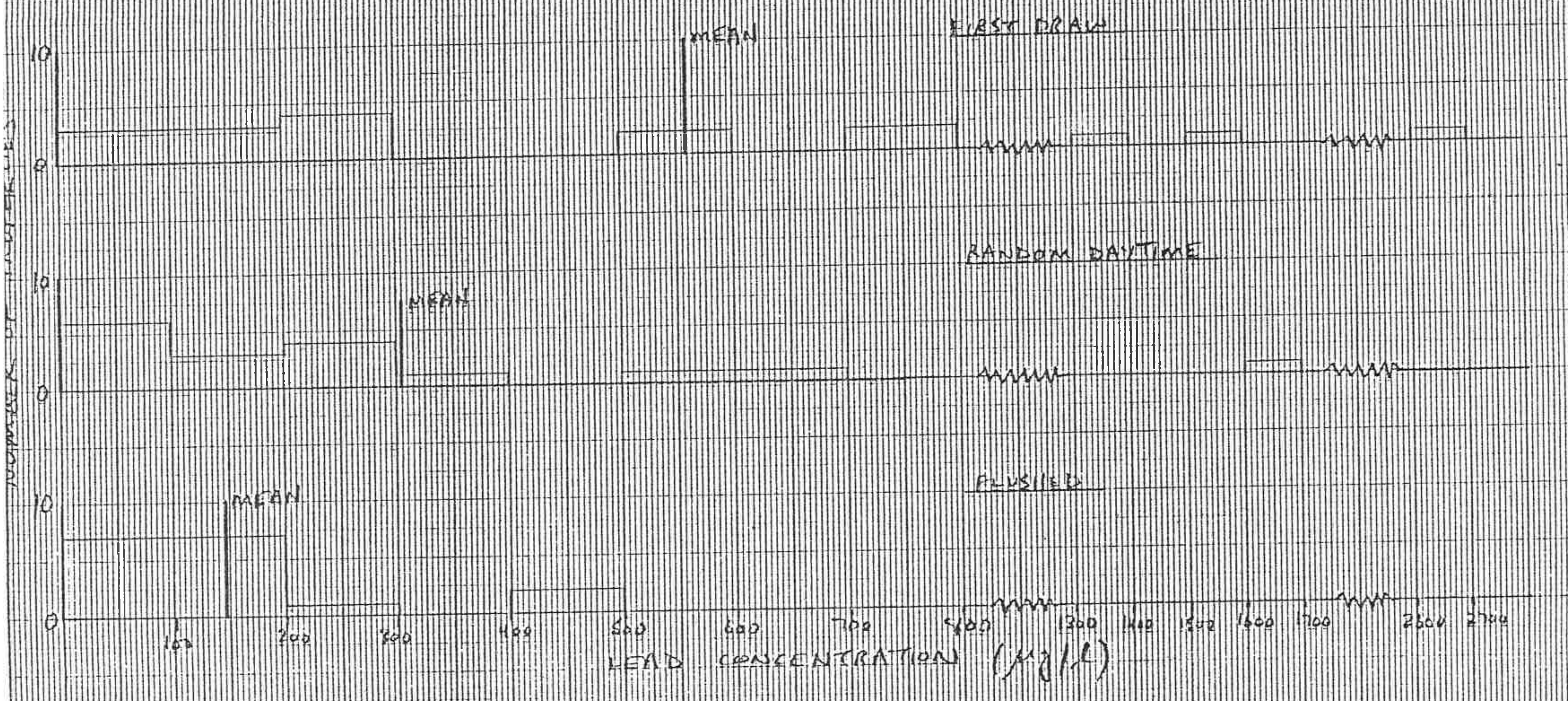


Fig 1i ALL TOWNS EXCLUDING TO

(167 properties)

