ANNEX - 1

INDEPENDENT STATE OF PAPUA NEW GUINEA

STATUTORY INSTRUMENT

No.8 of 1984

ON

Public Health (Drinking Water) Regulation

INDEPENDENT STATE OF PAPUA NEW GUINEA

STATUTORY INSTRUMENT

No. 8 of 1984

Public Health (Drinking Water) Regulation 1984

ARRANGEMENT OF SECTIONS

PART I. - PRELIMINARY

1. Interpretation -

"consumer
"distribution system"
"drinking water"
"drinking water quality standards"
"laboratory"
"raw water"
"raw water resource"
"standards for raw water"
"treat"
"treatment plant"
"water supplier"
"use".

PART II. - WATER QUALITY STANDARDS

2. Construction etc., of treatment plant.
3. Effect of approval
4. Standards for raw water
5. Standards for drinking water.
6. Duty of water supplier

PART III. - SAMPLING AND ANALYSIS

7. Sampling etc., of raw water.
8. Sampling, etc., of drinking water.
9. Cost of analysis and examination.
10. Department Head to order corrective action.
11. Department Head may order closure etc., of treatment plant.
12. Methods of analysis

PART IV. - MISCELLANEOUS

13. Inspection, etc., of treatment plant, etc.
14. Evidence
15. Appointment of analyst.

INDEPENDENT STATE OF PAPUA NEW GUINEA

STATUTORY INSTRUMENT

No. 8 of 1984

Public Health (Drinking Water) Regulation 1984,

Being a Regulation,

MADE by the Head of State, acting with, and in accordance with, the advice of the National Executive Council under the Public Health Act (Chapter 226).

PART I. - PRELIMINARY

1. INTERPRETATION

In this Regulation unless the contrary intention appears -

"consumer" means any person or body to whom or to which, as the case may be, a water supplier, supplies water for use by that person or body;

"distribution system' means the network of pipes through which drinking water is supplied to consumers;

"drinking water" means treated water that is supplied for use by a consumer;

"drinking water quality standards" means the quality standards for drinking water *referred to in Section 51*;

"laboratory" means the Central Public Health Laboratories as the Department Head by notice in the National Gazette designates;

"raw water" means any untreated water;

"raw water source" means any source, whether above or below the surface of the earth from which raw water is taken or abstracted;

"standards for raw water" means the standards for raw water referred to in Section 4;
"treat", in relation to raw water, means the application of physical or biological processes to the water with the view to achieving drinking water quality standards;

"treatment plant" includes the facilities equipment and procedures for treating water;

"water supplier; means any person or body (including a government department, local government body or statutory authority) that abstracts, treats and supplies water to a consumer;

"use", in relation to a consumer, means use by the consumer of water supplied by a water supplier, for culinary, domestic or manufacturing purposes.

PART II. - WATER QUALITY STANDARDS

2. CONSTRUCTION ETC., OF TREATMENT PLANT

A person shall not install or construct any plant for treating water unless he has, prior to commencing the installation or construction,submitted to the Department Head -

a) details of chemical and bacteriological analysis of the raw water he proposes to treat; and

b) particulars of the course of the water, and, subject to Sections 3 and 4, obtained from the Department Head, a written approval authorizing him to use that water.

Penalty: A fine not exceeding K100.00 or imprisonment for a term not exceeding three months or both.

3. EFFECT FOR APPROVAL

An approval by the Departmental Head under Section 3; authorizes the person to whom the approval relates to take or abstract water for the purposes of treatment from the raw water source named in approval and from no other source.

Penalty: A fine not exceeding K100.00 or imprisonment for a term not exceeding three months or both.

4. STANDARDS FOR RAW WATER

1) Subject to Subsection (2), the Departmental Head shall not grant his approval under Section 2 unless he is satisfied that the raw water to which the approval relates, complies with the standards for raw water set out in Schedule 1.

2) A person may apply to the Department Head for approval to abstract or take raw water, for treatment purposes, that does not comply with the standards referred to in Subsection (2).

(3) On receipt of an application under Subsection (2), the Department Head may -

a) refuse the application; or

b) if he is satisfied that special provision has been made for the proper treatment of the water to drinking water quality standards - grant the application subject to such conditions (if any) as he imposes.

5. STANDARDS FOR DRINKING WATER

Drinking water shall comply with the drinking water quality standards set out in Schedule 2.

6. DUTY OF WATER SUPPLIER

1) It is the duty of a water supplier to ensure that drinking water supplied by him to a consumer complies with the drinking water quality standards.

2) A water supplier who -

a) supplies to a consumer; or

b) has in his distribution system, drinking water that does not comply with the drinking water quality standards, is guilty of an offence.

Penalty: A fine not exceeding K100.00 or imprisonment for a term not exceeding three months or both.

PART II. - SAMPLING AND ANALYSIS.

7. SAMPLING ETC., OF RAW WATER

A water supplier shall, for the purposes of ensuring compliance with the standards for raw water forward to the laboratory samples of the raw water for analysis and examination -

a) in the case of water from a surface raw water source - at least once in each year; and

b) in the case of water from a ground raw water source - at least three times in each year.

8. SAMPLING, ETC., OF DRINKING WATER

1) A water supplier shall, for the purposes of ensuring compliance with the drinking water quality standards, forward to the Laboratory samples of the water from his treatment plant and his distribution system for analysis and examination.

2) For the purposes of Subsection (1), the number of samples and the frequency at which the samples are to be taken are as set out in Schedule 3.

3) The sampling and analysis of drinking water for radio - activity examination shall be at such frequency and in accordance with such requirements as the Departmental Head in each particular case determines.

9. COST OF ANALYSIS AND EXAMINATION

1) The cost of analysis and examination shall be -

a) borne by the water supplier; and

b) paid to the Departmental Head at such rates as he determines.

2) The Departmental Head may, in his discretion, exempt a water supplier from the requirements of Subsection (1).

10. DEPARTMENTAL HEAD TO ORDER CORRECTIVE ACTION

1) Where it is established by analysis and examination that drinking water supplied by a water supplier does not comply with the drinking water quality standards the Departmental Head shall by written notice direct the water supplier to take such corrective measures as are specified in the notice.

2) A water supplier shall comply with a direction under Subsection (1).

Penalty: A fine not exceeding K100.00 or imprisonment for a term not exceeding three months or both.

11. DEPARTMENTAL HEAD MAY ORDER CLOSURE ETC., OF TREATMENT PLANT

1) Where -

a) there has been an outbreak of waterborne disease in an area in which a treatment plant or a distribution system is located; or

b) other emergency circumstances do exist which, in the opinion of the Departmental Head, have adversely affected or may adversely affect the quality of water supplied by a water supplier,

the Departmental Head may by written notice direct the water supplier to effect such correction or precautionary measures as are specified in the notice.

2) Where the correction measures specified in a notice under Subsection (1) fail to produce the required results, the Department Head may order the water supplier to cease treatment and supply of water forthwith.

3) A water supplier shall comply with an order under Subsection (1) or (2l).

Penalty: A fine not exceeding K100.00 or imprisonment for a term not exceeding three months or both.

12. METHODS OF ANALYSIS

Analysis, for the purposes of this Regulation, of any water shall be effected in accordance with the methods set out in the National Technical Standard PNGS 1025-82 established under the National Technical Standards Act 1978.

PART IV. - MISCELLANEOUS

13. INSPECTION, ETC., OF TREATMENT PLANT, ETC.

1) The Departmental Head or a person authorized by him in writing may enter upon any premises for the purposes of inspecting any water treatment plant or any water distribution system.

2) The Departmental Head may be written notice require a water supplier to make such alterations, or to effect such repairs, to his treatment plant or distribution system as the Department Head considers necessary in the interests of public health.

3) Where a water supplier refuses or fails to comply with a requirement under Subsection (2), the Departmental Head may -

a) cause the necessary alterations or repairs to be executed at the cost of the water supplier; and

b) for the purposes of executing the alterations or repairs, enter and remain, by such servants, agents and workmen as the Departmental Head considers necessary, on the land upon which the treatment plant or distribution system is situated.

4) The costs and expenses incurred by the Departmental Head in and about the execution of the alterations or repairs under Subsection (2) are recoverable from the water supplier as a debt due to the State.

14. EVIDENCE

In any legal proceedings under this act, a certificate purporting to be signed by a person appointed under Section 15 and setting out the results of an analysis of any matter or thing submitted for analysis under this regulation is a admissible in evidence and shall be sufficient evidence of -

a) the identity of the matter or thing analysed; and

b) the results of the analysis; and

c) the manner in which the analysis was carried out.

15. APPOINTMENT OF ANALYST

The Department Head may, for the purposes of this Regulation, appoint, by Notice in the National Gazette, a person to be an analyst.

Schedule 1.

Reg. Sec. 4.

Standards for Raw Water

The Standards for raw water shall be as shown below:-

1. Micro-Biological Standards — Maximum Allowable

Coliform Bacteria	20,000 per 100 mil

2) Toxic Contaminants Standards

Substances			Maximum Allowable
a)	Arsenic	(as As)	0.05 mg/l
b)	Cadmium	(as Cd)	0.01 mg/l
c)	Cyanide	(as Cn)	0.05 mg/l
d)	Lead	(as Pb)	0.10 mg/l
e)	Mercury	(total as Hg)	0.001 mg/l
f)	Selenium	(as Se)	0.01 mg/l
g)	Nitrate		45.0 mg/l
h)	Silver		0.05 mg/l
i)	Fluorides	(as F)	1.5 mg/l

3) Aesthetic Quality Standards

Substance or Characteristics		Maximum Allowable
a)	Colour	50 units *
b)	Odour	Unobjectionable
c)	Taste	Unobjectionable
d)	Iron	1 mg/l
e)	Manganese	0.5 mg/l
f)	Sulphate	400 mg/l
g)	Total Dissolved Solids	1 500 mg/l
h)	Chemical Oxygen Demand (COD)	10 mg/l
i)	Bio-Chemical Oxygen Demand (BOD)	6 mg/l
j)	Mineral Oil	1 mg/l

* On the platinum-cobalt scale.

Schedule 2

Reg. Sec. 5.

Standards for Drinking Water

Note: The standards in this Schedule have been adopted from the WHO International Standards for Drinking Water, 1971, and unless stated otherwise, shall comply with the standards contained therein.

1. Micro-Biological Standards

a) Chlorinated or otherwise disinfected water supplies.

i) For water entering the distribution system, the coliform count shall be zero in any 100 ml sample.

ii) For water in the distribution system;

a) Throughout any year, 90% of the sample shall not contain any coliform organisms in any sample of 100 ml;

b) There shall be no E. coli in any sample of 100 ml;

c) No sample shall contain more than 10 coliform organisms per 100 ml;

d) Coliform organisms shall not be detectable in both of any of two (2) consecutive 100 ml samples.

b) Non-disinfected water supplies:-
(Individual or Small Community Supplies)

i) There shall be no E. Coli in any sample of 1-0 ml.

ii) If E. coli is absent, no sample shall contain more than 3 coliform organisms per 100 ml.

2. Toxic Contaminants Standards

No drinking water shall contain the following substances in amounts exceeding the stated upper limit of concentration.

Substances			Upper Limit of Concentration
a)	Arsenic	(as As)	0.05 mg/l
b)	Cadmium	(as Cd)	0.01 mg/l
c)	Cyanide	(as Cn)	0.05 mg/l
d)	Lead	(as Pb)	0.1 mg/l
e)	Mercury	(as Hg)	0.001 mg/l
f)	Selenium	(as Se)	0.01 mg/l
g)	* Nitrate		45.00 mg/l
h)	* Silver		0.05 mg/l

Note: Standards for Substances marked thus * are Papua New Guinea requirements as distinct from WHO.

3. Aesthetic and other qualities standards

Note: These standards for substances and characteristics affecting the acceptability of water for domestic use, follow the WHO International Standards for Drinking Water, 1971, except for those standards marked thus *, which indicate that these have been modified to allow for the great variation of physical and chemical qualities for the various sources throughout Papua New Guinea:

Substances or Characteristics		Highest Desirable Level	Maximum Permissible Level
a)	Colour	5 units	50 units **
b)	Odour	Unobjectionable	Unobjectionable
c)	Taste	Unobjectionable	Unobjectionable

d)	Suspended Matter (Turbidity)	5 units	25 units ***
e)	Total Solids	500mg/l	1,500 mg/l
f)	pH range	7.0 - 8.5	6.5 - 9.2
g)	Mineral Oil	0.01 mg/l	0.30 mg/l
g)	* Total Hardness	200 mg/l ($CaCO_3$)	600 mg/l ($CaCO_3$)
i)	Calcium (as Ca)	75 mg/l	200 mg/l
j)	* Chloride	200 mg/l	1 000 mg/l ($CaCO_3$)
k)	Copper (as Cu)	0.05 mg/l	1.5 mg/l
l)	Iron (Total as Fe)	0.1 mg/l	1.0 mg/l
m)	Magnesium (as Mg)	Not more than 30 mg/l if there are more than 250 mg/l of sulphate	150 mg/l
n)	Manganese (as Mn)	0.05 mg/l	0.5 mg/l
o)	Sulphate	200 mg/l	400 mg/l
p)	Zinc (as Zn)	2.0 mg/l	15 mg/l
q)	* Fluoride	1.0 mg/l	1.5 mg/l

Note: ** On the platinum-cobalt scale
*** *Jacksons Turbidity Units (J.T.U)*

Schedule 3.

Reg. Sec. 8(2).

WATER SAMPLING FOR COMMUNITY WATER SUPPLY SYSTEMS MONITORING REQUIREMENTS FOR BACTERIOLOGICAL ANALYSIS

Column 1	Column 2	Column 3
Population Served	Minimum number of samples per month	Frequency
a) Individual or Small Community Water Supplies		
1,001 to 2,000	3	Once a month
b) Community Water Supplies for Urban Centres		
2,001 to 4,000	4	Twice per month
4,001 to 5,000	6	"
5,001 to 8,000	8	"
8,001 to 10,000	10	"
10,001 to 15,000	17	Once a week
15,001 to 20,000	15	"
20,001 to 30,000	18	"
30,001 to 50,000	20	"
50,001 to 75,000	25	"
75,001 to 100,000	30	"
100,001 to 150,000	40	
150,001 and above	40 plus 1 sample per 10,000 population	once a day

Dated this 5th day of April 1984

GOVERNOR-GENERAL

ANNEX-2

MONTHLY SUMMARY RESULTS

OF

SELF MONITORING IN TREATMENT PLANT

FOR

THE YEAR 1991

MT. ERIAMA WATER TR1EATMENT PLANT
WATER ANALYSIS SUMMARY
MONTH: JANUARY TO MARCH, 1991

			JANUARY	FEBRUARY	MARCH
1.	**RAW WATER**				
1.1	Alkalinity	mg/l	20 - 40	20 - 45	15 - 35
1.2	Turbidity	N.T.U	5 - 80	10 - 20	20 - 25
1.3	Calcium	mg/l	15 - 30	10 - 35	15 - 40
1.4	Magnesium*	mg/l	5 - 15	10 - 20	2 - 10
1.5	Total Hardness	mg/l	18 - 30	15 - 35	15 - 40
1.6	Temperature	^{o}C	26 - 30	25 - 29	26 - 28
1.7	pH		6.8 - 7.4	6.9 - 7.6	7.0 - 7.3
1.8	Jar Test	mg/l	15 - 35	20 - 30	20 - 30
2.	**SETTLED WATER**				
2.1	Settled 1 pH		5.0 - 6.8	6.4 - 7.0	6.4 - 6.9
2.2	Settled 2 pH		6.1 - 6.8	6.4 - 6.9	6.3 - 6.9
2.3	Settled 3 pH		5.7 - 6.7	6.4 - 6.9	6.4 - 6.9
3.	**TREATED WATER**				
3.1	Alkalinity	mg/l	25 - 38	20 - 40	20 - 35
3.2	Turbidity	N.T.U	Less 5.0	Less 5.0	Less 5.0
3.3	Calcium	mg/l	15 - 40	15 - 25	15 - 40
3.4	Magnesium*	mg/l	No reagents for Test	5 - 15	3 - 10
3.5	Total Hardness	mg/l	No reagents for Test	18 - 40	15 - 35
3.6	Temperature	^{o}C	25 - 30	25 - 28	25 - 27
3.7	pH		7.0 - 8.0	7.0 - 8.0	7.0 - 8.3
3.8	Residual free Cl_2	mg/l	0.7 - 1.10	0.7 - 1.05	0.8 - 1.05
4.	**CHEMICAL USAGE**				
4.1	Alum Sulphate	Metric Tonne	71.85	63.9	66.3
4.2	Hydrated Lime	Metric Tonne	33.175	30.85	32.115
4.3	Liquid Chlorine	Metric Tonne	3.0	3.0	3.0

Note: *Magnesium (Mg) value is computed as difference between Total Hardness and Calcium (Ca).

MT. ERIAMA WATER TR1EATMENT PLANT
WATER ANALYSIS SUMMARY
MONTH: APRIL TO JUNE, 1991

			APRIL	MAY	JUNE
1.	**RAW WATER**				
1.1	Alkalinity	mg/l			20 - 35
1.2	Turbidity	N.T.U			10 - 25
1.3	Calcium	mg/l			15 - 25
1.4	Magnesium*	mg/l			No reagent for Test
1.5	Total Hardness	mg/l			No reagent for Test
1.6	Temperature	^{o}C			26 - 28
1.7	pH				7.0 - 7.3
1.8	Jar Test	mg/l			10 - 20
2.	**SETTLED WATER**				
2.1	Settled 1 pH				5.7 - 6.8
2.2	Settled 2 pH				6.1 - 6.9
2.3	Settled 3 pH				6.3 - 6.9
3.	**TREATED WATER**				
3.1	Alkalinity	mg/l			15 - 37
3.2	Turbidity	N.T.U			Less 5.0
3.3	Calcium	mg/l			15 - 30
3.4	Magnesium*	mg/l			5 - 15
3.5	Total Hardness	mg/l			15 - 35
3.6	Temperature	^{o}C			25 - 28
3.7	pH				7.0 - 7.9
3.8	Residual free Cl_2	mg/l			0.6 - 1.06
4.	**CHEMICAL USAGE**				
4.1	Alum Sulphate	Metric Tonne			48.55
4.2	Hydrated Lime	Metric Tonne			29.075
4.3	Liquid Chlorine	Metric Tonne			3.9

Note: *Magnesium (Mg) value is computed as difference between Total Hardness and Calcium (Ca).

MT. ERIAMA WATER TR1EATMENT PLANT
WATER ANALYSIS SUMMARY
MONTH: JULY TO SEPTEMBER, 1991

			JULY	AUGUST	SEPTEMBER
1.	**RAW WATER**				
1.1	Alkalinity	mg/l	24 - 35	25 - 35	20 - 40
1.2	Turbidity	N.T.U	10 - 20	10 - 100	10 - 25
1.3	Calcium	mg/l	10 - 30	15 - 30	10 - 30
1.4	Magnesium*	mg/l	5 - 15	2 - 25	5 - 20
1.5	Total Hardness	mg/l	15 - 40	15 - 45	20 - 37
1.6	Temperature	^{o}C	25 - 30	26 - 28	25 - 30
1.7	pH		6.8 - 7.2	7.0 - 7.2	6.8 - 7.3
1.8	Jar Test	mg/l	10 - 30	10 - 50	20 - 30
2.	**SETTLED WATER**				
2.1	Settled 1 pH		5.9 - 6.9	5.5 - 7.1	5.6 - 6.9
2.2	Settled 2 pH		6.1 - 6.8	5.3 - 6.9	6.0 - 6.9
2.3	Settled 3 pH		6.3 - 6.9	6.2 - 6.8	6.0 - 6.7
3.	**TREATED WATERRANGE**				
3.1	Alkalinity	mg/l	20 - 37	20 - 50	25 - 40
3.2	Turbidity	N.T.U	LESS 5.0	Not Taken	Less 5.0
3.3	Calcium	mg/l	10 - 40	15 - 35	15 - 35
3.4	Magnesium*	mg/l	2 - 15	2 - 25	5 - 20
3.5	Total Hardness	mg/l	15 - 40	15 - 45	15 - 40
3.6	Temperature	^{o}C	25 - 29	24 - 28	25 - 28
3.7	pH		7.0 - 7.9	6.9 - 8.1	6.9 - 7.9
3.8	Residual free Cl_2	mg/l	0.7 - 1.2	0.70 - 1.05	0.8 - 1.10
4.	**CHEMICAL USAGE**				
4.1	Alum Sulphate	Metric Tonne	47.05	57.55	70
4.2	Hydrated Lime	Metric Tonne	27.90	25.4	26.6
4.3	Liquid Chlorine	Metric Tonne	4.2	4.68	3.9

Note: *Magnesium (Mg) value is computed as difference between Total Hardness and Calcium (Ca).

MT. ERIAMA WATER TR1EATMENT PLANT
WATER ANALYSIS SUMMARY
MONTH: OCTOBER TO DECEMBER, 1991

			OCTOBER	NOVEMBER	DECEMBER
1.	**RAW WATER**				
1.1	Alkalinity	mg/l	25 - 40	20 - 36	15 - 38
1.2	Turbidity	N.T.U	10 - 80	10 - 40	10 - 150
1.3	Calcium	mg/l	15 - 35	15 - 35	15 - 36
1.4	Magnesium*	mg/l	3 - 25	5 - 12	2 - 30
1.5	Total Hardness	mg/l	20 - 40	15 - 37	15 - 40
1.6	Temperature	^{o}C	26 - 30	26 - 29	25 - 28
1.7	pH		7.0 - 7.5	7.0 - 7.4	7.0 - 7.2
1.8	Jar Test	mg/l	10 - 30	20 - 35	20 - 30
2.	**SETTLED WATER**				
2.1	Settled 1 pH		5.7 - 6.9	5.0 - 6.9	6.0 - 6.8
2.2	Settled 2 pH		5.7 - 6.8	5.6 - 6.8	6.0 - 6.8
2.3	Settled 3 pH		6.0 - 6.7	6.0 - 6.9	6.0 - 6.8
3.	**TREATED WATERRANGE**				
3.1	Alkalinity	mg/l	20 - 40	15 - 35	20 - 40
3.2	Turbidity	N.T.U	Less 5.0	Less 5.0	Not taken
3.3	Calcium	mg/l	10 - 35	15 - 35	10 - 40
3.4	Magnesium*	mg/l	3 - 20	2 - 20	3 - 20
3.5	Total Hardness	mg/l	15 - 40	20 - 40	15 - 40
3.6	Temperature	^{o}C	25 - 28	25 - 30	26 - 29
3.7	pH		7.0 - 8.1	7.0 - 8.0	7.0 - 7.5
3.8	Residual free Cl_2	mg/l	0.8 - 1.0	0.78 - 1.06	0.7 - 1.06
4.	**CHEMICAL USAGE**				
4.1	Alum Sulphate	Metric Tonne	81.35	85.6	69.9
4.2	Hydrated Lime	Metric Tonne	31.88	25.9	27.8
4.3	Liquid Chlorine	Metric Tonne	4.13	4.03	4.20

Note: *Magnesium (Mg) value is computed as difference between Total Hardness and Calcium (Ca).

DATA BOOK

SUMMARY RESULT SHEET FOR MONTHLY MONITORING OF THE LALOKI RIVER, WITH RESPECT TO EFFLUENT DISCHARGED BY HUGO MEAT CANNERY

DATE	SAMPLING LOCATION	WATER QUALITY PARAMETER AND DATA						REMARKS
		pH	SOLIDS (mg/L)		BOD5 (mg/L)	Microbiological (organisms/100mL)		
			Total Suspended	Total Dissolved		Total Coliform	Faecal Coliform	
13/02/90	A	7.5	11	60	5	110	30	
	B	7.7	8	57	4	110	30	
	C	7.7	9	58	8	20	20	
	D	5.8	710	920	1440	5.8×10^{2}	1.5×10^{3}	
22/03/90	A	7.3	2	87	5	230	60	
	B	6.9	6	83	4	100	40	
	C	7.2	3	87	4	30	30	
	D	9.7	1820	1300	2500	5.0×10^{4}	2.0×10^{4}	
23/04/90	A	7.3	17	100	4	130	NIL	Nil recorded for microbiological organism in the effluent discharge from the factory. Otherwise they are present at other sites in the river apart from site A which recorded Nil FC.
	B	7.5	16	96	6	440	120	
	C	7.5	14	94	5	130	10	
	D	11.4	1400	580	280	NIL	NIL	
04/06/90	A	7.2	47	59	7	12000	1400	
	B	7.3	51	63	7	5000	2100	
	C	7.2	51	62	7	11000	1600	
	D	5.7	1400	680	1650	2.0×10^{4}	1.0×10^{4}	
26/06/90	A	7.5	22	34	5	800	160	
	B	7.6	22	37	11	1350	240	
	C	7.5	21	40	8	800	210	
	D	5.7	690	930	1780	1.7×10^{4}	6.0×10^{3}	
06/08/90	A	7.7	7	46	7	5900	70	No data provided for site C, probably because no samples were taken at this site at this time.
	B	7.6	6	46	5	435	20	
	C	-	-	-	-	-	-	
	D	5.3	5110	1160	2600	1.8×10^{3}	1.2×10^{3}	
24/09/90	A	7.7	16	47	4	350	60	
	B	7.9	16	50	4	800	70	
	C	7.9	14	64	4	730	70	
	D	5.4	1050	1200	2370	8×10^{3}	5.7×10^{3}	
23/10/90	A	7	73	75	37	2600	500	
	B	7.2	33	81	12	2000	200	
	C	7.3	27	75	14	3000	2000	
	D	5.7	1750	930	2450	8.1×10^{2}	4.4×10^{3}	
21/11/90	A	7.4	7	76	2	1300	60	
	B	7.7	5	71	1.6	410	30	
	C	7.6	4	67	1.2	220	160	
	D	5.8	1400	1180	3190	1.1×10^{4}	7.9×10^{3}	
21/12/90	A	7.4	16	25	2	400	160	The date as provided by NAL is 21-11-91 on which they say samples were collected. And the date on which the report was provided is 10-01-91. It is assumed that the right date is 21-12-90.
	B	7.4	6	44	4	200	40	
	C	7.5	8	40	4	2000	2000	
	D	5.3	147	145	184	2×10^{4}	1.1×10^{5}	

Mid Jan 91	A	7.8	33	92	<1	2000	800	No date was provided for sample collection but the reported date is 30-01-91. It is therefore assumed that sampling was done mid-January 1991. BWR to confirm this with concerned bodies.
	B	7.7	42	89	<1	2000	1000	
	C	7.6	26	87	<1	3500	2000	
	D	5.8	2570	1810	3100	5.1×10^3	4.5×10^3	
05/03/91	A	7.6	40	42	7	100	20	
	B	7.6	31	41	7	130	10	
	C	7.6	31	51	6	350	140	
	D	6.2	1130	570	3700	4.8×10^3	3×10^3	
21/03/91	A	7.6	5	52	5	50	40	
	B	7.4	6	61	7	70	40	
	C	7.6	6	61	6	800	770	
	D	5.6	1720	910	3000	3.4×10^3	2.4×10^3	
22/04/91	A	7.8	17	90	4	4000	NIL	
	B	7.5	50	45	3	3600	130	
	C	7.6	60	50	4	3800	600	
	D	5.7	2300	720	3100	3.5×10^4	6.3×10^4	
21/05/91	A	7.4	13	70	12	230	30	
	B	7.6	13	80	14	450	40	
	C	7.6	10	20	8	2000	1900	
	D	5.8	2130	960	2500	8.6×10^3	5×10^3	
24/06/91	A	7.5	8	70	5	8600	1800	
	B	7.7	6	37	5	600	100	
	C	7.7	8	90	7	760	110	
	D	5.5	950	980	2000	1.8×10^4	1.1×10^4	
30/07/91	A	7.6	7	57	5	600	30	
	B	7.7	7	54	6	700	50	
	C	7.5	9	50	5	11000	3200	
	D	5.6	550	720	1700	1.9×10^4	1×10^4	
28/08/91	A	7.7	3	58	3	70	NIL	
	B	7.6	4	37	2	80	NIL	
	C	7.6	3	58	3	240	60	
	D	6.1	1570	690	2400	2×10^4	6.8×10^4	
25/10/91	A	7.3	11	113	6	1000	NIL	
	B	7.3	12	122	5	220	NIL	
	C	6.8	10	141	6	750	140	
	D	5	1580	280	700	5.1×10^3	1.3×10^4	
27/11/91	A	N/A	6	88	5.7	80	NIL	The factory was shut down for inspection in January 1992. No samples were therefore collected for this period (Jan - Feb 1992).
	B	N/A	7.5	79	6.3	160	NIL	
	C	N/A	7	79	6	240	NIL	
	D	N/A	200	150	740	1.3×10^3	1.4×10^3	
27/03/92	A	N/A	6	31	2.4	190	190	Both FC and TC levels were similar. This could mean that the TCs were actual FCs.
	B	N/A	5.6	60	1.6	1500	1500	
	C	N/A	5	53	2	700	700	
	D	N/A	76	140	200	1000	1000	

NOTE: A - Laloki at upstream of Bluff Inn Motel.
B - Laloki at downstream of Bluff Inn Motel.
C - Laloki at downstream of Hugo Cannery.
D - Hugo Cannery effluent.

MT ERIAMA WATER TREATMENT PLANT

DAILY LOG SHEET

DAY: TUESDAY

OPERATOR: TOM TEPA

DATE: 10th/11/92

RAW WATER

TIME: 9.00 AM
pH: 7.8
TURB: 0.9 N.T.U
Cl: 25 g/m³
ALK: 35 g/m³
LIME: 25 g/m³
TOTAL HARDNESS 45 g/m³
TEMPERATURE 27 °C
Mg: 20 g/m³

GRAVITY MAIN I: METER READING Today :
Yesterday: /
MEGA LITRES REC:

GRAVITY MAIN II: METRE READING: Today : /
Yesterday:

REC: /

MEGA LITRES REC: /

FILTERED WATER METRE READING

SETTLED WATER pH

BLOCK I: 7.0
BLOCK II: 6.8
BLOCK III: 7.0

FILTER 1: Today :
Yesterday: /
Thru Put :

FILTER 2: Today : 585.179
Yesterday: 575.765
Thru Put : 9414

FILTER 3: Today : 636.246
Yesterday: 618.644
Thru Put : 17.602

FILTER 4: Today : /
Yesterday: /
Thru Put :

FILTER 5: Today : 3469.40
Yesterday: 3445.00
Thru Put : 24.40

FILTER 6: Today : 4845.77
Yesterday: 4808.00
Thru Put : 37.77

TOTAL THRU PUT: 89.186 MEGA LITRES 89.186

CORRECTED WATER METER READINGS

TURBIDITY : 0.7 NTU
TEMPERATURE: 27 °C
RES: Cl 1.10 g/m³
pH: 7.4
ALK: 40 g/m³
LIME: 24 g/m³
TOTAL HARDNESS 35 g/m³
Mg: 11 g/m³

321" MAIN: Today :
Yesterday: /
Thru Put : /

252" MAIN:

24" MAIN: Today : 38706.0
600: MAIN: Yesterday: 38629.1
Thru Put : 77.9

TOTAL THRU PUT: 77.9 MEGA LITRES 77.9

CHEMICALS

BAGS USED	KG USED	g/m³	PLANT STOCK IN BAGS.
ALUM			
LIME			
FLUORIDE			

CHLORINE FEEDING 17 NEXT ON: 3

Line 1. Cl POSITION	17	2898	1232			
Line 2.	18	3	2061	3591		
EMPTY CYLINDERS	19		13			

RESULTS OF WATER ANALYSIS

Table 1a Initial Raw water sampled 8/10/92

Parameters and Units	Location number & time sampled					
	1	2	3	4	5a	5b
	10.09	11.05	11.45	12.45	14.10	14.25
pH	7.9	7.9	7.4	7.7	6.5	6.8
a/temp (°C)	30	32	30	29	27	27
w/temp (°C)	26	29	29	27	29	30
odour	nil	nil	nil	nil	nil	nil
colour (pt Co)	20	25	35	15	3	15
turbidity (FTU)	3	5	4	3	1	2
TSS	95	109	69	0	0	0
TDS	30	43	33	34	31	30
total solids	125	152	102	34	31	30
total hardness (mgL^{-1} $CaCO_3$)	34	40	45	42	42	39
conductivity ($uScm^{-1}$)	80	90	70	60	70	90
total coliform per ml	75	95	270	115	nil	nil
faecal coliform per ml	46	70	66	66	nil	nil
BOD_5	8	11	14	12	1.3	0.8
COD (Mn)	0.3	0.4	0.4	0.6	0.5	0.5
COD (Cr)	10	12	16	14	5	3
free chlorine	na	na	na	na	na	na
total chlorine	na	na	na	na	na	na
chloride	12	6	7	10	8	8
nitrite	0.009	0.210	0.350	0.165	0.035	0.060
nitrate	3.5	2.0	4.5	4.2	2.2	2.3
total nitrogen	5	3	6	5	4	4
total iron	0.30	0.45	0.52	0.35	0.29	0.09
total manganese	0.30	0.35	0.25	0.31	0.29	0.05

All concentrations are in mgL^{-1}, unless stated
na : not applicable
Note location number

1 Brown river at Hiritano Highway bridge
2 Goldie river at Army Barracks intake (Tank Hill)
3 Laloki river at Bomana intake and pump house
4 Laloki river at rouna 1/3 head pond gravity intake
5a Eriama treatment plant - stage 2 clarrifier effluent
5b Eriama treatment plant - filter No.3 effluent

Mid Jan 91	A	7.8	33	92	<1	2000	800	No date was provided for sample collection but the reported date is 30-01-91. It is therefore assumed that sampling was done mid-January 1991. BWR to confirm this with concerned bodies.
	B	7.7	42	89	<1	2000	1000	
	C	7.6	26	87	<1	3500	2000	
	D	5.8	2570	1810	3100	5.1×10^4	4.5×10^3	
05/03/91	A	7.6	40	42	7	100	20	
	B	7.6	31	41	7	130	10	
	C	7.6	31	51	6	350	140	
	D	6.2	1130	570	3700	4.8×10^3	3×10^3	
21/03/91	A	7.6	5	52	5	50	40	
	B	7.4	6	61	7	70	40	
	C	7.6	6	61	6	800	770	
	D	5.6	1720	910	3000	3.4×10^3	2.4×10^3	
22/04/91	A	7.8	17	90	4	4000	NIL	
	B	7.5	50	45	3	3600	130	
	C	7.6	60	50	4	3800	600	
	D	5.7	2300	720	3100	3.5×10^7	6.3×10^4	
21/05/91	A	7.4	13	70	12	230	30	
	B	7.6	13	80	14	450	40	
	C	7.6	10	20	8	2000	1900	
	D	5.8	2130	960	2500	8.6×10^3	5×10^3	
24/06/91	A	7.5	8	70	5	8600	1800	
	B	7.7	6	37	5	600	100	
	C	7.7	8	90	7	760	110	
	D	5.5	950	980	2000	1.8×10^4	1.1×10^4	
30/07/91	A	7.6	7	57	5	600	30	
	B	7.7	7	54	6	700	50	
	C	7.5	9	50	5	11000	3200	
	D	5.6	550	720	1700	1.9×10^3	1×10^4	
28/08/91	A	7.7	3	58	3	70	NIL	
	B	7.6	4	37	2	80	NIL	
	C	7.6	3	58	3	240	60	
	D	6.1	1570	690	2400	2×10^4	6.8×10^6	
25/10/91	A	7.3	11	113	6	1000	NIL	
	B	7.3	12	122	5	220	NIL	
	C	6.8	10	141	6	750	140	
	D	5	1580	280	700	5.1×10^3	1.3×10^4	
27/11/91	A	N/A	6	88	5.7	80	NIL	The factory was shut down for inspection in January 1992. No samples were therefore collected for this period (Jan - Feb 1992).
	B	N/A	7.5	79	6.3	160	NIL	
	C	N/A	7	79	6	240	NIL	
	D	N/A	200	150	740	1.3×10^3	1.4×10^3	
27/03/92	A	N/A	6	31	2.4	190	190	Both FC and TC levels were similar. This could mean that the TCs were actual FCs.
	B	N/A	5.6	60	1.6	1500	1500	
	C	N/A	5	53	2	700	700	
	D	N/A	76	140	200	1000	1000	

NOTE: A - Laloki at upstream of Bluff Inn Motel.
B - Laloki at downstream of Bluff Inn Motel.
C - Laloki at downstream of Hugo Cannery.
D - Hugo Cannery effluent.

Table 1b Repeat raw water sampled - 22/10/92

Parameters and Units	Location number and time sampled					
	1	2	3	4	5a	5b
	16.40	16.00	13.40	12.05	11.15	10.55
pH	7.8	8.1	7.6	7.4	7.3	6.8
a/temp (°C)	28	31	26	29	30	26
w/temp (°C)	29	30	28	27	28	30
odour	nil	nil	nil	nil	nil	nil
colour (pt Co)	9	12	18	25	3	0
turbidity (FTU)	3	4	6	3	0	3
TSS	10	25	13	0	0	0
TDS	32	43	32	31	34	33
total solids	42	68	45	31	34	33
total hardness (mgL^{-1} $CaCO_3$)	35	45	51	40	45	35
conductivity ($uScm^{-1}$)	70	100	70	60	60	70
total coliform per ml	53	80	670	64	nil	nil
faecal coliform per ml	20	31	420	44	nil	nil
BOD_5	10	11	8	9	3	3
COD (Mn)	0.4	0.5	0.5	0.5	0.6	0.6
COD (Cr)	12	13	14	11	5	4
free chlorine	na	na	na	na	na	na
total chlorine	na	na	na	na	na	na
chloride	12	8	8	8	10	10
nitrite	0.010	0.150	0.132	0.009	0.021	0.009
nitrate	2.9	3.5	3.3	1.9	1.3	1.1
total nitrogen	5	4	7	5	4	4
total iron	0.23	0.15	0.22	0.27	0.09	0.09
total manganese	0.25	0.32	0.26	0.30	0.30	0.08

All concentrations are in mgL^{-1}, unless stated
na : not applicable
Note location number

1 Brown river at Hiritano Highway bridge
2 Goldie river at Army Barracks intake (Tank Hill)
3 Laloki river at Bomana intake and pump house
4 Laloki river at rouna 1/3 head pond gravity intake
5a Eriama treatment plant - stage 2 clarrifier effluent
5b Eriama treatment plant - filter No.3 effluent

Table 2a Treated distributed City water sampled on 15/10/92

Parameters and Units	Location number and time sampled				
	1	2	3	4	5
	10.05	11.40	12.10	11.05	12.45
pH	8.4	7.7	8.0	7.8	8.0
a/temp (°C)	27	28	31	27	27
w/temp (°C)	29	27	28	27	27
odour	nil	nil	nil	nil	nil
colour (pt Co)	0	2	2	7	0
turbidity (FTU)	0	2	0	4	2
TSS	0	0	0	0	0
TDS	41	46	45	54	50
total solids	41	46	45	54	50
total hardness (mgL^{-1} $CaCO_3$)	38	35	38	35	45
conductivity ($uScm^{-1}$)	100	90	90	90	90
total coliform per ml	nil	nil	nil	nil	nil
faecal coliform per ml	nil	nil	nil	nil	nil
BOD_5	2	1.3	0.9	2.1	2.0
COD (Mn)	0.4	0.5	0.4	0.6	0.4
COD (Cr)	3.6	2.2	1.1	3.2	2.6
free chlorine	0.4	0.5	0.5	0.5	0.4
total chlorine	0.5	0.6	0.5	0.5	0.6
chloride	12	8	8	8	7
nitrite	0.004	0.009	0.009	0.007	0.010
nitrate	1.8	2.2	3.6	3.7	2.9
total nitrogen	2	3	4	4	4
total iron	0.03	0.03	0.03	0.04	0.02
total manganese	0.07	0.08	0.25	0.30	0.15

All concentrations are in mgL^{-1}, unless stated

Note location number

1 Gerehu model area - Household tap (Udia st.)
2 Gordons model area - Household tap (Heni cres.)
3 Boroko model area - household tap (Siale cres.)
4 Tokarara area - Household tap (Manoka cress.)
5 Town area - Tearoom tap of Town Police station

Table 2b Repeat of treated distributed City water sampled on 23/10/92 and 28/10/92 (sample 5)

Parameters and Units	Location number and time sampled				
	1	2	3	4	5
	12.05	11.20	11.00	12.30	9.55
pH	7.8	7.6	7.8	7.7	7.3
a/temp (°C)	27	28	31	27	27
w/temp (°C)	28	28	30	28	27
odour	nil	nil	nil	nil	nil
colour (pt Co)	6	2	0	0	5
turbidity (FTU)	10	3	0	0	1
TSS	0	0	0	0	0
TDS	47	40	40	40	39
total solids	47	40	40	40	39
total hardness (mgL^{-1} $CaCO_3$)	35	36	36	40	39
conductivity ($uScm^{-1}$)	80	80	80	80	80
total coliform per ml	nil	nil	nil	nil	nil
faecal coliform per ml	nil	nil	nil	nil	nil
BOD_5	1.5	1.3	1.2	0.9	0.9
COD (Mn)	0.6	0.4	0.4	0.5	0.3
COD (Cr)	2.9	3.2	1.1	3.3	2.7
free chlorine	0.4	0.4	0.3	0.4	0.2
total chlorine	0.4	0.4	0.4	0.4	0.3
chloride	12	8	8	8	8
nitrite	0.006	0.007	0.005	0.005	0.006
nitrate	1.9	1.2	0.9	1.2	1.2
total nitrogen	2	2	2	2	2
total iron	0.03	0.03	0.02	0.01	0.03
total manganese	0.08	0.12	0.07	0.05	0.05

All concentrations are in mgL^{-1}, unless stated

Note location number

1 Gerehu model area - Household tap (Udia st.)
2 Gordons model area - Household tap (Heni cres.)
3 Boroko model area - household tap (Siale cres.)
4 Tokarara area - Household tap (Manoka cress.)
5 Town area - Tearoom tap of Town Police station

APPENDIX C

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

POPULATION ESTIMATION AND DISTRIBUTION

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APPENDIX C POPULATION ESTIMATION AND DISTRIBUTION

1. Introduction

National population census in Papua New Guinea is conducted by the National Statistics Office (NSO) every ten years from 1980. The latest national census was conducted in 1990 and preliminary results from this census for NCD is available now.

No detailed population projections for the NCD have been prepared since 1983, when the Department of Physical Planning and Environment prepared projections for 1983 and 1990 as part of the process of preparing the Port Moresby Interim Plan. Population projections for the 25 largest cities and towns were made for 1990 and 2000 in the National Development Plan 1986. These projections were made based on the urban growth rates observed in the 1980's. Urban growth rates were drawn from the Urban Household Survey of six towns, including NCD, conducted by NSO in 1986. Future population and its distribution to be used for this study are estimated, taking into account the past projections mentioned above.

For the purpose of the population projection and its distribution, the planning zone system developed by NSO has been adopted. The zone system consists of 1990 Census Division (CD), and Census Unit (CU) which is a sub-division of CD. There are 9 CDs and 426 CUs in NCD. Fig. C.1, C.2 and C.3 illustrate the zone system. Developed CDs, such as Nos. 80 to 86 have definite CU divisions in them. Gerehu, Waigani/University, Hohola /Tokarara, Gordons/Saraga, Boroko/Korobosea, Kilakila/Kaugere and Town/Hanuabada areas are included in CU Nos. 80 to 86. City planning has been established in these CDs. While undeveloped areas, such as CD Nos. 87 and 88 where Laloki/Napanapa and Bomana are located, do not have a definite CU division. Population in these CDs are relatively small and most of the population consists of squatters or settlement inhabitants. No city planning is available in these CDs. In this report, CD Nos. 80 to 86 are referred to as "urban area", and CD Nos. 87 and 88 are referred to as "nourban area".

2. Population Estimation

2.1 General

Future population is usually estimated based on either the past trends or various growth factors. Projections based on past trends are commonly used because of the simplicity.

These projections are often regarded as guidelines for planning. Projections based on the analysis of various growth factors yield a more realistic future population figure if these factors are correctly assumed. In this study, the former method was initially used, and future population which will be the basis of the study, was estimated by the latter method.

Information obtained from the latest census taken in 1990 was used, where available. However, some data is still being processed and are not available. The lacking data was supplemented by data from the 1980 census. Also data lacking for NCD but available for the country, was used in the study.

The target year for the projection is 2015.

2.2 Past Trends

The population of NCD was 15,688 according to the 1954 census. It grew to 42,000 in 1966 and 76,504 in 1971. The average annual growth rate between 1966 and 1971 was about 13 %. At the time of the 1980 census, the population increased to 123,624, with an average annual growth rate of 6 %.

According to the preliminary accounts of the 1990 census, the population of NCD stood at 195,382 giving a current annual growth rate of 4.7 %. Non-citizen population which accounted for 11 % in 1980 decreased to 4 % of the total in 1990.

Average annual population growth rates of NCD between the last four census are as follows:

1966 to 1971	12.7 %
1971 to 1980	5.5 %
1980 to 1990	4.7 %

The average annual growth rate of citizen population of NCD between 1980 and 1990 is 5.3 % which is slightly higher than that of the total population.