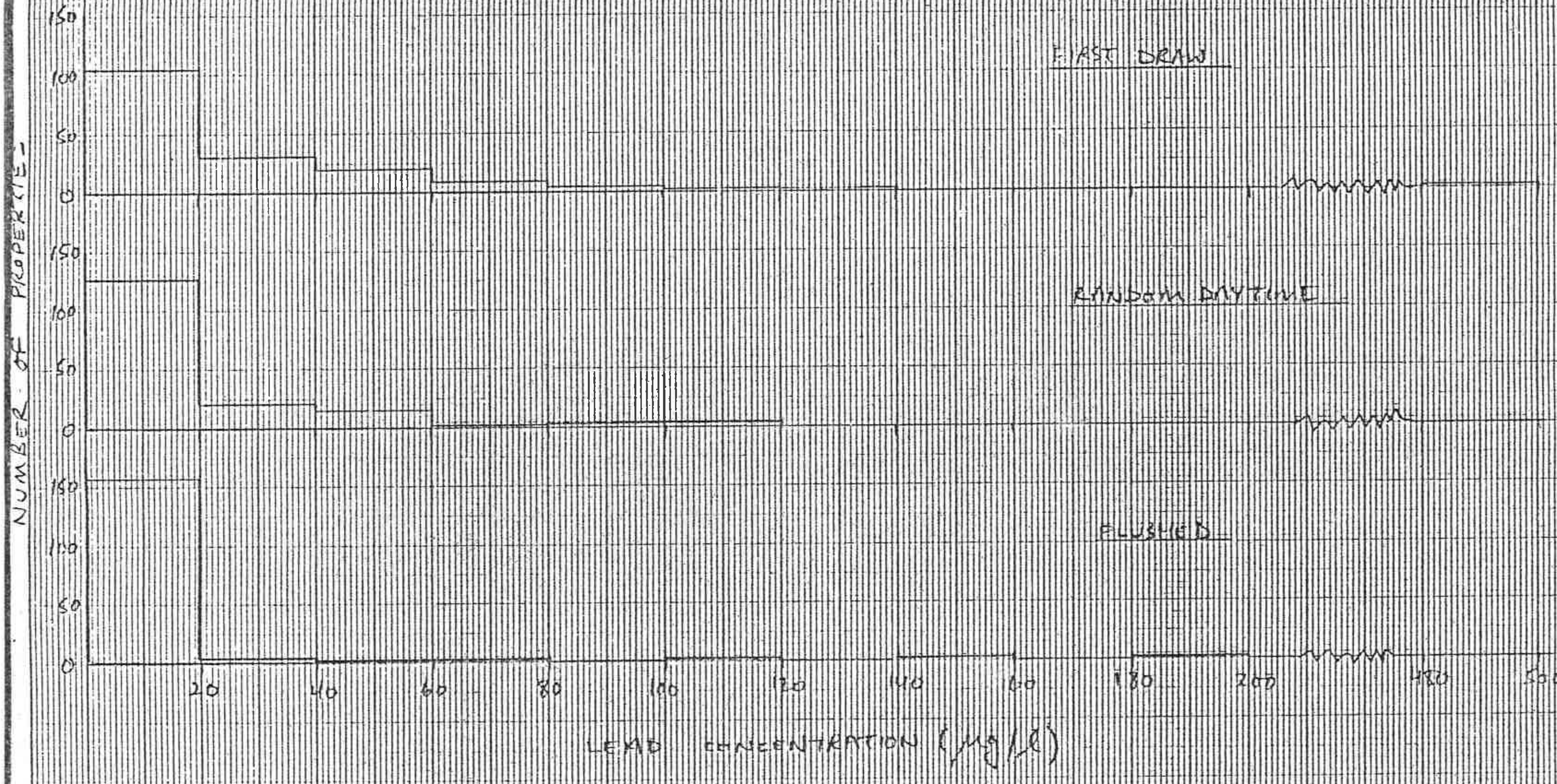


Fig 2 Flushing curves