2.3 Estimation by Past Trends

There are several methods for projecting population based on past trends, such as using an average increment, an average growth rate, a logistic curve, and regression curves. In this study, two methods, by an average growth rate and regression curves were used.

An average growth rate of 5.3 % between the last two census was used for projecting citizen population. Non-citizen population was fixed at the present level of 7,500 because of the relatively stable balance of arrival and departure of foreigners today.

A linear regression curve for the population figures was plotted for the period from 1971 to 1990 when stable growth was recognized. This curve was extended to the target year to project the future population.

2.4 Cohort Component Method

There are several other methods for population projection based on various growth factors. In this study, Cohort Component Method was used. This method uses the population growth factors, viz. fertility and mortality rates of age and sex groups, and immigrant population. The projection starts from a certain year in which population breakdowns by age and sex groups are available. Projection is carried out on a yearly basis using the following four steps.

Step 1: Population by age and sex groups in 1990 as shown in Table C.1 was considered as the first fixed population.

Step 2: Number of deaths for each age and sex group in 1990 was calculated based on group population and mortality rate (refer to Fig. C.4). Number of deaths was subtracted from each age group. One year was added to every age group. Population over 1 year old in 1991 was calculated by summing up all the age groups.

Step 3: Number of births in 1990 was calculated based on fertile female population (age 19 to 49) and specific fertility rates in NCD (shwon in Table C.2). A total of these numbers gives the 0 age child population in 1991. This number was divided into males and females by using the sex ratio for children at birth (male : female = 107 : 100).

Step 4: In-coming and out-going population by age and sex group was added or subtracted from the fixed population obtained through steps 1 to 3. A constant number of 5,100 persons (1990) was used as in-coming population up to 2015. In-coming population was divided into age and sex groups by the ratios obtained from the 1980 census (male : female = 137 : 100, Table C.3).

Steps 1 to 4 were repeated until the target year.

2.5 Future Population

Estimated future populations up to 2015 by various methods are compared in Fig. C.5 and Table C.4. Population in 2015 was estimated to be 610,000 with an average growth rate of 4.7 %. If the growth rate of 5.3 % for citizen population is adopted and non-citizen population of 7,500 is added, the total population will reach 690,000 in 2015. These two figures may be higher, reflecting the past high growth rate. The growth rate of NCD has been decreasing since 1966. Population in 2015 was estimated to be 350,000 by the linear regression curve obtained from the 1971 to 1990 data. It is considered too low .

The Cohort Component Method estimated the population in 2015 at 526,000. This figure lies in between the estimates of the growth rate and the regression curve methods. Growth rates of 5 year intervals up to 2015 decrease gradually as shown below.

Annual growth rates by the Cohort Component Method

Year	1990	1995	2000	2005	2010	2015
Rate(%)	5.3	4.5	3.9	3.4	3.2	

The gradual decrease in the population growth rate reflects the current trend in NCD. Therefore, population estimation by the Cohort Methods was adopted for this study.

3. Population Distribution

3.1 General

Population of NCD in 2015 was estimated by the Cohort Method as 526,000, which is 2.6 times that in 1990. This estimated population should be distributed properly in each area of NCD. City planning is a key element in population distribution. However, comprehensive city planning to cover the study area is yet to be made. The present status of the city planning of NCD is explained briefly below.

The first city planning of NCD was called as "Port Moresby Development Study" carried out in 1970. The form of the original development is generally similar to the plan proposed by the study. The City Center and industrial areas in the Waigani Corridor from Korobosea to Gerehu have been developed according to the plan. However, no substantial residential development has taken place in the Nine Mile-Bomana and Laloki-Napanapa areas.

The detailed physical planning of the city was guided by several plans, viz, a simple Zoning Plan, the Port Moresby Downtown Plan, the Waigani City Center Plan and the Port Moresby Interim Development Plan. While these have been useful in the past for guiding physical development, they are now out of date, and moreover the plans do not cover the study area comprehensively .

The NCDC Physical Planning Board was set up recently by virtue of the new Planning Act 1989 and will draw up town planning in 1993/94. However the plan will not be available during the course of the study. Consequently, a development plan was delineated by the study team.

3.2 Past Development

The transition of past developments analyzed from the aerial photographs taken in 1972, 1978 and 1980, is illustrated in Fig. C.6. Urbanization of NCD began with the port city, as suggested by its name. Urban area at the initial stage of development was limited to the Town area located on the seashore of the peninsula. Later, in the 1950's the Korobosea and the Boroko areas were developed, followed by the Gordons in 1960's, and development extended along the Tokalala and the Hohola valleys. Development of the valleys is still going on today. In 1970's, The Waigani area and the Gerehu area, located north of Waigani, were developed as the new government center and its satellite city respectively. Nearly 95 % of the total population inhabited these urban areas, according to the 1990 census.

On the other hand, no systematic development has taken place in the Bomana and the Laloki/Napanapa areas which are located in the suburbs of NCD. Scattered settlements can be seen in these areas, except for a small congested area near the Nine-mile area. Therefore, vast land space for development still remains in these areas. Only 5 % of the total population inhabited these areas in 1990.

The development of NCD has been extending in the following two directions;

- from the seashore to the first valley
- in the inland area, from south to north and from flat land upward along the valleys (from Boroko to Gerehu)

Taking into consideration the above-mentioned trends, the areas for possible future development are likely to be as follows;

-further inland, along the third valley (from the airport to the Waigani Swamp)
- north of the Gerehu, and upward along the valley
- areas surrounding the new government center of Waigani

3.3 Possible Development Area

There are a number of undeveloped areas in NCD. These are areas remote from the city center, and include swamps, steep terrains, and customary-owned lands. Various physical, economic and social constraints have prevented the development of these areas. The main constraints are briefly described below.

There are many hills in NCD as shown in Fig. C.7, which restricted the development in the past. According to the Port Moresby Water Supply Study 1980, the water supply system was designed to supply water to the areas below 90 m MSL, and all the reservoirs are located at about 100 m MSL. Pumps are used to supply water to limited number of areas at high altitude. In general, the terrain becomes very steep above 80 m MSL. It is physically and economically difficult to develop steep areas.

Ownership of land in NCD is classified into two categories, -customary land or government land. Customary land is owned by the original inhabitants of the area, namely. the Koita and the Motu clans. Most of the customary lands with a few exceptions are unregistered, which means that there is no authoritative record showing which clan groups and who owns this land. Government land is owned by the government. Fig. C.8 shows the classification of land ownership in NCD. The southern half and most of the coastal areas of NCD are customary lands. Government land occupies peninsular and the northern half of NCD. No development has taken place in customary lands in the past. It is most likely that the customary land will not be developed by the government in the near future because of the peculiarities of land ownership and the difficulties in changing the system.

Based on this thinking, the following criteria have been established in selecting possible development areas.

- government land
- areas below 90 m MSL
- flat land
- outside the swamp area (Waigani Swamp)
- outside the Laloki river flood plain

Selected areas are shown in Fig. C-9, and their land areas by CDs are shown in Table C.5.

Area that can be developed and located in the southernmost part, behind Mt. Eriama, are excluded since development will not reach these areas until 2015.

3.4 Population Density

The saturation population density to be used for the population distribution was determined by analyzing the past and present densities. In general, population densities vary significantly depending on the types of housing, e.g. low in the high cost housing areas and high in the settlement and squatter areas. Each census division has a specific housing type. The saturation population densities ware determined by analyzing the population densities of the census divisions.

The following data was used;

- 1980 population by collection unit
- 1990 population by collection unit
- Town zoning map

Population densities calculated by census units are grouped into census divisions and shown in Table C.6. Population densities of residential areas lie between 76 to 120 persons/ha, with an average of 92 persons/ha. These figures include population inhabiting, non-residential areas. To obtain more precise population densities in residential areas, collection units consisting of purely residential areas were selected. Population densities of these purely residential areas lie between 59 to 143 persons/ha, with an average of 111 persons/ha.

Frequency distribution curves of population densities of census divisions in 1980 and 1990 are shown in Fig. C.10. As shown in the figure, the distribution curve of Gerehu has one peak, and the peak has shifted from 50 persons/ha in 1980 to 70 persons/ha in

1990. Simultaneously, units of higher densities appeared and frequency of the occurrence increased. Frequency distributions of Waigani/University and Boroko/Korobosea are similar to that of Gerehu although the shapes of the peaks are slightly different. Frequency distributions of Hohola/Takalala, Gordons/Saraga, Kilakila/Kaugere and Town/Hanuabada are similar to each other, and population densities from low to high were recognized in 1980. The occurrence of low densities decreased, while that of high densities increased.

Two patterns of movement of the frequency distribution of population densities were recognized. They are :

- the curve does not change its shape but shifts to higher densities
- the shift from low densities to high densities can be clearly recognized

There are units with over 200 persons/ha in every census division in 1980 and 1990. Housing conditions in these units are extraordinary, with over concentration of settlements. Therefore, it is not correct to take these high population densities as saturation population densities for residential area under normal conditions. The saturation population densities for the future population distribution is determined as the average figure of the higher 20 % of purely residential units. Table C.6 shows the results.

3.5 Future Population Distribution

Distribution was estimated by the following four steps;

Step 1 Division of population in 2015 into two categories, urban and non-urban

Step 2 Division into urban and non-urban for years between 1990 and 2015 at 5 year intervals

Step 3 Distribution to census divisions

Step 4 Distribution to collecting units

Future population distribution was estimated under the following conditions;

- Population was distributed to census divisions, and further to the collecting units, and other possible development areas.

- Distribution was estimated until 2015 at 5 year intervals.

- Population of a division or a unit will increase with the growth rate of the same division or unit obtained from the previous period.

- If the population density of a division or unit exceeded the saturation density, saturation population was taken as the maximum population for the division or unit. The maximum population was fixed for the following years.

- Excess population was distributed to possible development areas in proportion to their areas.

Population distribution by census divisions are shown in Table C.7 and Fig. C.11. Population distributions in new development areas are shown in Table C.8.

TABLE C.1 CITIZEN POPULATION BY AGE AND SEX IN 1990

Age	Population		Age	Population	
	Male	Female		Male	Female
0	2728	2556	38	1443	1028
1	2665	2454	39	1004	645
2	2953	2720	40	1959	1098
3	2981	2813	41	657	363
4	3013	2627	42	914	529
5	2951	2572	43	534	405
6	2755	2544	44	414	298
7	2498	2375	45	1001	482
8	2499	2195	46	406	308
9	2371	2095	47	377	249
10	2565	2173	48	725	437
11	2010	1793	49	372	231
12	2177	1902	50	801	558
13	2097	1848	51	262	167
14	2039	1810	52	344	233
15	2136	1910	53	246	155
16	2246	1972	54	269	192
17	2182	1808	55	330	229
18	2776	2178	56	254	156
19	3070	2023	57	177	117
20	3396	2631	58	239	167
21	2890	2162	59	164	109
22	2741	1991	60	429	335
23	2295	1907	61	109	71
24	2482	1892	62	129	117
25	2991	2111	63	111	80
26	2534	1894	64	104	78
27	2093	1569	65	159	122
28	2284	1868	66	63	50
29	1805	1586	67	80	62
30	3045	2244	68	65	45
31	1317	1010	69	55	53
32	1947	1530	70	140	121
33	1188	952	71	41	27
34	1450	1059	72	33	28
35	1874	1194	73	26	15
36	1550	1077	74	14	25
37	1008	716	75+	230	209
Total				104282	83355
Grand- Total					187637

TABLE C.2 AVERAGE SPECIFIC FERTILITY RATES BY AGE GROUP IN 1980

per woman

Age Group	15-19	20-24	25-29	30-34	35-39	40-44	45-49
ASFR	0.133	0.261	0.246	0.175	0.108	0.061	0.008

TABLE C.3 POPULATION OUTSIDE PROVINCE

Age Group	Population		Rate	
	Male	Female	Male	Female
0-9	6349	5720	0.10	0.13
10-19	11414	8839	0.18	0.19
20-29	20413	14874	0.33	0.33
30-39	13779	9664	0.22	0.21
40-49	6660	3823	0.11	0.08
50-59	2726	1710	0.04	0.04
60-69	1094	811	0.02	0.02
70-	374	310	0.01	0.01
Total	62809	45751	1.01	1.01

TABLE C.4 POPULATION ESTIMATION

Year	Annual Growth Rate and Method			
	4.7	5.3	Cohort	Regression
1990	195,140	195,140	195,140	195,140
1995	245,800	250,400	252,400	226,600
2000	309,300	322,000	314,300	258,000
2005	389,100	414,700	380,100	289,400
2010	489,500	534,700	449,900	320,800
2015	615,900	690,000	526,400	352,200

TABLE C.5 POSSIBLE DEVELOPMENT AREA BY CENSUS DIVISION

Census No.	Division Name	URBANISED AREA (ha)	POSSIBLE DEVELOPMENT AREA (ha)
80	Gerehu	611	148
81	Waigani/University	803	192
82	Hohola/Tokarara	759	167
83	Gordons/Saraga	1185	31
84	Korobosea/Boroko	560	98
85	Kilakila/Kaugere	485	0
86	Town/Hanuabada	552	0
87	Napanapa/Laloki	220	1640
88	Bomana	240	1130
Total		5215	3406

Possible Development Area in New Development Area

87	Napanapa/Laloki								
		L1	L2	L3	L4	L5	L6	L7	Total
		120	70	190	180	750	300	30	1640
88	Bomana								
		B1	B2	B3	B4				
		390	250	450	40				1130

TABLE C.6 POPULATION DENSITY

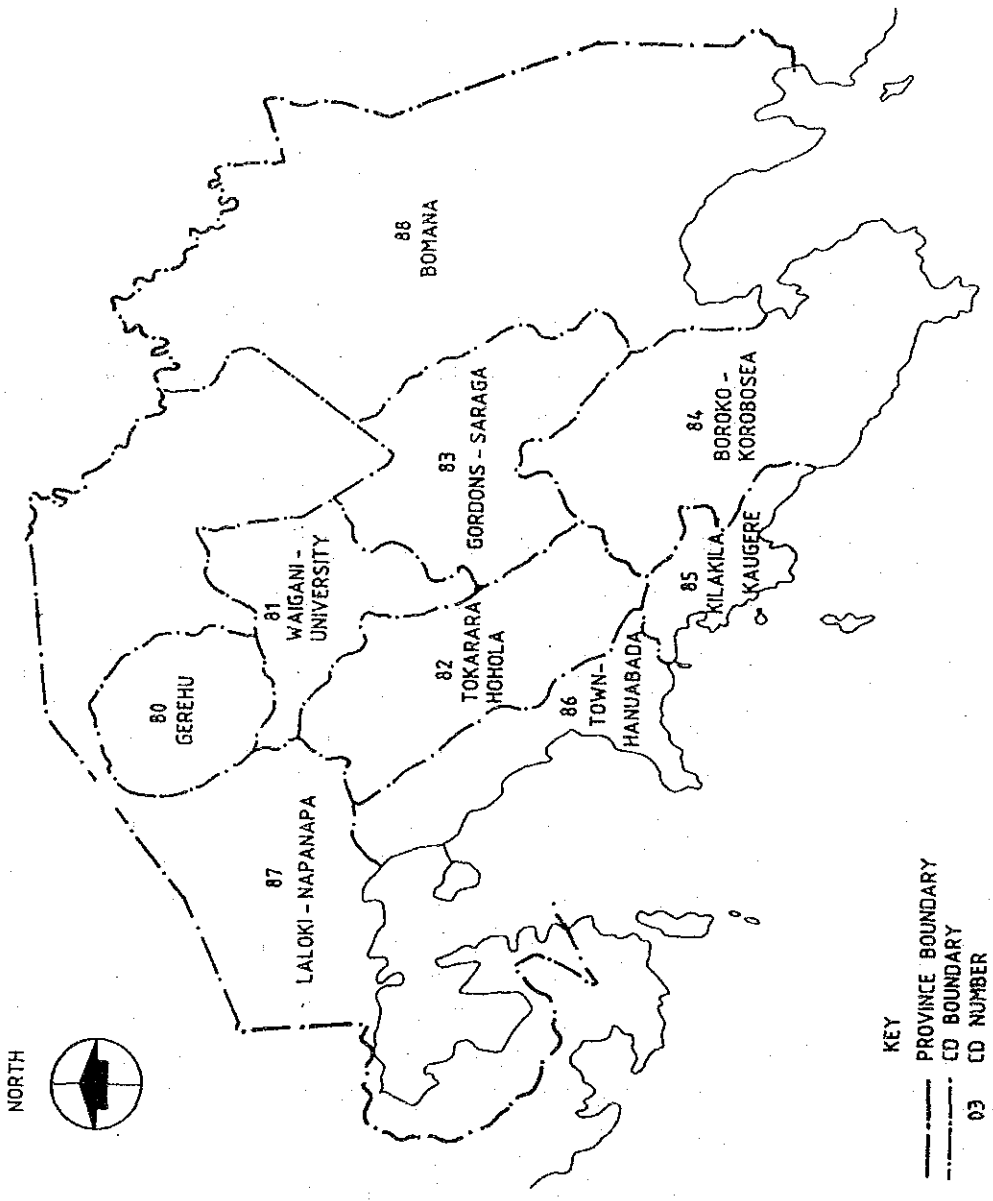
Census Division No.	Name	Population Density (persons/ha) Residential	Exclusive Residential	Saturated
80	Gerehu	82	101	150
81	Waigani/University	76	76	120
82	Hohola/Tokarara	97	91	160
83	Gordons/Saraga	103	101	180
84	Korobosea/Boroko	79	59	90
85	Kilakila/Kaugere	120	143	260
86	Town/Hanuabada	88	74	150
87	Napanapa/Laloki	-	-	-
88	Bomana	-	-	-
Total		92	111	-

TABLE C. 7 POPULATION DISTRIBUTION BY CENSUS DIVISION

Census Division		Year					
No.	Name	1990	1995	2000	2005	2010	2015
80	Gerehu	22700	28026	33170	40545	50219	53400
81	Waigani/University	16362	19822	23098	27725	33681	37900
82	Hohola/Tokarara	32232	40341	48271	59737	67401	67400
83	Gordons/Saraga	31400	43464	56514	58000	58000	58000
84	Korobosea/Boroko	26806	31842	35304	35304	35304	35300
85	Kilakila/Kaugere	28860	36086	43149	53367	62701	62700
86	Town/Hanuabada	25965	30320	34294	39723	44300	44300
87	Napanapa/Laloki	3013	7565	16061	29594	48866	92705
88	Bomana	8044	14935	24439	36106	49434	74595
Total		195382	252401	314300	380101	449906	526306

TABLE C.8 POPULATION DISTRIBUTION IN NEW DEVELOLPMENT AREA

	Year					
	1990	1995	2000	2005	2010	2015
Napanapa/Laloki						
CUs	3015	5103	8635	12608	14404	16642
L1	0	180	543	1243	2522	5566
L2	0	105	317	725	1471	3247
L3	0	285	860	1968	3993	8812
L4	0	270	815	1864	3782	8348
L5	0	1126	3396	7768	15760	34785
L6	0	450	1358	3107	6304	13914
L7	0	45	136	311	630	1391
Total	3015	7564	16060	29594	48866	92705
Bomana						
CDs	8067	11251	15691	18088	19486	21412
B1		1271	3019	6219	10336	18355
B2		815	1935	3986	6626	11766
B3		1467	3484	7175	11926	21179
B4		130	310	638	1060	1883
Total	8067	14934	24439	36106	49434	74595



TITLE

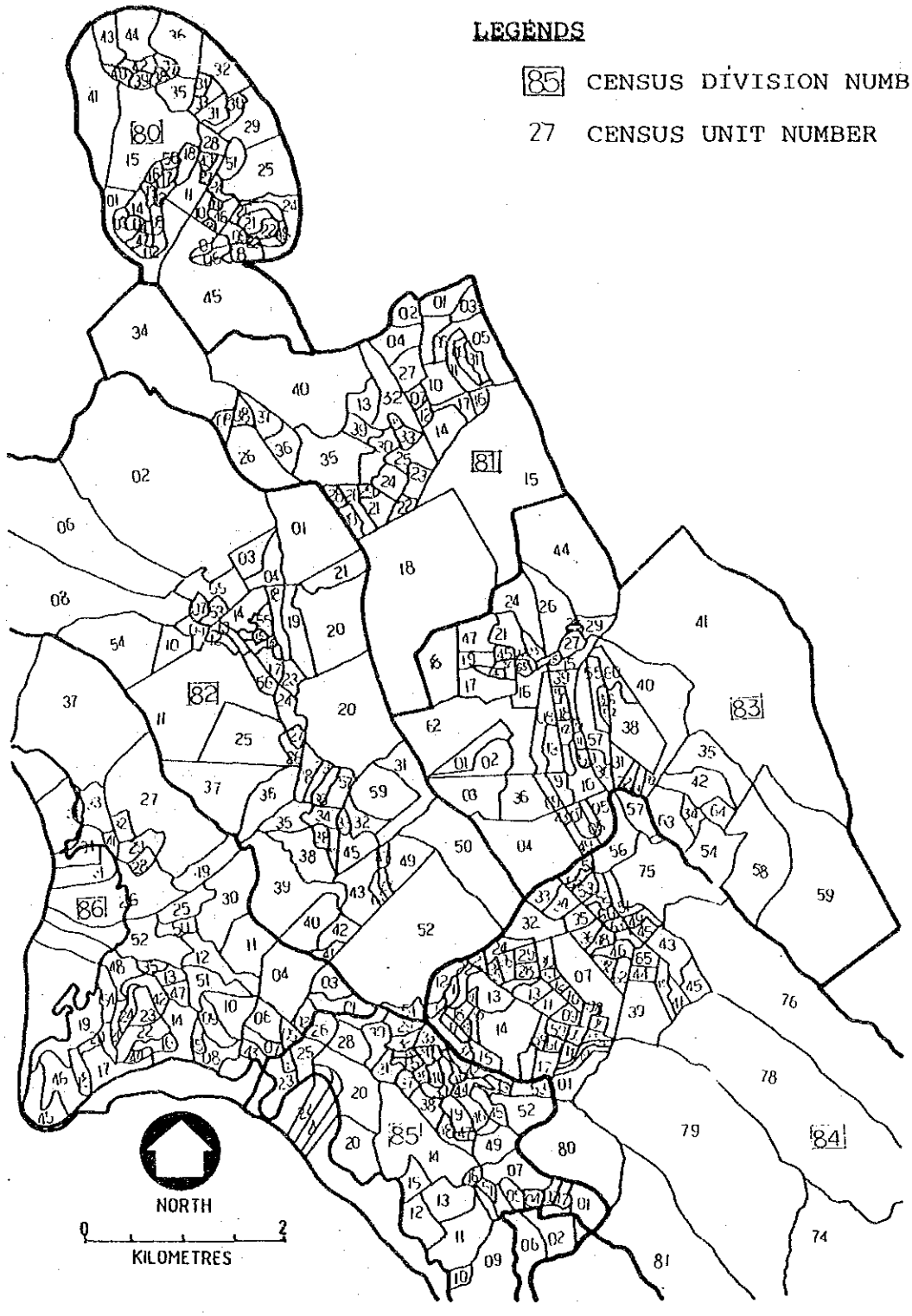
CENSUS DIVISIONS

Fig. No.

C.1

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



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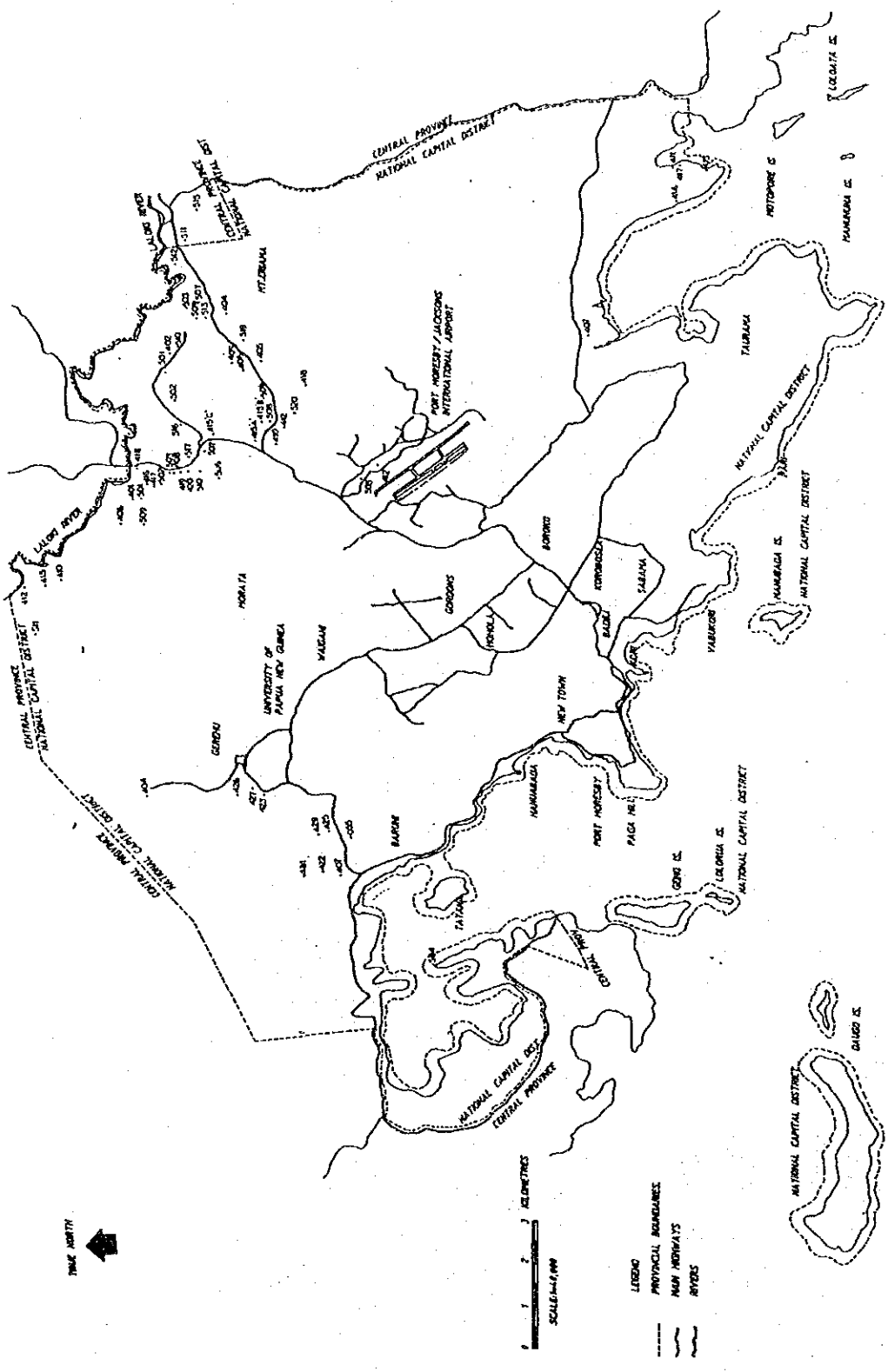
CENSUS UNITS IN URBAN AREA

Fig. No.

C.2

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



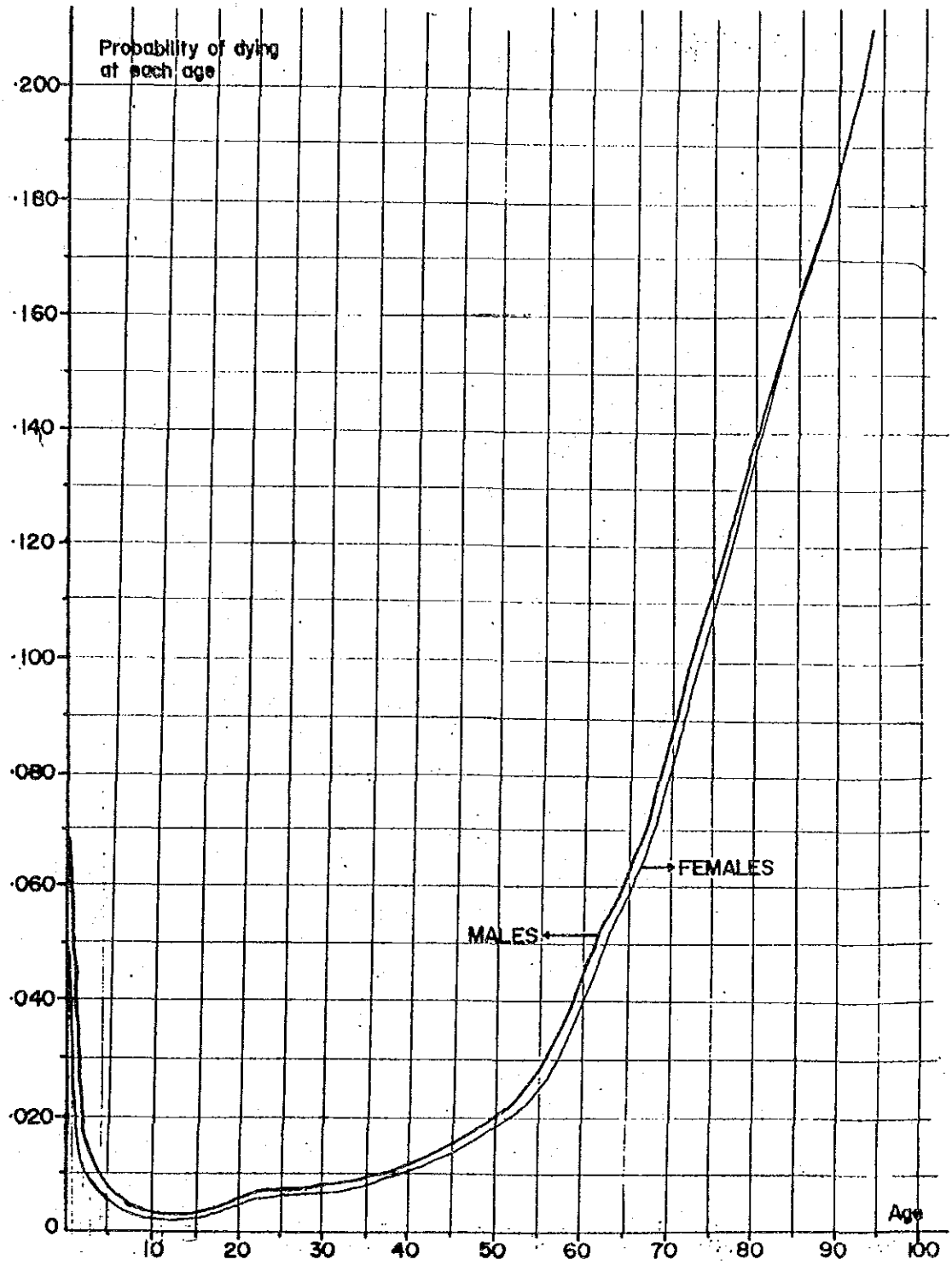
TITLE

CENSUS UNITS IN NON-URBAN AREA

Fig. No.
C.3

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

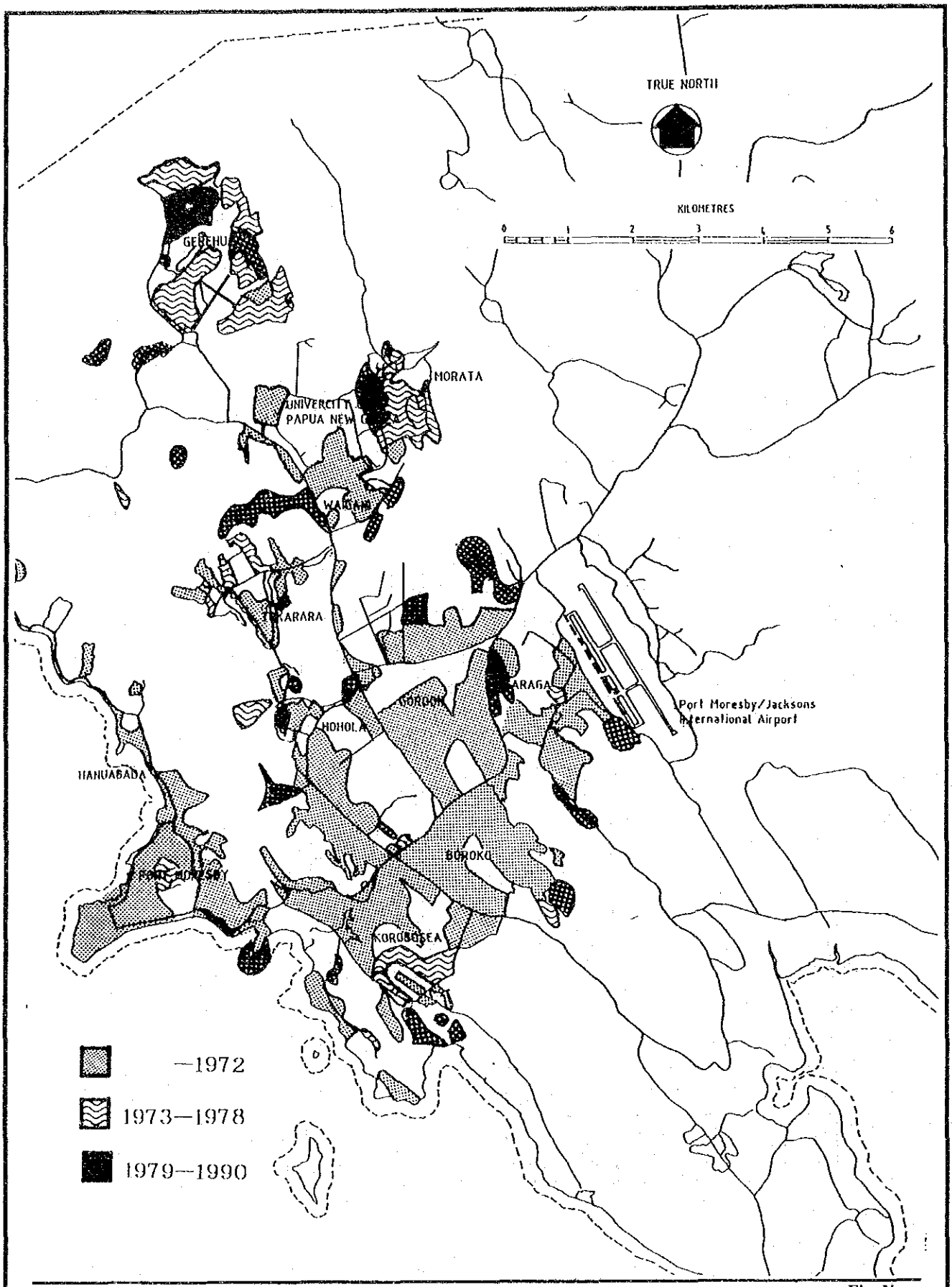
MORTALITY RATE BY AGE AND SEX IN 1980

Fig. No.

C.4

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

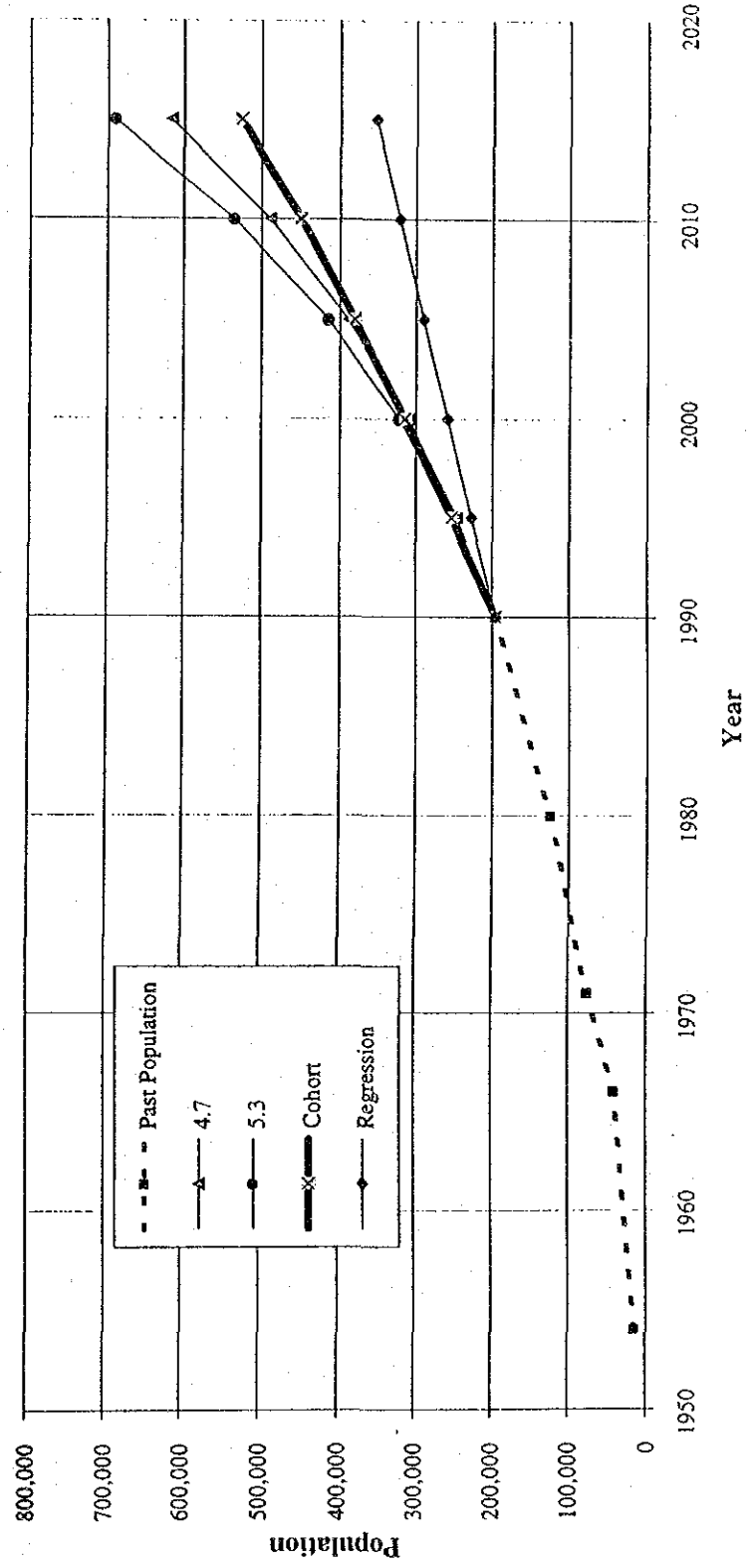
PAST LAND DEVELOPMENT (1972-1990)

Fig. No.

C.5

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

POPULATION ESTIMATION

Fig. No.

C.6

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

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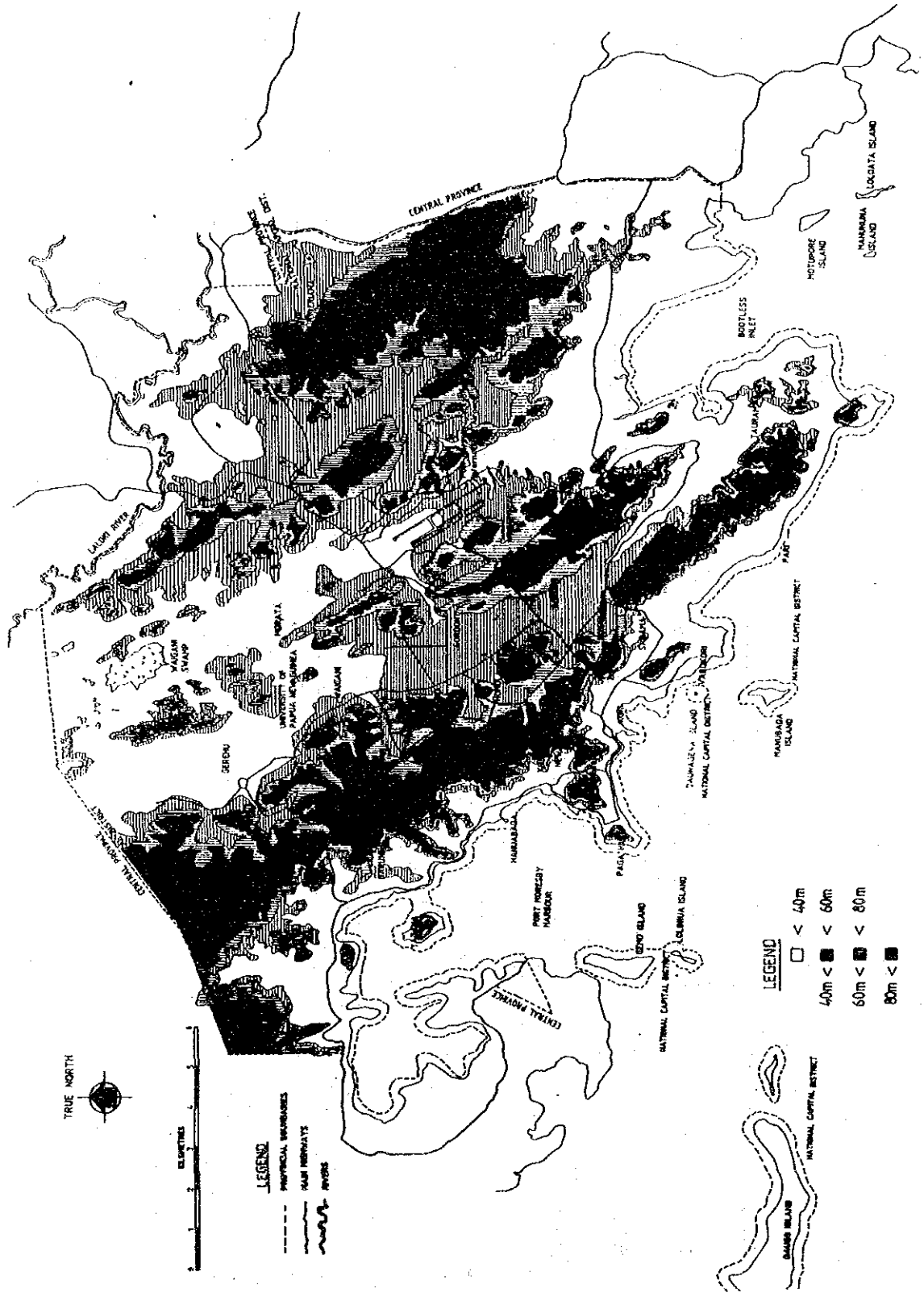

TITLE

ELEVATION IN NCD

Fig. No.

C.7

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

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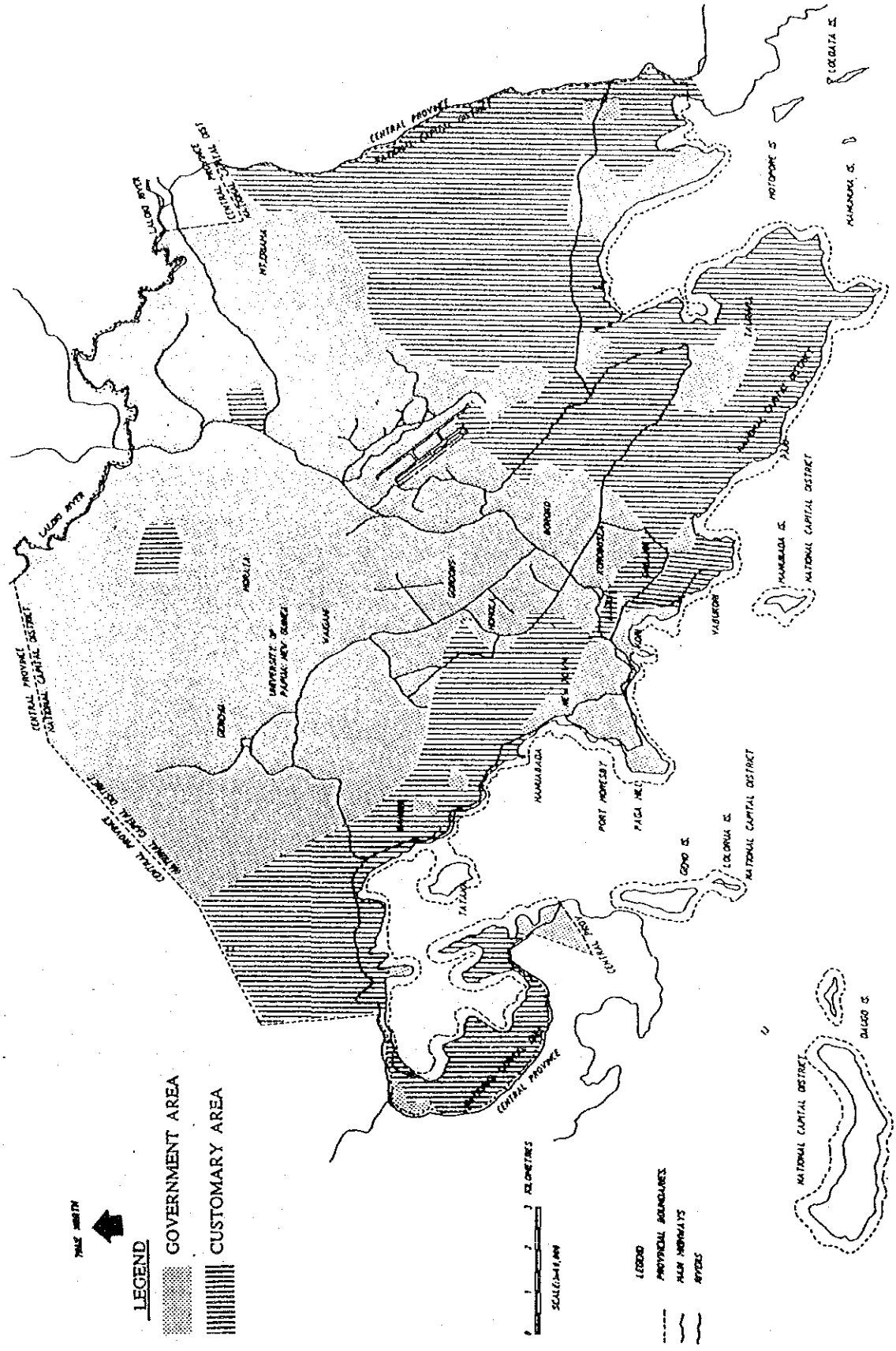

TITLE

LAND OWNERSHIP

Fig. No.