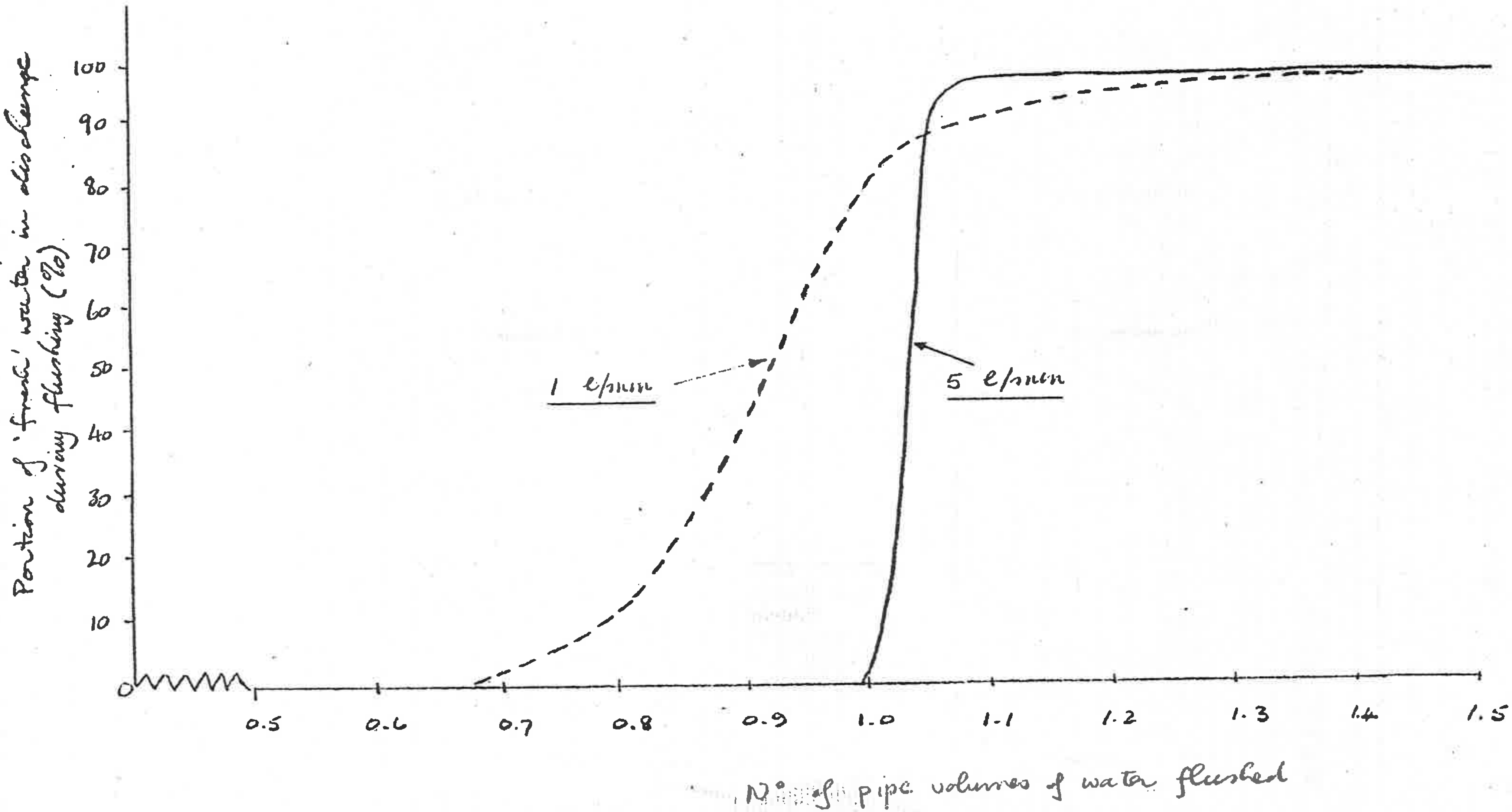


Fig 3 Effect of flow rate on lead conc^n achieved by flushing