C.8

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

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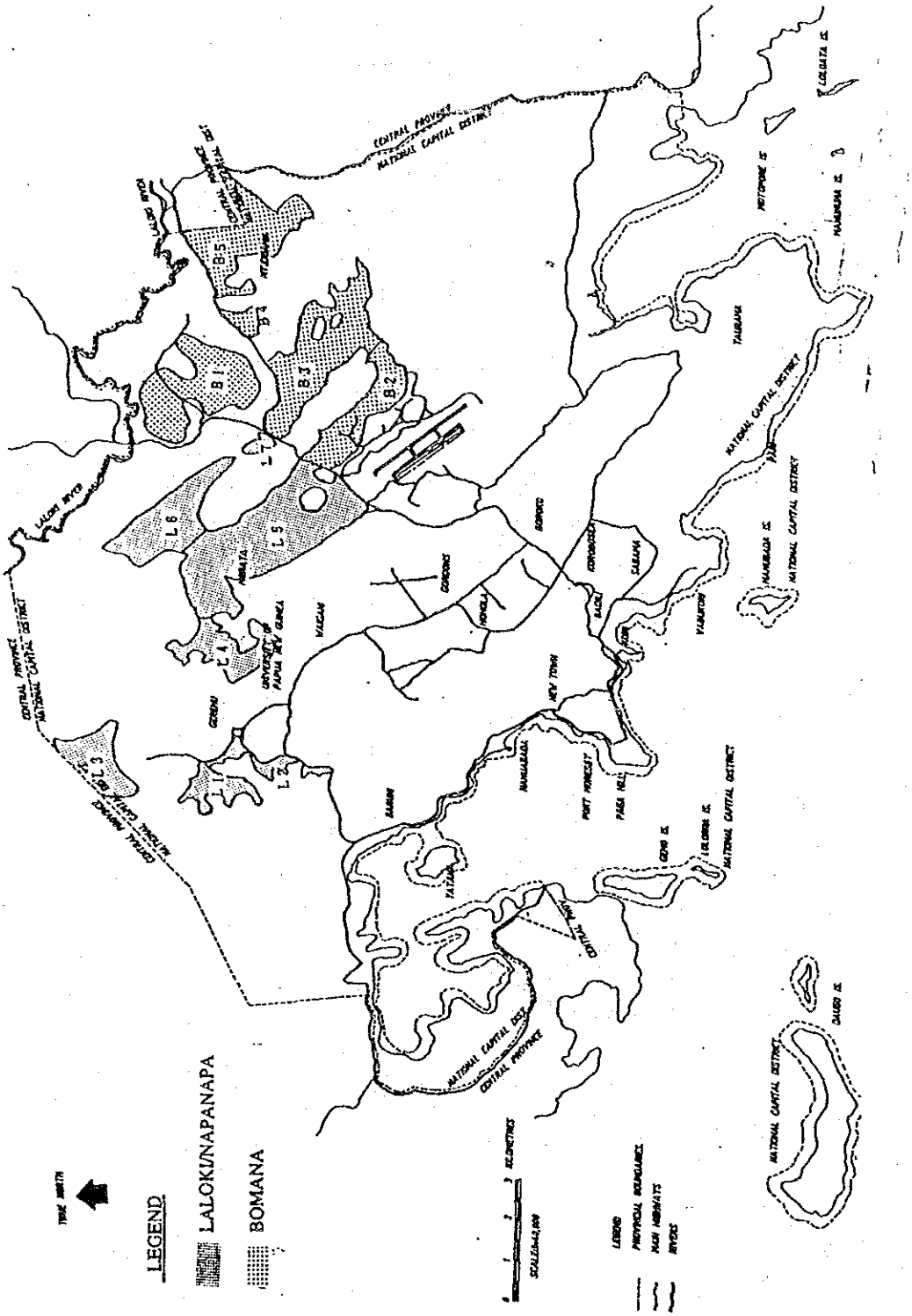


TITLE

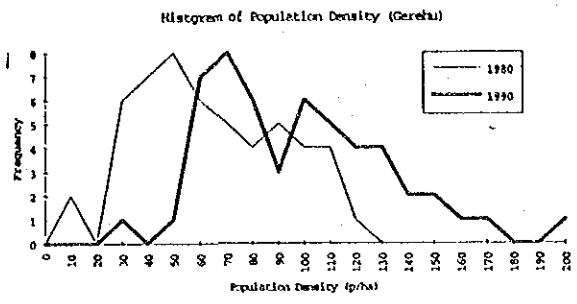
POSSIBLE DEVELOPMENT AREA

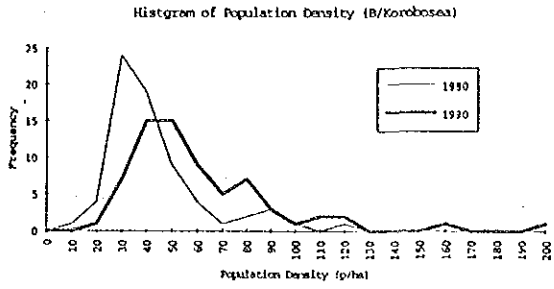
Fig. No.

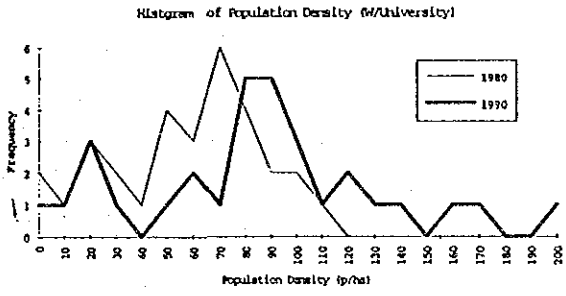
C.9

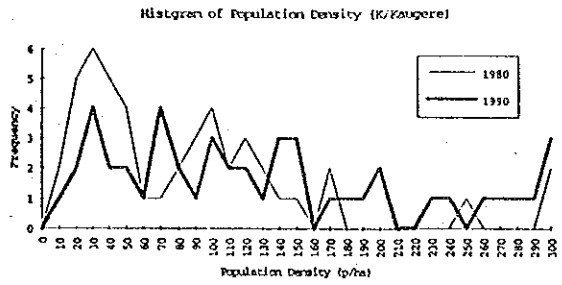
PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

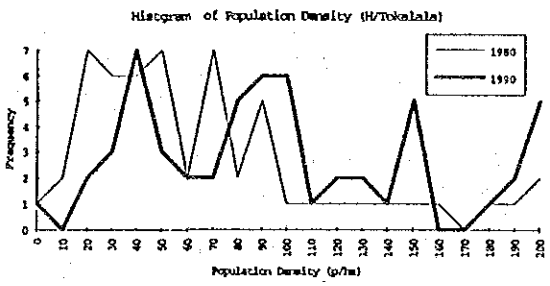
TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

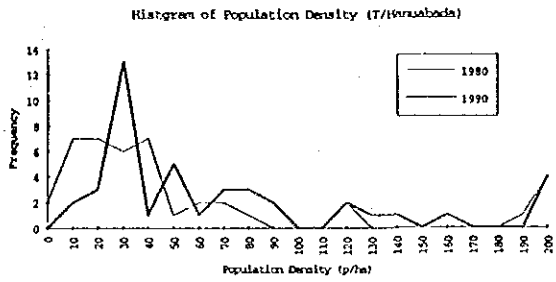


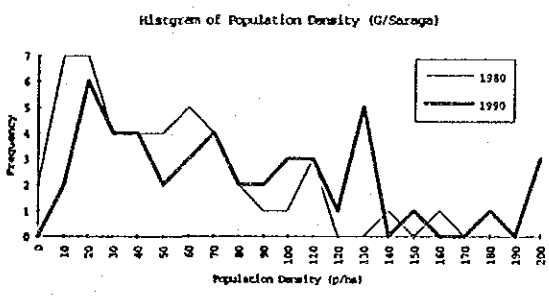












TITLE

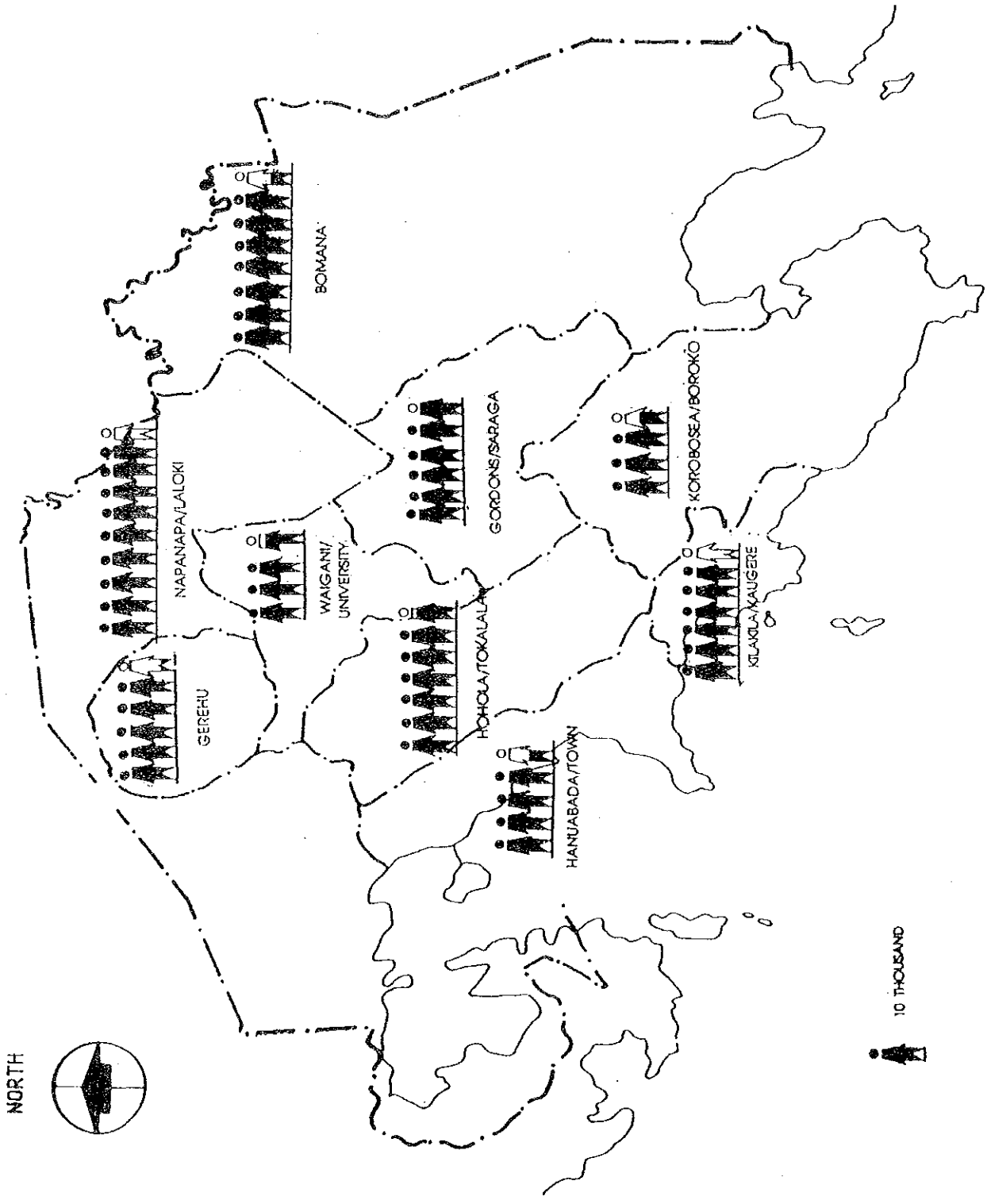
HISTOGRAM OF POPULATION DENSITY

Fig. No.

C.10

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

POPULATION DISTRIBUTION (2015)

Fig. No.

C.11

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

APPENDIX D

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN
WATER CONSUMPTION

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APPENDIX D WATER CONSUMPTION

D.1 GROSS DEMAND

The average daily demand was 642 liters per capita per day (lcd) in 1979 while the maximum daily demand was 765 lcd.

The dry period per capita demand (nearly maximum daily demand) in 1986 and 1987 is between 733 and 767 lcd. These values are obtained by dividing the supplied amount (assuming the supplied amount was same as the current 125 mld) by the population (population was estimated at 163,000 in 1986 and 170,500 in 1987 using a 4.7 % annual increase). At that time, water was supplied adequately. The current water crisis started in the 1987 dry period.

The above values are very similar to the 1979 values. If the 1979 per capita value is still applicable today (probably so), average and maximum daily demands should be 138 mld and 165 mld respectively in 1992.

D.2 NCDC Records

Meter reading records prepared by the NCDC financial division and submitted to the study team contain the following;

- Account Number
- Location (Section Name, Section No. and Lot No.)
- Area (ha)
- Rate Category (Residential, Commercial *1, Standpipe, Public, Straight Pipe, and Exempt)
- Meter Number
- Connection Number
- Reading Date (oldest and latest)
- Meter Reading (oldest and latest)

*1 Records in commercial category include commercial, industrial and public records.

The available data was 19,967 records for 5 quarters ending September 1992 since the NCDC files could store the latest five records. Out of the total, 11,208 records could be

used. These records were read at least twice with meters so that consumption could be calculated. The results are summarized in Table D.1. Per capita residential consumption was calculated as approximately 350 liters per day. The consumption can be regarded as an annual average demand because the durations in each record differ, ranging from one-quarter to five-quarters. Daily metered consumption was approximately 42 mld in total, 27 mld for residential and 15 mld for non-residential use.

D.3 RESIDENTIAL CONSUMPTION

Water is consumed by residential, commercial, industrial and institutional bodies. In this section, residential consumption is analyzed.

D.3.1 Field Investigation

In conjunction with the leakage measurement in the three model areas (explained in Appendix "Leakage"), the per capita consumption was measured during October and November 1992, when there was no rainfall. Population was approximately 1,400 in the three model areas, which is 0.7 % of the city population. Field work required reading of all meters weekly over a period of 3 weeks, together with interviews of residents about number of persons in the house, rooms and water-consuming-utilities like washing machine. The results are shown in Tables D.2 to D.4. The per capita consumption in each model area was calculated weekly. The results showed fairly consistent values throughout the three weeks; (in liters per day)

Gerehu : 249(first week), 257(second week), 290(third week), 265(average)
Boroko : 388(first week), 370(second week), 379(average)
Gordons: 534(first week), 528(second week), 498(third week), 520(average)

Next, the NCDC records corresponding to each model area were analyzed according to housing types. Results are shown in Tables D.5 to D.12 with a summary in Table D.13. Both values in per capita consumption are similar, with a 15 % difference. JICA's values give higher consumption because they were measured during the dry period of October and November 1992 when rainfall was poor. Hence, it is higher than the average per capita consumption given by the NCDC records.

D.3.2 Housing Type Consumption

After the JICA's spot readings were found to match NCDC's meter records, NCDC records were further analyzed to obtain per capita consumption in various housing types

since wide variations in the patterns of water use have been noted in Port Moresby, depending on housing type.

Several distinct housing categories have been defined by the National Statistical Office which are useful for water supply purposes. The categories are as follows;

1) High Cost : Houses and flats which are well built, fully lined and fully serviced with water supply, electricity and sewage facilities.

2) Low Cost : Houses and flats which are significantly smaller than the high-cost houses. They are often unlined and have fewer amenities. They may be located in either of the following areas;

   (a) Suburban Areas - Areas have been subdivided into sections and allotments with roads and street lighting. Most dwellings in such areas are connected to the reticulated sewage system.

   (b)Villages and Settlements - Low cost dwellings in these areas may be distinguished from those in suburban areas in that they are not connected to the sewage system, but use pit latrines, and consequently consume less water.

3) Self Help : Houses are built by the occupants themselves from brought or foraged materials. These houses are found in traditional village in both planned and unplanned (squatter) settlements. They have no electricity and no water supply, and have individual or communal pit latrines. A few have communal flush toilets and bathing facilities not connected to the sewage system.

The National Statistical Office conducted a Household Expenditure Survey in 1976 which indicated the percentage of dwellings in each housing category. The results of this survey are shown in Table D.14.

High cost housing was fully equipped with piped water supply, flush toilet and bath or showers in 1977. Domestic quarters and low cost housing in suburban area were almost fully equipped. Low cost houses in settlements were also almost fully equipped, except flush toilet. Only self- help housing lacked such facilities. These equipment arrangements increase water consumption.

A survey of the three model areas in late 1992 by the study team confirms the above equipment arrangements. Further, random checking in late 1992 for low cost housing

and self-help housing show much higher development of piped water supply, often with individually developed reticulation system from the standpipes.

Comparison of the 1980 and 1990 census shows that housing standards have improved as seen in Table D.15. High cost housing, consisting of high cost houses, flats and self-help high cost housing constitutes 37.7 % of the 1990 population. Low cost housing - duplex, domestic quarters and low cost housing - constitutes 34.7 %. Adding the above two types to special dwelling, formal housing constitutes 75.4 %. The remaining 24.6 % is informal housing, make-shift, traditional and self-help low cost housing.

With this information in mind, census sub-divisions consisting of single housing type were identified in the 1990 census. Then, the NCDC records corresponding to these sub-divisions were analyzed. The analyzed per capita consumptions are shown in Table D.16 and are summarized as follows;

* High cost housing : 371 liters per day
* Flat : 371 liters per day
* Low cost housing : 259 liters per day
* Duplex : 272 liters per day

D.3.3 Per Capita Consumption

The following per capita consumptions are derived from various investigations .

High cost housing : 380 liters per capita per day
- high cost housing
- flat
- high cost self help

Low cost housing : 300 liters per capita per day
- low cost housing
- duplex
- domestic quarters
- special dwelling

Informal housing : 300 liters per capita per day
- make shift
- traditional
- low cost self help

Daily average consumption for residential use is calculated as approximately 325 liters per capita per day using the composition rates of housing types.

The above values are higher than the value used for design by the Waterboard, which is responsible for town water supply systems. It assumes the following consumption; 225 lcd for a high cost house, 185 lcd for a low cost house, 77 lcd for a self-help dwelling, and 45 lcd for a village settler.

However, actual consumption seems to exceed the above values. The reported average daily consumption for the specified period in 1987 in Lae and Wewak was 2000 l/d/allotment for a high covenant and 1400 l/d/allotment for a low covenant. If assuming 7 person reside in one allotment, per capita consumption becomes as follows; 286 l/d for a high covenant and 200 l/d for a low covenant.

It is noted that these values are for the towns with relatively small rainfall, however, annual rainfall is at least two times that of Port Moresby; 2230 mm in Wewak, 4550 mm in Lae and 1200 mm in Port Moresby. Furthermore, only Port Moresby and its surroundings are located in a complete half-year dry period climate zone. Considering this, higher consumption in Port Moresby is judged reasonable.

D.4 NON-RESIDENTIAL CONSUMPTION

There are a few water intensive industries and, lots of government offices. Towns with major commercial activities are Boroko, Town and Badili; Industrial areas are Gordons (Spring Garden road area) and Badili; and government offices are Waigani and Konedobu. Besides, airport, army barracks and police barracks are located in the city.

NCDC meter cards were checked to determine non-residential consumptions. Total consumption was 15 mld in 1991/92. Table D.17 shows 26 large-consumers in 1988 with some NCDC records, totaling 6 mld.

D.4.1 Industrial

Available Data

For the estimation of industrial water consumption, the following data can be used.

- NCDC Meter Reading

- "Larger Water Consumption Survey" conducted in 1988
- List of Factories in NCD (145 factories in total)
- Town Zoning Map

Estimation Procedure

It is desirable to estimate the industrial water consumption from meter reading records of all the factories. However, meter reading records are not available for all the factories, and some factories are missing in the list. Therefore, the industrial water consumption was estimated by the following procedure.

Step 1 Sum up water consumption of factories for which meter reading records are available.

Step 2 If meter reading records are not available, and "Lager Water Consumption Survey" data are available, sum up the latter.

Step 3 Water consumption is measured on site for a water intensive factory i.e. SP Brewery.

Step 4 For factories whose water consumption can not be calculated by Steps 1 to 3, water consumption is calculated by the following method.

1) Lot areas occupied by operational factories in the industrial zone marked on the Town Zoning Map, are measured based on the information obtained from the site visits by the study team.

2) Reduce the lot areas occupied by factories whose water consumption is calculated by Steps 1 to 3 from the above.

3) Lot areas calculated in 2) above are multiplied by water consumption rates per area which are obtained from the factories in Steps 1 to 3. Two different rates, one for a lot 1 ha or more and another for a lot less than 1 ha, are used because rates clearly vary the size of lot area. Water consumption rate analyzed by lot areas and water consumption in records are shown below.

Classification	Lot Areas (ha)	Consumption Rates (m3/ha/day)	WaterConsumption (m3/day)
Lot area 1 ha or less	15.75	751	48
Lot area more than 1 ha	19.32	150	8

Step 5 Industrial areas in Laloki/Napanapa and Bomana could not be measured because these districts are non-urban and outside the zoning area. Industrial water consumption in these districts are calculated on the basis of population and per-capita industrial water consumption rate. Per-capita rate for Kilakila/Kaugere district is used because of similar characteristics of residential use ie., settlement area.

Industrial water consumption by census divisions estimated by Steps 1 through 5 are tabulated in Table D.18.

D.4.2 Public

Available Data

For the estimation of public water consumption, the following data can be used.

- NCDC Meter Reading Records
- "Large Water Consumption Survey" conducted in 1988
- NCDC Staff Number List
- School Student Number List
- Other Public Institute
  (Large Hospitals, Barrack, Parks etc.)

Estimation Procedure

Public water consumption was estimated by the following three categories, viz. government office, school, and other public institutions. Estimation procedures for the three categories are as follows:

1. Government Office

Various government offices are included in this category. Water consumption by NCDC is also included in this category. Meter reading records for these offices were collected. Water consumption rate per person shown below, was calculated from these records.

Public Office	No.of Persons	Water Consumption (l/day)	Consumption Rates (l/person/day)
Parliament House	177	45254	256
Works Department	301	103515	345
Tarpot (4 mile)	271	123236	455
Average			363

2.Schools

Various kinds of schools are included in this category. The same procedure for the government office, i.e. consumption rate per student, was used for this category. Water consumption for this category is shown below.

School	No.of Students	Water Consumption (l/day)	Water Rate (l/student/day)
Ororo Community	584	17958	31
Koki St.Francis Community	384	16629	43
June Valley Community	525	24307	46
Avcrage			39

3. Other Public Institutions

Hospitals, barracks, parks and other public institutions are included in this category. NCDC meter reading records are also the basis for estimation of water consumption for this category. The result of the estimation is shown below.

Public water consumptions by census divisions are tabulated in Table D.19.

	Public Institute	NCDC Records (l/day)	1988 water Consumption Survey (l/day)
Hospital			
	Port Moresby General Hospital	503859	
	Laloki Psychiatric Health Center		238300
Barracks			
	Gordons Police Barracks		598000
	Kila Police Barracks		221300
	Taurama Barracks		170000
Park/Field			
	Sir Hubert Murry Memorial Park	234220	
	Botanical Garden	85911	
	Sir Donald Cleland Pool		20700
	Sir John Guise Stadium	115007	
D.C.A. Jacksons Airport			1166000

D.4.3 Commercial

Available Data

The following data can be used for the estimation of commercial water consumption.

- NCDC Meter Reading Records
- Town Zoning Map
- Hotel List

Estimation Procedure

The commercial category for the NCDC Meter Reading Records includes industrial and public consumers. Firstly, records for the two categories were separated from commercial records. Then, water consumptions by hotels and a golf course was estimated separately because these consume relatively large quantities of water and are located outside commercial areas. Other commercial consumptions were estimated based on land use, i.e. commercial area, and unit rates per area. Commercial water consumptions in Laloki/Napanapa and Bomana, which are both, non-urban areas, were

estimated by the same method as for industrial consumption, i.e. per-capita commercial consumption rate obtained from other districts with similar characteristics.

Water consumption for hotels was estimated from Meter Reading Records. Records for all major hotels are available. An average unit water consumption rate per room was calculated as 1,350 l/room/day as shown below.

Hotel	No.of Rooms	Water Consumption (l/day)	Water Rate (L/room/day)
Gate Way	96	88949	927
Travelodge	177	185656	1049
Islander	163	310287	1904
Average			1341

A golf course is located in NCD, and it consumes a large quantity of the water supplied by NCDC. Water consumption for the golf course was estimated by using unit consumption rate of the botanical garden, since Meter Reading Records are not available for the course. The unit consumption rate of the botanical garden is 3.0 m3/ha/day as shown below.

Unit Water Consumption Rate of the Botanical Garden

Area (ha)	Water Consumption (m^3/day)	Consumption Rate (m3/ha/day)
31.6	85.9	2.7 = 3.0

Commercial water consumptions by census divisions are tabulated in Table D.20.

D.4.4 Summary of Water Consumption

Unit water consumption rates of domestic and non-domestic use by category are shown below.

Summary of Unit Water Consumption Rates

Category	Classification	Unit Rate	(unit)
Domestic	High cost housing	380	l/p/day
	Low cost housing	300	l/p/day
	Informal housing	300	l/p/day
Industrial	Lot area 1 ha or less	48	m^3/ha/day
	Lot area more than 1 ha	8	
Commercial	Area 0.5 ha or less	58	m^3/ha/day
	Area more than 0.5 ha	6	
	Hotel	1,350	l/room/day
	Field	3	m^3/ha/day
Public	Government offices	365	l/p/day
	School	40	l/p/day

Water consumptions by census divisions are tabulated in Table D.21.

D.5 DEMAND CHARACTERISTICS

D.5.1 Hourly Maximum Demand

Demand characteristics are usually derived from the output records of the treatment plant. However, this was not possible in this Study because supply was almost constant at full capacity throughout the Study period (refer to Fig. D.1).{1}

Flow measurements were conducted, to know the demand characteristics at Gerehu to which water is supplied through a 250mm single pipe. Its population is 22,727 persons according to 1990 census. However, daylight demand was almost constant at 1.1 times the average demand with no clear peak demand for the entire Gerehu area, as shown in Table D.22 and Fig. D.2. The absence of high peaks in the curve was attributed to the high minimum daily flow which reflects system losses, wastage and poor distribution to certain areas during peak demand.

Flows for small sections were measured{2}; *in Boroko, Gordons and Gerehu areas* (refer to Table D.23). Pressures in these areas were high throughout the measurement periods so no demand suppression occurred. Also individual water storage tanks were not observed within the model area.

Hourly demand fluctuations are significant in the demand curves for the three model areas as shown in Fig. D.3. to D.5 and in Table D.24. The fluctuation at Godons model area is maximum and lies between 1.71 and 0.55 with an effective pressure of 65 to 80 m. Peak hourly demands occur twice; once in the morning and once in the evening.

Area demand fluctuates depending on time. Demand increases at 5:00 to 6:00 in the morning and recahes a peak between 6:00 and 7:00 on weekdays, and at 9:00 on weekend. After the morning peak demand, daytime demand gradually decreases to the evening peak between 18:00 and 19:00. Minimum demand is between 02:00 and 03:00.

The shape of Gerehu model area is also similar, although the range of fluctuation is slightly smaller, between 1.50 and 0.73, with effective pressure of 23 to 66 m, compared to Gordons. The shape of the two demand curve are typically found in water supply systems elsewhere, except for the occasional high demand during daytime.

On the other hand, the demand curve in Boroko is unique. The peak is not significant. Daytime demand between 11:00 and 16:00 is equal to the morning peak demand. Long daytime demand is attributed to the filling of the swimming pool. If this consumption is eliminated, the shape of the demand curve will resemble those at the two model areas and the peak demand value will rise.

Furthermore, if the baseflow is reduced, for example, through leakage control measures, the peak hourly flow will increase. On the other hand, peak hourly demand usually decreases as water supply system expands. Considering the above contradiction, a peak hourly flow of about 1.7 times the average hourly flow is used for design purposes.

D.5.2 Daily Maximum Demand

A report related to maximum and average consumption says that ;

1) the total Mt.Eriama treatment plant treated water production for 1979 was 28,582 ml, or 78 mld.

2) the maximum daily consumption during 1979 was 83 mld.

3) In May 1980, a daily consumption of 93 mld was recorded.

4) the maximum daily consumption is 10 % to 30 % higher than the average daily consumption.

The seasonal consumption variations reflect the distinct climatic regime of the NCD. The high dry season consumptions observed throughout NCD show high correlation with areas where garden watering is significant. That is, in high cost areas with large gardens, and low cost areas where a vegetable gardens is important to the house owner for a variety of socio-economic reasons.

A survey of Victorian cities (Australia) determined that garden watering represents 30-50% of the mean annual use and 50-70% of mean summer use. In an ordinary residence in Japan where watering of garden is not appreciable and water is used mainly for washing, bathing, flushing toilet and cooking, the per capita consumption is about 200 to 250 liters per day. If this figure is used here and 50 % is added for watering garden, per capita consumption should be 300 to 375 liters per day. These assumed figures match the obtained per capita consumption mentioned before.

Consumption for garden watering almost equals other consumption for other purposes. Hence, the maximum daily consumption is about 25 % higher than the average daily consumption. For planning purposes, a maximum daily demand 30 % higher than the average demand, is a reasonable assumption.

D.6 Water Demand

D.6.1 Current Water Demands

Residential water demands were estimated based on the population and per-capita water consumption both classified into a few groups according to the types of housing. Non-residential water demands were estimated based on the NCDC meter reading records and unit consumption rates calculated from the records. Water demands (daily maximum) by category in each census division, are shown in Table D.25.

D.6.2 Future Water Demands

Future water demands in the study area were estimated with the conditions mentioned below.

1. For residential water demands, current per-capita consumption rates were used for the following reasons:

- NCD is more urbanized than any other city in PNG.
- Most of the city area has been provided sewage facilities.
- Flush toilets and showers are widespread.
- Current consumption rate is considerably high compared with those of similar cities of the other countries. Main reason for the higher consumption rate is sprinkling of water in gardens. The minimum supply for basic human needs is already satisfied.

Per-capita water consumption rates are shown below.

High cost housing : 380 lpcd
Low cost housing and Informal housing : 300 lpcd

Ratios of each housing type in the census unit will not change, in future.

2. Non-residential water demands, viz. public, industrial and commercial demands were estimated assuming that the current ratio of commercial demand to the domestic demand is constant. Ratios tare as follows:

Public demand	:	0.129 of domestic demand
Industrial demand	:	0.124 of domestic demand
Commercial demand	:	0.048 of domestic demand

3. Current water leakage has been estimated as 30 % of the total production. The aim of the study is to decrease this ratio to 20 % by 2000. Therefore, water leakage ratio was set at 20 % in 2000 and thereafter.

4. The daily maximum consumption is considered to be 30 % higher than the daily average, which is the same as it is now.
   Daily maximum consumption factor: 1.3

Future water demands were estimated as shown below and in Fig.D.6, with and without leakage control.

Total Future Water Demands (Daily Max)

	Year					
	1990	1995	2000	2005	2010	2015
Water Demands (mld)	156	201	220	265	314	367

D.6.3 Distribution of Future Water Demands

Distribution of future water demands in census divisions and units was performed by two steps given below.

Step 1

Water demands of each category were distributed in the census divisions. Domestic demands were distributed firstly in census divisions based on their population. Each census division in the urban area has distinctive features of water consumption. For instance, Gordon is characterized by its industrial area and industrial consumption is higher than in other districts. Public consumption in Waigani is relatively high, because there are many government offices. These features are likely to be unchanged in the foreseeable future. Therefore, for census divisions in urban areas, non-domestic demands were distributed so as to maintain constant the ratio of demand of each category to residential demand. The current ratios of non-domestic demands, which will be constant in future, are shown in Table D.26 and also shown below.

Public	:	0.1232
Industrial	:	0.1262
Commercial	:	0.0499

Census divisions in non-urban areas (Divisions 87 and 88) have not been developed yet and features of water consumption will change from the present status. Therefore, non-domestic demands of these divisions were estimated by using average ratios of divisions in urban areas.

The sum of distributed demands of a non-domestic category is not equal to the total demand estimated previously. Thus, distributed demands were adjusted in proportion to their magnitudes, to equalize the sum and the total demands of the category.

Step 2

Water demands of census divisions distributed in Step 1 were further distributed in the census units. Areas of land use categories were the basis for the distribution, i.e. residential area for domestic demands, institutional area for public demands and industrial area for industrial demands. Division demands of each category were distributed in the units in proportion to the units' land use areas.

For units in non-urban areas, water demands of all categories were distributed in proportion to population figures, because no land use plan is available.

Water demands of each census division are shown in Table D.27.

TABLE D.1 NCDC METER RECORDS

Category	No.of Accounts	No.of meters	No. Billed **	Consumption (liter/day)	Per Capita Consumption (l/d)*
Residential					
Boroko section	2,677	1,914	2,625	5,778,371	386
Granville section	1,883	611	1,059	1,645,070	268
Hohola section	10,387	6,137	6,965	16,701,328	362
Matirogo section	1,543	425	476	2,051,288	582
(without sec 16 lot 10)		424	460	1,359,038	399
Rural area	257	51	73	407,817	843
Others	28	0	0	0	
Total	16,775	9,138	11,198	26,583,874	358
without sec 16 lot 10		9,137	11,182	25,891,624	349
Standpipe					
Boroko section	60	0	0	0	
Granville section	207	0	0	0	
Hohola section	166	10	10	18,831	
Matirogo section	1,110	0	0	0	
Rural area	65	0	0	0	
Others	7	0	0	0	
Total	1,615	0	0	18,831	
Commercial	1,519	713	0	15,000,989	
Public	8	5	0	108,532	
Straight Pipe	44	0	0	0	
Exempt	6	1	0	421	
Total	19,967	9,867	11,208	41,712,647	

as of October, 1992,

* assuming 7 persons per household

** number of meters read at least twice

TABLE D.2 PER CAPITA CONSUMPTION IN BOROKO MODEL AREA (1/2)

Section number	Lot number	Number of person			Per capita consumption (liters per day)			Number							Capacity (m3)			Type of House
		House	Flat	Quarters	Total	1st week	2nd week	Total	Kitchen	Bath	Shower	Toilet	Washing Machine	Air conditioner	Car	Solar Tank	Water Tank	Swimming Pool	
24	1	4			4	596	671	634	1	1	1	1	1		2	0.43			High
24	2	6			6	207	214	211	1	1	1	1	1		2	0.43			High
24	3		3		3				1	2	2	2	1	1		0.43			Flat
24	3		2		2				1	2	2	2	2	1		0.43			Flat
24	3		3		3				1	2	2	2	1	1		0.43			Flat
24	3		4		4				1	2	2	2	1	3	2	0.43			Flat
S.t					12	317	302	310											Flat
24	4		5		5				1	2	3	3	1	3	1	0.43			Flat
24	4		3		3				1	2	3	3	1	3	1	0.43			Flat
24	4		2		2				1	2	3	3	1	3	1	0.43			Flat
24	4		1		1				1	2	3	3	1	3	1	0.43			Flat
24	4		2		2				1	2	3	3	1	3	1	0.43			Flat
S.t					13	3	3	3										78	Flat
24	5	7			7		No meter		1	1	1	1	1	1	2	0.43			High
24	6	6			6	771	852	812	1	1	1	1	1		1	0.43			High
24	7	6			6	Meter malfunction			1	1	1	1	1		2	0.43			High
24	7	2			2	Meter malfunction			1	1	1	1	1			0.43			High
24	8	3			3	667	671	669	1	1	1	1	1	2	1	0.43			High
24	9	7			7	1,251	933	1,092	1	1	1	1	1		3	0.43			High
24	10				0	Vacant													LD
24	11	7			7	382	343	362	1	1	1	1			1	0.43			High
24	12	7			7				1	1	1	1			2	0.43			HD
24	12			6	6														HD
S.t					13	179	156	168											HD
24	13	6			6				2	2	2	2	1		2	0.43			HD
24	13			12	12														HD
S.t					18	560	517	539											HD
24	14	8			8	407	421	414	1	1	1	1	1	1		0.43			High
24	15	3			3	776	671	724	1	1	1	1	1		1	0.43			High

TABLE D.2 PER CAPITA CONSUMPTION IN BOROKO MODEL AREA (2/2)

Section number	Lot number	Number of person				Per capita consumption (liters per day)			Number							Capacity (m3)			Type of House
		House	Flat	Quarters	Total	1st week	2nd week	Total	Kitchen	Bath	Shower	Toilet	Washing Machine	Air conditioner	Car	Solat Tank	Water Tank	Swimming Pool	
24	16	6			6				1	1	1	1	1		2	0.43			HD
24	16			4	4														HD
S.t					10	366	387	376											HD
24	17	3			3	1,133	1,181	1,157	1	1	1	1	1		2				High
24	18	8			8	Metermalfunction			1	1	1	1	1		2	0.43			High
24	19	6			6				1	2	1	1	1	1	2	0.43			HD
24	19			4	4														HD
S.t					10		No meter												HD
24	20	5			5				1	1	1	1	1			0.43			?
24	20			6	6														?
S.t					11	23	35	29											?
24	21	7			7				1	1	1	1	1		1	0.43			HD
24	21			4	4														HD
S.t					11	156	253	205											HD
24	22	10			10				1	1	1	2	1	1	2	0.43			HD
24	22			3	3														HD
S.t					13		No meter												HD
24	23				0			Inn	1	10	10	10	3	7	3	0.43			Inn
24	24		7		7				1	1	1	1	1						Flat
24	24		6		6				1	1	1	1	1						Flat
24	24		4		4				1	1	1	1	1						Flat
24	24		4		4				1	1	1	1	1						Flat
24	24		7		7				1	1	1	1	1						Flat
24	24		3		3				1	1	1	1	1						Flat
24	24		6		6				1	1	1	1	1						Flat
S.t					37	384	343	363											Flat
24	25				0	Office			12	10	10	14	1	8	1	0.43x6			Office
24	25				0	Office													Office
24	25				0	Office													Office
S.t					0	Office													
97	1							Club House	1	1	5	12		13	1				?
Total		117	62	39	218	388	370	379	39	39	39	39	35	17	27	30	1	1	

TABLE D.3 PER CAPITA CONSUMPTION IN GEREHU MODEL AREA (1/2)

Section number	Lot number	Number of persons				Per capita consumption (liters per day)				Number						Capacity (m3)				Type of House
		House	Flat	Quarters	Total	1st week	2nd week	3rd week	Total	Kitchen	Bath	Shower	Toilet	Washing Machine	Air conditioner	Car	Solat Tank	Water Tank	Swimming Pool	
Hohola																				
259	11	13			13	686	815	720	740	1	1	1	1	1	-	1	-	-	-	High
259	12	4			4				0	1	1	1	1	1	-	1	-	-	-	High
259	13	4			4	168	293	250	237	1	1	1	1	1	-	2	0.43	-	-	High
259	14	2			2	179	321	307	269	1	1	1	1	-	-	1	0.43	-	-	High
259	15	5			5	474	1,109	220	601	1	1	1	1	-	1	1	-	-	-	High
259	16	1			1	843	757	300	633	1	1	1	1	1	-	1	-	-	-	High
259	17	4			4				0	1	1	1	1	1	-	2	-	-	-	High
259	18	8			8	143	163	177	161	1	1	1	1	1	-	-	-	-	-	High
260	10	9			9	348	314	325	329	1	1	1	1	1	-	1	0.43	-	-	High
260	11		4		4	307	164	125	199	1	1	1	1	-	-	-	0.43	-	-	D
260	11		5		5				0	1	1	1	1	-	-	-	0.43	-	-	D
260	11								-											D
260	11		6		6	205	214	167	195	1	1	1	1	-	-	-	0.43	-	-	D
260	11		6		6	57	88	152	99	1	1	1	1	-	-	-	0.43	-	-	D
260	11		6		6				0	1	1	1	1	-	-	-	0.43	-	-	D
260	11		12		12	17	37	30	28	1	1	1	1	-	-	1	0.43	-	-	D
260	11		4		4	507	593	618	573	1	1	1	1	1	-	1	0.43	-	-	D
260	12	10			10	561	484	773	606	1	1	1	1	-	-	3	0.43	-	-	High
261	1	12			12	144	156	298	199	1	1	1	1	1	-	1	-	-	-	High
261	2	8			8	323	255	246	275	1	1	1	1	1	-	1	-	-	-	High
261	3		5		5	923	934	769	875	1	1	1	1	-	-	-	-	-	-	High
261	4	Vacant							-											High
261	5	7			7				0	1	1	1	1	-	-	3	-	-	-	High
261	6		5		5				0	1	1	1	1	-	-	-	0.43	-	-	D
261	6		5		5				0	1	1	1	1	-	-	-	0.43	-	-	D
261	7	19			19	138	154	135	142	1	1	1	1	-	-	-	-	-	-	High
261	8	7			7	1,224	1,978	1,784	1,662	1	1	1	1	1	-	-	0.43	-	-	High
261	9	6			6	62	55	119	79	1	1	1	1	1	-	-	0.43	-	-	High
261	10	10			10	529	426	487	480	1	1	1	1	1	-	-	-	-	-	High
261	11	6			6				0	1	1	1	1	1	-	2	-	-	-	High
261	12	3			3	648	695	552	632	1	1	1	1	-	-	-	0.43	-	-	High
261	13								-											D
261	13		5		5				0	1	1	1	1	-	-	1	-	-	-	D
261	14	6			6	183	155	269	202	1	1	1	1	-	-	2	0.43	-	-	High
261	15		1		1				0	1	1	1	1	-	-	-	0.43	-	-	High
261	15		6		6				0	1	1	1	1	-	-	-	0.43	-	-	High
	s.t.				7			1,771	590											High
262	1	7			7				0	1	1	1	1	-	-	-	-	-	-	High
262	2	4			4				0	1	1	1	1	1	-	-	-	-	-	High
262	3	6			6	274	274	586	378	1	1	1	1	1	-	2	0.43	-	-	High
262	4								-											High
262	5	8			8	193	229	248	223	1	1	1	1	1	1	1	-	-	-	High
262	6		5		5				0	1	1	1	1	-	-	-	-	-	-	D
262	6		8		8				0	1	1	1	1	-	-	-	-	-	-	D
262	7	3			3	881	1,014	1,414	1,103	1	1	1	1	1	-	-	-	-	-	High
262	8	11			11				0	1	1	1	1	-	-	2	-	-	-	High
262	9	3			3	410	195	219	275	1	1	1	1	-	-	-	-	-	-	High
262	10	5			5	80	94	134	103	1	1	1	1	-	-	-	-	-	-	High

TABLE D.3 PER CAPITA CONSUMPTION IN GEREHU MODEL AREA (2/2)

Section number	Lot number	Number of persons				Per capita consumption (liters per day)				Number						Capacity (m3)				Type of House
		House	Flat	Quarters	Total	1st week	2nd week	3rd week	Total	Kitchen	Bath	Shower	Toilet	Washing Machine	Air conditioner	Car	Solat Tank	Water Tank	Swimming Pool	
262	11	1			1				0	1	1	1	1	1	-	-	-	-	-	High
262	12	8			8	325	288	259	290	1	1	1	1	-	-	1	-	-	-	High
262	13	9			9	498	397	363	420	1	1	1	1	-	-	2	-	-	-	High
262	14	11			11	356	314	429	366	1	1	1	1	1	-	1	0.43	-	-	High
262	15	4			4	1,507	1,354	1,461	1,440	1	1	1	1	-	1	-	0.43	-	-	High
262	16	7			7	447	347	447	414	1	1	1	1	-	-	1	0.43	-	-	High
262	17	7			7	163	182	216	187	1	1	1	1	1	-	-	-	-	-	High
262	8	7			7	159	145	190	165	1	1	1	1	-	-	-	0.43	-	-	High
262	19	8			8	318	313	277	302	1	1	1	1	1	-	2	0.43	-	-	High
262	20	5			5				0	1	1	1	1	-	1	2	0.43	-	-	High
262	21	9			9				0	1	1	1	1	-	-	-	-	-	-	High
262	22								-											High
262	22		4		4	207	229	193	210	1	1	1	1	1	-	-	-	-	-	High
262	23	6			6	67	26	45	46	1	1	1	1	1	-	1	-	-	-	High
262	24	7			7				0	1	1	1	1	1	-	1	-	-	-	High
263	2	9			9				0	1	1	1	1	1	-	-	0.43	-	-	High
263	3	6			6	269	257	312	279	1	1	1	1	1	-	4	0.43	-	-	High
263	4	5			5	143	137	149	143	1	1	1	1	-	-	-	0.43	-	-	High
263	5	8			8	304	339	234	292	1	1	1	1	-	-	-	0.43	-	-	High
263	6	14			14	94	96	97	96	1	1	1	1	-	-	1	-	-	-	High
263	7	1			1	1,014	1,300	1,186	1,167	1	1	1	1	1	-	1	-	-	-	High
263	8	9			9	187	187	178	184	1	1	1	1	1	-	1	-	-	-	High
263	9	6			6	167	164	110	147	1	1	1	1	1	-	2	0.43	-	-	High
263	10	7			7	771	739	722	744	1	2	2	2	1	1	2	0.43	-	-	High
263	11	11			11	1,023	808	960	930	1	1	1	1	1	-	2	-	-	-	High
263	12	7			7	192	165	198	185	1	1	1	1	1	-	1	0.43	-	-	High
263	13	9			9	17	17	13	16	1	1	1	1	-	-	1	0.43	-	-	High
263	14	10			10	359	357	420	379	1	1	1	1	1	-	-	-	-	-	High
264	2	5			5	169	154	143	155	1	1	1	1	-	-	1	-	-	-	High
264	3	9			9	81	81	86	83	2	2	2	2	1	1	1	0.43	-	-	High
264	4	6			6	214	298	755	422	1	1	1	1	1	-	1	0.43	-	-	High
264	5	9			9	575	546	578	566	1	1	1	1	1	-	1	0.43	-	-	High
264	6	6			6	421	412	407	413	1	1	1	1	-	-	-	-	-	-	High
264	7	7			7	227	278	324	276	1	1	1	1	-	-	-	-	-	-	High
264	8	9			9	203	221	248	224	1	1	1	1	-	-	1	0.43	-	-	High
264	9	8			8	291	243	300	278	1	1	1	1	1	1	1	0.43	-	-	High
264	10	6			6	90	83	107	94	1	1	1	1	1	-	1	-	-	-	High
264	11	7			7	133	108	133	124	1	1	1	1	-	-	2	0.43	-	-	High
264	12	12			12	373	426	467	422	1	1	1	1	1	-	3	-	-	-	High
264	13	9			9	317	225	192	245	1	1	1	1	1	-	1	-	-	-	High
264	14	8			8	59	48	45	51	1	1	1	1	-	-	2	-	-	-	High
264	15	7			7	118	351	243	237	1	1	1	1	1	-	1	-	-	-	High
264	16	8			8				0	1	1	1	1	1	1	-	-	-	-	High
264	17	4			4				0	1	1	1	1	1	-	2	0.43	-	-	High
264	18	5			5	103	154	137	131	1	1	1	1	1	-	1	-	-	-	High
264	19	9			9				0	1	2	2	2	1	-	-	0.43	-	-	High
Total		521	82	0	603	249	257	290	265											
		74	15	0	89															

TABLE D.4 PER CAPITA CONSUMPTION IN GORDONS MODEL AREA

Section number	Lot number	Number of person				Per capita consumption (liters per day)				Number							Capacity (m3)				Type of House
		House	Flat	Quarters	Total	1st week	2nd week	3rd week	Total	Kitchen	Bath	Shower	Toilet	Washing Machine	Air conditioner	Car	Solat Tank	Water Tank	Swimming Pool	
68	8	7			7	369	427	616	471	1	2	2	2	1		2	0.43			1High
68	8	6			6	690	836	714	747	1	1	1	1							4 D
68	9		7		7	582	565	547	565	1	1	1	1	1		1	0.43			2 Flat
68	9		19		19	187	247	195	210	1	1	1	1			Co.1	0.43			2 Flat
68	10		8		8	57	57	71	62	1	1	1	1			1	0.43			2 Flat
68	10		15		15	153	218	177	183	1	1	1	1	1		3	0.43			2 Flat
68	11		9		9	1,410	1,240	1,246	1,298	1	1	1	1				0.43			2 Flat
68	1		6		6	1,112	1,026	650	929	1	1	1	1	1		1	0.43			2 Flat
68	12	7			7	986	847	1,020	951	1	1	1	1	1		1	El.He			1High
68	13	1			1		Meter malfunction			1	1	1	1	1		1	El.He			1 High
68	14		6		6	490	483	240	405	1	1	1	1			1	0.43			2 Flat
68	14		5		5	80	137	106	108	1	1	1	1	1		1	0.43			2 Flat
68	15		6		6	181	195	176	184	1	1	1	1			1	0.43			1 High
69	10		5		5					2	2	2	2	2	4	2	El.He			1 High
69	10				0	2 Units use														1 High
	S.t.				5	1,023	1,257	1,226	1,169											
69	11	2			2	1,879	1,571	1,200	1,550	1	1	1	1	1		Co.1	0.43			1 High
69	12	10			10					1	2	2	2	1	4	1	0.43	3.86	98	1 High
69	12			6	6					1	1	2	2							4 D
	S.t.				16		Meter malfunction													
69	13	5			5	551	574	309	478	1	2	2	2	1	1	2	0.43			1 High
69	14	5			5	300	320	283	301	1	1	1	1	1			0.43			1 High
69	15		3		3					1	1	1	1	1		1	El.He			2 Flat
69	15		2		2					1	1	1	1	1		1				2 Flat
	S.t.				5	483	517	663	554											
69	16		4		4					1	1	1	1	1		1	0.43			2 Flat
69	16		8		8					1	1	1	1	1		1	0.43			2 Flat
	S.t.				12	207	264	177	216											
69	16		5		5					1	1	1	1	1		1	0.43			2 Flat
69	16		5		5					1	1	1	1	1		1	0.43			2 Flat
	S.t.				10	134	143	66	114											
69	17	2			2	1,464	1,557	1,707	1,576	1	1	1	1	1	1	1	0.43		28	1 High
69	18	8			8	1,159	786	764	903	1	1	1	1	1		1	El.He			1 High
69	19	Vacant			0															?
69	20	2			2	3,750	1,779	2,029	2,519	1	1	1	1	1	2	2	El.He		56	1 High
69	21	4			4	1,025	1,025	1,511	1,187	1	2	2	2	1	2	2	0.43		44	1 High
69	22		9		9					1	1	1	1							2 Flat
69	22		4		4					1	1	1	1	1		1				2 Flat
69	22		1		1					1	1	1	1							2 Flat
69	22		2		2					1	1	1	1							2 Flat
69	22				0															2 Flat
	S.t.				16	1,202	1,176	539	972											
69	23	8			8	514	623	848	662	1	1	1	1	1		2	El.He			1 High
69	24	6			6	274	252	224	250	1	2	2	2	1		1	0.43			1 High
69	25		5		5					1	1	1	1	1	1	1	El.He			2 Flat
69	25		5		5					1	1	1	1	1	1	1	El.He			2 Flat
	S.t.				10	481	419	406	435											
69	26		7		7					1	1	1	1			1				2 Flat
69	26		7		7					1	1	1	1				El.He			2 Flat
69	26		6		6					1	1	1	1	1						2 Flat
69	26		9		9					1	1	1	1	1		1				2 Flat
69	26		3		3					1	1	1	1							2 Flat
69	26		6		6					1	1	1	1			1				2 Flat

	S.t.			38	852	921	906	893											
69	27		2	2					1	1	1	1	1			0.43		2 Flat	
69	27		3	3					1	1	1	1	1		1	0.43		2 Flat	
69	27		6	6					1	1	1	1	1		1	0.43		2 Flat	
69	27		5	5					1	1	1	1	1			0.43		2 Flat	
69	27		5	5					1	1	1	1	1			0.43		2 Flat	
69	27		6	6					1	1	1	1	1		1	0.43		2 Flat	
	S.t.			27	Meter malfunction														
69	28			0														2 Flat	
69	28		4	4					1	1	1	1	1			0.43		2 Flat	
69	28		6	6					1	1	1	1				0.43		2 Flat	
69	28		7	7					1	1	1	1				0.43		2 Flat	
	S.t.			17	397	331	534	421											
70	9	6		6	Meter malfunction				1	1	1	1	1			0.43		1 High	
70	10	10		10	333	249	401	328	1	1	1	1	1	1	1	0.43		1 High	
70	11	3		3	1,471	1,481	733	1,229	1	1	1	1			1	0.43		1 High	
70	12	7		7	216	233	224	224	1	1	1	1	1					1 High	
70	13	7		7					1	1	1	1	1	1		0.43		2 Flat	
70	13	3		3					1	1	1	1	1	1		0.43		2 Flat	
70	13		6	6					1	1	1	1	1	1	1	0.43		2 Flat	
70	13			0															
	S.t.			16		282	304	196											
70	14		5	5					1	1	1	1	1		1			2 Flat	
70	14		4	4					1	1	1	1	1			El.He		2 Flat	
70	14		4	4					1	1	1	1	1			El.He		2 Flat	
70	14		4	4					1	1	1	1	1		1	El.He		2 Flat	
	S.t.			17	Meter malfunction														
70	15		5	5					1	1	1	1	1					2 Flat	
70	15		6	6					1	1	1	1	1		1	0.43		2 Flat	
70	15		2	2					1	1	1	1	1		1	0.43		2 Flat	
70	15		4	4					1	1	1	1	1	1	1	0.43		2 Flat	
	S.t.			17	316	327	343	329											
70	16		5	5					1	1	1	1				El.He		2 Flat	
70	16		5	5					1	1	1	1				El.He		2 Flat	
70	16		6	6					1	1	1	1	1			El.He		2 Flat	
70	16		5	5					1	1	1	1	1			El.He		2 Flat	
	S.t.			21	703	732	561	665											
70	17		5	5					1	1	1	1	1		1			2 Flat	
70	17		7	7					1	1	1	1							
	S.t.			12	325	206	204	245											
70	18	Vacant		0															?
70	19		6	6					1	1	1	1	1					2 Flat	
70	19		2	2					1	1	1	1	1			El.He		2 Flat	
	S.t.			8	729	800	964	831											
70	20		5	5					1	1	1	1	1					2 Flat	
70	20		6	6					1	1	1	1	1					2 Flat	
70	20		3	3					1	1	1	1	1		1			2 Flat	
70	20		3	3					1	1	1	1	1		1			2 Flat	
70	20		4	4					1	1	1	1	1			El.He		2 Flat	
70	20		5	5					1	1	1	1	1					2 Flat	
	S.t.			26	88	137	160	129											
70	21	6		6	7	7	7	7	1	1	1	1						1 High	
70	21		4	4	1,425	1,279	1,354	1,352	1	1	1	1						4 D	
70	22		5	5					1	1	1	1	1					2 Flat	
70	22			0														2 Flat	
	S.t.			5	1,403	1,394	1,366	1,388											
74	1	15		15	316	332	334	328	1	1	1	1	1		2	0.43		1 High	
74	2	10		10	291	227	306	275	1	1	1	1			1	0.43		1 High	
74	3	2		2	4,100	436	507	1,681	1	2	2	2			1	El.He		1 High	
74	4	4		4	5,100	4,846	4,996	4,981	1	1	1	1			1	El.He		1 High	
74	5	8		8	163	191	205	186	1	1	1	1	1		2	0.43		1 High	
74	6,7	7		7	124	135	127	129	1	1	1	1			1			2 Flat	
74	6,7	4		4	611	625	643	626	1	1	1	1			1			2 Flat	
74	6.7	5		5	183	194	177	185	1	1	1	1			1			2 Flat	
75	9	24		24	356	367	330	351	1	1	1	1	1		2			1 High	
75	10	4		4	268	182	332	261	1	1	1	1			1			1 High	

75	11	8		8	300	548	320	389	1	1	1	1										1 High
75	12	3		3	Meter malfunction				1	1	1	1	1	1	2	0.43						1 High
78	1		4	4					1	1	1	1										2 Flat
78	1		2	2					1	1	1	1	1		Co.1							2 Flat
78	1		2	2					1	1	1	1	1			El.He						2 Flat
78	1		13	13					1	1	1	1			1	El.He						2 Flat
78	1		7	7					1	1	1	1	1									2 Flat
78	1		5	5					1	1	1	1	1			El.He						2 Flat
	S.t.			33	471	485	425	460														
78	2		4	4					1	1	1	1	1		2	El.He						2 Flat
78	2		3	3					1	1	1	1	1		1	El.He						2 Flat
78	2		6	6					1	1	1	1	1		2	El.He						2 Flat
78	2		2	2					1	1	1	1	1		1	El.He						2 Flat
78	2		3	3					1	1	1	1	1		1	El.He						2 Flat
78	2		3	3					1	1	1	1	1		1	El.He						2 Flat
	S.t.			21	303	381	313	332														
Total		205	391	10	606				109	115	116	116	77	22	77	73	1	15	108			
	Person/Family 5.56				534	528	498	520														
	Household				32	74	2	108														

* Section Name: Hohola, Co:company car, El.He:electric heater

TABLE D.5 Per Capita Consumption of High Cost Housing (Boroko Model Area)

Section						JICA Spot Meter Reading		NCDC Meter Reading Record			
No.	Name	No.	Lot No.	No. of House hold	Population	2 week	lpd	Oldest Reading Date	Latest Reading Date	Consumption (m3)	Consumption (lpd)
1	Boroko	24	1	1	4	35.5	634				
2		24	2	1	6	17.7	211	27-aug-91	21-sep-92	979	417
3		24	6	1	6	68.2	812	27-aug-91	21-sep-92	2799	1193
4		24	8	1	3	28.1	669	27-aug-91	21-sep-92	992	846
5		24	9	1	7	107.0	1092	27-aug-91	21-sep-92	2339	855
6		24	11	1	7	35.5	362	27-aug-91	21-sep-92	912	333
7		24	14	1	8	46.4	414	27-aug-91	21-sep-92	711	227
8		24	15	1	3	30.4	724	23-jun-92	21-sep-92	191	707
9		24	17	1	3	48.6	1157	27-aug-91	21-sep-92	756	645
		part-Total		8	43	381.9	634				
	Total			9	47	417.4	634			9679	614
Spot	Reading "0"										
1		24	5	1	7		no meter	27-aug-91	23-jun-92	1172	556
2		24	7	1	6		not working	27-aug-91	21-sep-92	824	351
3		24	7	1	2		not working	15-oct-91	21-sep-92		0
4		24	18	1	8		not working	27-aug-91	21-sep-92	25	8
part-Total without No2				1	3						462
Total				4	23						

TABLE D.6 Per Capita Consumption of High Cost Housing (Gordons Model Area)

Section						JICA Spot Meter Reading Consumption (3 weeks)		NCDC Meter Reading Record			
No.	Name	No.	Lot No.	No. of House hold	Popula tion	m3	lpd	No.of House hold	Oldest Reading Date	Latest Reading Date	lpd
1	Hohola	68	8	1	7	69.2	471	1	30-jan-92	13-aug-92	371
2		68	8	1	6	94.1	747	1	10-oct-91	3-aug-92	567
3		68	12	1	7	139.8	951	1	30-jan-92	3-aug-92	1287
4		68	15	1	6	23.2	184	1	10-oct-91	3-aug-92	92
5		69	10	2	5	122.7	1169	2	28-mar-92	3-aug-92	1000
6		69	11	1	2	65.1	1550	1	30-jan-92	7-sep-92	1272
7		69	13	1	5	50.2	478				
8		69	14	1	5	31.6	301	2	13-nov-91	3-aug-92	331
9		69	17	1	2	6.2	1576	1	10-oct-91	3-aug-92	1416
10		69	18	1	8	151.7	903	1	10-oct-91	3-aug-92	488
11		69	20	1	2	105.8	2519	1	30-jan-92	7-sep-92	2125
12		69	21	1	4	99.7	1187	1	0-oct-91	3-aug-92	821
13		69	23	1	8	111.2	662	1	30-jan-92	3-aug-92	356
14		69	24	1	6	31.5	250	1	28-sep-91	3-aug-92	209
15		70	10	1	10	68.8	328	1	11-oct-91	3-aug-92	254
16		70	11	1	3	77.4	1229	1	11-oct-91	3-aug-92	1520
17		70	12	1	7	33	224	1	11-oct-91	-aug-92	176
18		74	1	1	15	103.2	328	1	16-dec-91	3-aug-92	384
19		74	2	1	10	57.7	275	1	30-jan-92	3-aug-92	212
20		74	3	1	2	70.6	1681	1	10-oct-91	25-aug-92	2250
21		74	4	1	4	18.4	4981	1	4-may-92	3-aug-92	409
22		74	5	1	8	31.3	186	1	15-mar-92	3-aug-92	199
23		75	9	1	24	176.9	351	1	6-jan-92	3-aug-92	74
24		75	10	1	4	21.9	261	1	30-jan-92	3-aug-92	137
25		75	11	1	8	65.4	389	1	15-oct-91	3-aug-92	416
Total wihout No.21				25	164	1868.2	542				---
Total				26	168	2286.6	648				448
Spot Reading "0"											
1		68	13	1	1	meter malfunction		1			
2		70	9	1	6	meter malfunction		1	1-oct-91	3-aug-92	159
3		75	12	1	3	meter malfunction		1			
part-Total				1	6			---			159
Total				3	10		542				
Grand-Total				29	178		542				448

TABLE D.7 Per Capita Consumption of High Cost Housing (Gerehu Model Area 1/2)

				JICA Spot Meter Reading				NCDC Meter Reading Record			
No.	Name	No.	No.	No. of House-holds	Popul ation	Consumption (3 weeks) m3	lpd	No. of Hous-holds	Oldest Reading Date	Latest Reading Date	lpd
1	Hohola	259	11	1	13	202.1	740	1	27-feb-92	31-aug-92	320
2		259	13	1	4	19.9	237	1	29-oct-91	31-aug-92	180
3		259	14	1	2	11.3	269	1	29-oct-91	31-aug-92	227
4		259	15	1	5	63.1	601	1	29-oct-91	31-aug-92	989
5		259	16	1	1	13.3	633				
6		259	18	1	8	27.0	161	1	27-feb-92	31-aug-92	154
7		260	10	1	9	62.2	329				
8		260	12	1	10	73.2	349	1	28-mar-92	30-aug-92	586
9		261	1	1	12	50.2	199	1	29-oct-91	22-sep-92	199
10		261	2	1	8	46.2	275	1	29-oct-91	30-aug-92	264
11		261	3	1	5	91.9	875				
12		261	7	1	19	56.8	142				
13		261	8	1	7	244.3	166				
14		261	9	1	6	9.9	79	1	27-feb-92	30-aug-92	99
15		261	10	1	10	100.9	481	1	29-oct-91	30-aug-92	362
16		261	12	1	3	39.8	632				
17		261	14	1	6	25.5	202	1	29-oct-91	30-aug-92	196
18		262	3	1	6	47.6	378	1	29-oct-91	1-jun-92	282
19		262	5	1	8	37.5	223				
20		262	7	1	3	69.5	110	1	27-feb-92	31-aug-92	333
21		262	9	1	3	17.3	275	1	29-oct-91	31-aug-92	849
22		262	10	1	5	10.8	103				
23		262	12	1	8	48.8	291	1	28-may-91	27-feb-92	234
24		262	13	1	9	79.3	420	1	29-sep-91	31-aug-92	285
25		262	14	1	11	84.6	366	1	27-feb-92	31-aug-92	550
26		262	15	1	4	121.0	144	1	27-feb-92	31-aug-92	2500
27		262	16	1	7	60.8	414	1	29-oct-91	31-aug-92	323
28		262	17	1	7	27.5	187				
29		262	18	1	7	24.2	165	1	28-may-91	31-aug-92	148
30		262	19	1	8	50.8	302	1	29-oct-91	31-aug-92	183
31		262	22		4	17.6	210	1	29-oct-91	31-aug-92	108
32		262	23	1	6	5.8	46	1	28-may-91	31-aug-92	45
33		263	3	1	6	35.2	279	1	29-oct-91	31-aug-92	202
34		263	4	1	5	15.0	143	1	1-jun-92	31-aug-92	145
35		263	5	1	8	49.1	292	1	29-oct-91	31-aug-92	253
36		263	6	1	14	28.1	96				
37		263	7	1	1	24.5	116	1	28-may-91	27-feb-92	1865
38		263	8	1	9	34.8	184	1	29-oct-91	31-aug-92	185
39		263	9	1	6	18.5	147	1	29-oct-91	31-aug-92	135
40		263	10	1	7	109.4	744	1	29-oct-91	1-jun-92	265
41		263	11	1	11	214.9	930				
42		263	12	1	7	27.2	185	1	29-oct-91	31-aug-92	162
43		263	13	1	9	3.0	16	1	29-oct-91	31-aug-92	263
44		263	14	1	10	79.5	379	1	1-jun-92	31-aug-92	285
45		264	2	1	5	16.3	155	1	29-oct-91	31-aug-92	110
46		264	3	1	9	15.6	83	1	29-oct-91	31-aug-92	68
47		264	4	1	6	53.2	422	1	29-oct-91	31-aug-92	239
48		264	5	1	9	107.0	566	1	23-may-92	31-aug-92	326
49		264	6	1	6	52.1	414				
50		264	7	1	7	40.6	276	1	29-oct-91	31-aug-92	302
51		264	8	1	9	42.3	224	1	29-oct-91	31-aug-92	181
52		264	9	1	8	46.7	278	1	29-oct-91	31-aug-92	250
53		264	10	1	6	11.8	94	1	28-mar-92	31-aug-92	74
54		264	11	1	7	18.3	124	1	28-may-91	1-jun-92	45

TABLE D.7 Per Capita Consumption of High Cost Housing (Gerehu Model Area 2/2)

				JICA Spot Meter Reading				NCDC Meter Reading Record			
No.	Name	No.	No.	No. of House-holds	Popul ation	Consumption (3 weeks) m3	lpd	No. of Hous-holds	Oldest Reading Date	Latest Reading Date	lpd
55		264	12	1	12	106.3	422	1	29-oct-91	31-aug-92	291
56		264	13	1	9	46.3	245	1	1-jun-92	31-aug-92	232
57		264	14	1	8	8.5	51	1	29-oct-91	31-aug-92	60
58		264	15	1	7	34.9	237				
59		264	18	1	5	13.8	131	1	29-oct-91	31-aug-92	91
60		261	15	1	7	86.8	90				
	part-Total			46	337	2241.7	317				277
	Total			59	437	3180.4	347				
	Spot Reading "0"										
1		259	12	1	4	disconnected		1	27-feb-92	1-jun-92	347
2		259	17	1	4	not working		1	28-may-91	31-aug-92	125
3		261	5	1	7	no meter		1	28-may-91	27-feb-92	319
4		261	11	1	6	not working		1	29-oct-91	30-aug-92	4901
5		262	1	1	7	disconnected		1	6-jul-88	16-aug-88	282
6		262	2	1	4	no meter					
7		262	8	1	11	not working		1	28-may-91	1-jun-92	38
8		262	11	1	1	disconnected		1	28-may-91	1-jun-92	405
9		262	20	1	5	no meter		1	28-may-91	27-feb-92	254
10		262	21	1	9	no meter					
11		262	24	1	7	no meter					
12		263	2	1	9	no meter		1	28-may-91	31-aug-92	0
13		264	16	1	8	no meter					
14		264	17	1	4	no meter					
15		264	19	1	9	not working		1	17-may-90	1-jun-92	2
part-Total				9	54				17-Feb-91	23-Jan-92	703
Total				15	95						
Grand-Total				74	532						

TABLE D.8 Per Capita Consumption of Flat (Boroko Model Area)

						JICA Meter Reading Consumption (3 weeks)		NCDC Meter Reading Record			
Section No.	Name	No.	Lot No.	No. of House hold	Popula tion	m3	lpd	Oldest Reading Date	Latest Reading Date	m3	lpd
1		24	3	4	12	52.0	310	23-jun-92	21-sep-92	417	386
2 *		24	4	5	13	0.6	3	23-jun-92	21-sep-92	140	120
part-Total				9	25					557	248
3		24	24	7	37	188.2	363				
Total without No.2				11	49	240.2	350				
Total				16	62	240.8	277				

* equipped with swimming pool (78 m3 Capacity)

TABLE D.9 Per Capita Consumption of Flat
(Gordons Model Area)

				JICA Spot Meter Reading				NCDC Meter Reading Record			
	Section		Lot	No.of House-	Populati on	Consumption (3 weeks)		No.of House-	Oldest Reading	Latest Reading	lpd
No.	Name	No.	No.	hold		m3	lpd	hold	Date	Date	
1	Hohola	68	9	1	7	83	565	1	10-oct-91	3-aug-92	482
2		68	9	1	19	83.8	210	1	10-oct-91	3-aug-92	235
3		68	10	1	8	10.4	62	1	10-oct-91	3-aug-92	113
4		68	10	1	15	57.6	183	1	10-oct-91	3-aug-92	194
5		68	11	1	9	245.4	1298	1	20-may-91	3-aug-92	
								1	30-jan-92	3-aug-92	1055
6		68	11	1	6	117.1	929	1	10-oct-91	3-aug-92	387
7		68	14	1	6	51	405	1	10-oct-91	3-aug-92	497
8		68	14	1	5	11.3	108	1	10-oct-91	3-aug-92	230
9		69	15	2	5	58.2	554	2	10-oct-91	3-aug-92	473
10		69	16-1	2	12	54.5	216	2	10-oct-91	3-sep-92	106
11		69	16-2	2	10	24	114	2	10-oct-91	3-sep-92	49
12		69	22	5	16	326.7	972				
13		69	25	2	10	91.4	435	2	10-oct-91	3-aug-92	365
14		69	26	6	38	712.6	893	6	24-oct-91	3-aug-92	733
15		69	28	4	17	150.3	421	4	10-oct-91	3-aug-92	427
16		70	13	4	16	65.7	196	4	27-nov-90	11-oct-91	663
17		70	15	4	17	117.3	329	4	11-oct-91	3-aug-92	445
18		70	16	4	21	293.4	665	4	13-nov-91	3-aug-92	356
19		70	17	2	12	61.7	245	2	14-may-91	-aug-92	239
20		70	19	2	8	39.6	831	2	30-jan-92	7-sep-92	527
21		70	20	6	26	70.2	129	6	11-oct-91	3-aug-92	88
22		70	22	2	5	145.7	1388	3	11-oct-91	3-aug-92	623
23		74	6,7	1	7	18.9	129	1	4-may-92	7-sep-92	109
24		74	6,7	1	4	52.6	626	1	10-oct-91	3-aug-92	506
25		74	6,7	1	5	19.4	185	1	10-oct-91	3-aug-92	152
26		78	1	6	33	318.8	460	6	11-oct-91	4-aug-92	361
27		78	2	6	21	146.5	332	6	30-jan-92	4-aug-92	424
	part-Total			65	342	3200.4	446				392
	Total			70	358	3527	469				---
	Spot Reading "0"										
1		69	27	6	27	meter malfunction		6	10-oct-91	3-aug-92	377
2		70	14	4	17	meter malfunction		4	27-nov-90	3-aug-92	810
	Total			10	44		469				544
	Grand Total			80	402		469				---

TABLE D.10 Per Capita Consumption of Duplex (Gerehu Model Area)

Section No.	Name	Lot No.	No. of House-holds	Popul ation	JICA Meter Reading Consumption (3 weeks) m3	lpd	NCDC Meter Reading Record No.of House-hold	Oldest Reading Date	Latest Reading Date	lpd
1		260 11	1	12	7.0	28				
2		260 11	1	6	12.5	99	1	8-may-91	30-aug-92	60
3		260 11	1	4	16.7	199	1	17-jul-92	30-aug-92	193
4		260 11	1	6	24.6	195				
5		260 11	1	4	48.1	573	1	29-oct-91	30-aug-92	629
part-	Total		3	14	77.3	263				260
Total			5	32	108.9	162				260
Spot Reading "0"										
1		260 11	1	5	disconnected					
2		260 11	1	6	not working					
3		261 6	1	5	no meter		1	29-oct-91	30-aug-92	212
4		261 6	1	5	no meter					
5		261 13	1	5	no meter					
6		262 6	1	5	no meter		2	6-dec-90	27-feb-92	403
7		262 6	1	8	no meter		1	29-oct-91	30-aug-92	315
part-Total			3	18						310
Total			7	39						
Grand-Total			12	71						

TABLE D.11 Per Capita Consumption of High Cost Housing with Quarters (Boroko Model Area)

Section No.	Name	Lot No.	No.of House-holds	Popula tion	JICA Spot Meter Reading Consumption (2 weeks) m3	lpd	NCDC Meter Reading Record Oldest Reading Date	Latest Reading Date	Consumption m3	lpd
1		24 12	2	13	30.5	168	17-mar-92	21-sep-92	458	187
2		24 13	2	18	135.8	539	27-aug-91	21-sep-92	2725	387
3		24 16	2	10	52.7	376	27-aug-91	21-sep-92	1546	395
4		24 21	2	11	31.5	205	27-aug-91	21-sep-92	1302	303
Total			8	52	250.5	344				321
Spot Reading "0"										
1		24 19	2	10	no meter					
2		24 22	2	13	no meter		27-aug-91	21-sep-92	1223	241
part-Total			4	23						241
Total			12	75						
Grand-Total										

TABLE D.12 Per Capita Consumption of High Cost Housing with Quarters
(Gordons Model Area)

			JICA Spot Meter Reading				NCDC Meter Reading Record			
	Section		No.of	Popula	Consu		No.of	Oldest	Latest	
No.	Name	No.	House-holds	tion	mption m3	lpd	House-holds	Reading Date	Reading Date	lpd
Hohola	69	12	2	16			1	29-sep-91	3-aug-92	
	70	21	2	10	114.5	1145	1	30-jan-92	3-aug-92	
Part-Total			2	10	114.5				2334	
Total			4	26	114.5	542				2334
Grand-Total			4	26		542				448

TABLE D.13 COMPARISON OF PER CAPITA CONSUMPTION

Model Area	Housing Type	Per Capita Consumption (liters per day) JICA	NCDC	Ratio JICA/NCDC
Gordons	High cost	542	448	1.21
Gordons	Flat	446	392	1.14
Gerehu	High cost	317	277	1.14
Gerehu	Duplex	263	260	1.01
Gerehu	Total	325	319	1.02
Boroko	High cost	634	614	1.03
Boroko	High cost with Q	344	321	1.07
Boroko	Flat	350	248	1.41
Boroko	Total	428	367	1.17

TABLE D.14 HOUSEHOLD WATER SUPPLY AND SEWERAGE FACILITIES FOR PORT MORESBY

	High Cost	Low Cost				
		Domestic Quarters	Suburban Area	Village and Settle	Self Help	All Type
WATER SUPPLY						
Piped into dwelling	100	93	86	75	5	67
Source outside dwelling	*	7	14	25	95	33
Hot water system	74	*	*	*	*	11
TOILET FACILITIES						
For own use						
Flush toilet	100	93	87	*	*	56
Pit or bucket	*	*	8	*	60	31
Total	100	93	95	96	60	87
Communal use						
Flush toilet	*	*	*	*	12	5
Pit or bucket	*	7	*	*	19	6
Total	*	7	5	*	31	11
No fixed arrangement	*	*	*	*	9	*
BATHING FACILITIES						
Bath or shower for own use	100	93	94	75	7	71
Communal bath or shower	*	7	6	*	14	7
Water carried from piped sources	*	*	*	21	79	22

* denotes less than 5 %.
Source: Household Expenditure Survey 1975/1976.

TABLE D.15 NCD HOUSING TYPE

Type of Housing	1980		1990 *	
	Number of Buildings	%	Number of Population	%
High Cost	3,869	16.5	38,034	19.5
Flat	2,786	11.9	23,044	11.8
Self Help High Costn	192	0.8	12,523	6.4
Total High Cost	6,847	29.3	73,601	37.7
Duplex	774	3.3	8,772	4.4
Domestic Quarters	1,465	6.3	13,223	6.8
Low Cost	6,079	26.0	45,914	23.5
Total Low Cost	8,318	35.5	67,909	34.7
Special Dwelling	2,339	10.0	5,912	3.0
Total Formal	17,504	74.8	147,422	75.4
Makeshift	2,077	8.9	32,645	16.7
Traditional	13	0.1	335	0.2
Self Help Low Cost	1,906	8.1	15,136	7.7
Total Informal	3,996	17.1	48,116	24.6
Vacant	,427	6.1		
Not Stated	249	1.1		
Total	23,401	100.0	195,538	100.0

* These data was obtained from NSO. Total number is different from the preliminary count of 195,140 also published in NSO.

TABLE D.16 PER CAPITA CONSUMPTION OF NCDC RECORDS ACCORDING TO HOUSING TYPE

No	Dwelling Type	Unit No.	Census Statistics: Census Unit Persons	House Occupied	Vacant House	Person per House	NCDC Meter Reading Record: No.of Metered House	Estimated Persons	Metered Consumption (l/d)	Meter malfunction	Effective Meter No.	Per Capita Consumption (lpd)
1	HCH	81-28	470	52	0	9.0	27	234	66887	1	26	286
2	HCH	83-06	156	31	1	5.2	37	161	60309	6	31	374
3	HCH	83-12	227	44	3	5.5	47	231	98442	5	42	426
4	HCH	83-14	220	35	0	6.3	38	233	101121	1	37	434
5	HCH	83-30	136	25	5	6.8	23	129	34499	4	19	267
6	HCH	83-49	116	19	1	6.4	13	77	33456	1	12	436
Average			1325	206	10	6.4	185	1065	394714	18	167	371
1	Flat	83-11	181	72	6	2.7	20	54	16136	0	20	299
2	Flat	83-37	336	52	9	7.8	51	382	144516	2	49	363
3	Flat	83-43	257	43	0	6.0	9	54	82783	0	9	1533
4	Flat	83-51	127	30	0	4.2	28	84	35935	1	20	428
5	Flat	84-68	157	34	4	5.2	22	114	38604	0	22	337
6	Flat	85-44	184	66	6	3.1	55	158	63293	4	51	400
7	Flat	85-54	236	85	5	3.0	11	33	8245	0	11	250
Average			1478	382	30	3.9	196	879	389512	7	182	443
Average without No.3			1221	339	30	3.6	187	825	306729	7	173	371
1	LCH	80-16	306	36	2	9.0	28	225	52540	3	25	234
2	LCH	80-19	341	40	3	9.2	30	257	64654	2	28	251
3	LCH	80-27	290	38	0	7.6	34	228	81526	4	30	358
4	LCH	80-34	455	45	0	10.1	37	343	83982	3	34	245
5	LCH	80-42	463	53	2	9.1	41	336	76716	4	37	228
6	LCH	80-49	259	35	5	8.6	26	197	61741	3	23	312
7	LCH	80-50	397	39	1	10.4	26	260	69233	1	25	266
8	LCH	81-13	436	47	2	9.7	37	339	70904	2	35	209
9	LCH	81-26	86	14	3	7.8	11	87	20243	0	11	236
10	LCH	82-24	327	32	0	10.2	6	51	6277	1	5	123
11	LCH	82-27	481	50	0	9.6	9	30	10614	6	3	369
12	LCH	82-37	459	52	0	8.8	5	19	2593	3	2	147
13	LCH	82-48	330	35	1	9.7	33	310	94164	1	32	303
Average			4630	516	19	9.0	323	2682	695187	33	290	259
1	Duplex	82-57	205	21	0	9.8	2	20	5338	0	2	272
1	DWQ	82-47	317	44	1	7.4	38	281	144577	0	38	514
1	MST	81-12	479	60	0	8.0	2	16	9451	0	2	591
2	MST	83-44	489	67	8	7.4	2	7	1335	1	1	180
3	MST	85-31	505	69	2	7.5	2	15	16633	0	2	1109
Average			1473	196	10	7.5	6	38	27419	1	5	721
Total			9428	1365	70	6.9	750	4965	1656747	59	684	334

Table D.17 COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL BULK METERS

Water Meter Number	Location (Meter Size)		Initial Reading Date	Total Usage (m3)	No. of Days	Average Daily Demand (m^3/day)	Accumulated	NCDC meter Demand (m^3/day)
31657381	D.C.A.Jacksons Airport	(6")	14/07/88	6046	8	755.0	755.0	
3650772	D.C.A.Jacksons Airport	(4")	14/07/88	3280	8	411.0	1,166.0	
81657385	Bomana Police Train College	(6")	19/07/88	3167	3	816.7	1,982.7	1,537.3
86606511	S.P.Brewery Gordons		29/07/88		5	737.0	2,719.7	935.0
83651437	Gordons Police Barracks	(6")	14/07/88	4784	8	598.0	3,317.7	
83651346	Islander Hotel	(4")	14/07/88	2514	8	314.3	3,632.0	306.3
--------	SDA University	(4")	19/07/88	862	3	287.3	3,919.3	
87601248	Central Government Office	(2")	14/07/88	2249	8	281.0	4,200.3	254.8
81656662	Travelodge Hotel	(4")	14/07/88	1989	8	248.0	4,448.3	185.7
86606520	Laloki Psychiatric Health Center	(2")	19/07/88	715	3	238.3	4,686.6	
81657041	Kila Police Barracks	(3")	22/07/88	664	3	221.3	4,907.9	
81650747	Morata House	(3")	14/07/88	1478	8	184.0	5,091.9	
--------	Taurama Barracks		30/06/88	1875	11	170.0	5,261.9	
81657041	Murray Barracks	(6")	22/07/88	(stuck)				
87601249	Pacific View Apartments	(2")	14/07/88	1090	8	136.0	5,397.9	
83650772	P.S.A.House	(3")	14/07/88	719	8	90.0	5,487.9	
86619377	S.P.Badili	(3")	01/07/88	127	10	12.7	5,500.6	13.3
81657196	S.P.Badili	(2")	01/07/88	651	10	65.1	5,565.7	
87601242	Badili Non Beverages	(2")	01/07/88	349	10	34.9	5,600.6	
81656738	Port Moresby General Hospital	(4")	01/07/88	1554	18	86.3	5,686.9	503.9
86609164	PNG University	(6")	01/07/88	588	7	84.0	5,770.9	
81657445	Coca Cola	(3")	29/07/88	349	5	70.0	5,840.9	
86619143	Hohola Soft Drink	(2")	18/07/88	272	4	68.0	5,908.9	38.9
86606520	Bomana C.I.S.	(3")	19/07/88	132	3	44.0	5,952.9	
88619163	Davara Hotel	(3")	22/07/88	68	3	22.7	5,975.6	
81656666	Sir Donald Cleland Pool	(4")	22/07/88	62	3	20.7	5,996.3	
83651344	Savloan House	(3")	22/07/88	40	3	13.3	6,009.6	

TABLE D.18 INDUSTRY WATER CONSUMPTION BY CENSUS DIVISION

Classfication	Census Division (m^3/day)									
	80 Gerehu	81 W/U	82 T/H	83 G/S	84 B/K	85 K/K	86 T/H	87 L/N	88 Bomana	Total
NCDC Record	36	0	91	613	14	74	126			954
Spot Reading	0	0	0	935	0	0	0			935
Reading 88	0	0	0	70	0	35	0			105
Estimation	495	0	605	3467	0	502	631			5718
Total	531	0	696	5085	32	611	757	63	169	7944

Reading 88 : 88 's spot reading in water consunption survey
Estimation : estimation by per unit consumption
L/N and Bomana are supplemented refering to K/K per capita of industry

TABLE D.19 PUBLIC WATER CONSUMPTION

Classfication	Census Division (m^3/day)									
	80 Gerehu	81 W/U	82 T/H	83 G/S	84 B/K	85 K/K	86 T/H	87 L/N	88 Bomana	Total
Shool	136	679	219	100	140	253	174		378	2079
Government		1030	1202	100	52		1263		134	3781
NCDC		186	123				86			395
reading 88									238	238
Others		115		1166	504					1785
Total	136	2010	1544	1366	696	253	1523	27	750	8278

TABLE D.20 COMMERCIAL WATER CONSUMPTION BY CENSUS DIVISION

Classfication	Census Division (m^3/day)									
	80 Gerehu	81 W/U	82 T/H	83 G/S	84 B/K	85 K/K	86 T/H	87 L/N	88 Bomana	Tot
Commercial	150	288	277	19	596	169	413	18	48	197
Hotel			310	354	48		186			89
Other (Golf Club)		239								23
Total	150	527	587	373	644	169	599	18	48	311

TABLE D.21 NON-RESIDENTIAL WATER CONSUMPTION BY CENSUS DIVISION

Classfication	Census Division (m^3/day)									
	80 Gerehu	81 W/U	82 T/H	83 G/S	84 B/K	85 K/K	86 T/H	87 L/N	88 Bomana	Tot
Public	136	2010	1544	1366	696	253	1523	27	750	827
Industry	531	0	696	5085	32	611	757	63	169	794
Commercial	150	527	587	373	644	169	599	18	48	311
Total	817	2537	2827	6824	1372	1033	2879	108	967	1933

TABLE D.22 FLOW TO ENTIRE GEREHU (m^3/s)

TIME	7/10/92	8/10/92	9/10/92	Average	INDEX	TIME	7/10/92	8/10/92	9/10/92	Average	INDEX
00:00		0.11110	0.11355	0.11233	0.94	12:00					
15		0.10774	0.11010	0.10892	0.91	15		0.12593		0.12593	1.05
30		0.09717	0.11010	0.10364	0.87	30		0.12082		0.12082	1.01
45		0.09486	0.10829	0.10158	0.85	45		0.12287		0.12287	1.03
01:00		0.10102	0.10739	0.10421	0.87	13:00		0.12663		0.12663	1.06
15		0.10503	0.10594	0.10549	0.88	15		0.12538		0.12538	1.05
30		0.10659	0.10478	0.10569	0.89	30		0.12473		0.12473	1.04
45		0.10107	0.10669	0.10388	0.87	45		0.10984		0.10984	0.92
02:00		0.10258	0.10548	0.10403	0.87	14:00		0.11180		0.11180	0.94
15		0.10438	0.10488	0.10463	0.88	15		0.11796		0.11796	0.99
30		0.10153	0.10518	0.10336	0.87	30		0.12408		0.12408	1.04
45		0.10283	0.10338	0.10311	0.86	45		0.12769		0.12769	1.07
03:00		0.10193	0.10779	0.10486	0.88	15:00		0.12383		0.12383	1.04
15		0.10128	0.10814	0.10471	0.88	15		0.12112		0.12112	1.01
30		0.10423	0.10879	0.10651	0.89	30		0.11776		0.11776	1.06
04:00		0.10143	0.10869	0.10506	0.88	16:00		0.12408		0.12408	1.04
15		0.10318	0.10554	0.10436	0.87	15		0.12398		0.12398	1.04
30		0.10438	0.10268	0.10353	0.87	30		0.12418		0.12418	1.04
45		0.10223	0.10418	0.10321	0.86	45		0.12428		0.12428	1.04
05:00		0.10062	0.10604	0.10333	0.87	17:00		0.12663		0.12663	1.06
15		0.10543	0.10293	0.10418	0.87	15		0.12804		0.12804	1.07
30		0.10824	0.10789	0.10807	0.90	30		0.12874		0.12874	1.08
45		0.11912	0.12132	0.12022	1.01	45		0.12779		0.12779	1.07
06:00		0.12859	0.12438	0.12649	1.06	18:00		0.12508		0.12508	1.05
15		0.12924	0.12949	0.12937	1.08	15		0.12623		0.12623	
30		0.13114	0.12904	0.13009	1.09	30		0.12623		0.12623	
45		0.13029	0.12749	0.12889	1.08	45		0.12343		0.12343	1.03
07:00		0.12743	0.12603	0.12673	1.06	19:00		0.12618		0.12618	1.06
15		0.12774	0.12944	0.12859	1.08	15		0.12623		0.12623	1.06
30		0.12698	0.12738	0.12718	1.07	30		0.12433		0.12433	1.04
45		0.12623	0.12488	0.12556	1.05	45		0.12453		0.12453	1.04
08:00		0.12703	0.12538	0.12621	1.06	20:00		0.12588		0.12588	1.05
15		0.12493	0.12879	0.12686	1.06	15		0.12593		0.12593	1.05
30		0.12568	0.12884	0.12726	1.07	30		0.12523		0.12523	1.05
45		0.12804	0.12723	0.12764	1.07	45		0.12503		0.12503	1.05
09:00		0.12889	0.13159	0.13024	1.09	21:00		0.12142		0.12142	1.02
15		0.12498	0.13320	0.12909	1.08	15		0.12217		0.12217	1.02
30		0.12884		0.12884	1.08	30	0.12693	0.12378		0.12536	1.05
45		0.12323		0.12323	1.03	45	0.12353	0.12313		0.12333	1.03
10:00		0.12598		0.12598	1.06	22:00	0.11866	0.11992		0.11929	1.00
15		0.12964		0.12964	1.09	15	0.11856	0.11967		0.11912	1.00
30		0.12232		0.12232	.02	30	0.11957	0.12152		0.12055	1.01
45		0.12728		0.12728	1.07	45	0.11526	0.11706		0.11616	0.97
11:00		0.12608		0.12608	1.06	23:00	0.11446	0.11902		0.11674	0.98
15		0.12473		0.12473	1.04	15	0.11255	0.11496		0.11376	0.95
30		0.12217		0.12217	1.02	30	0.11887	0.11325		0.11606	0.97
45		0.12508		0.12508	1.05	45	0.11466	0.11155		0.11311	0.95
12:00		0.12022		0.12022	1.01	24:00	0.11110	0.11355		0.11233	0.94
						No.	10	96	38	96	96
						Averg	0.11831	0.11892	0.11501	0.11941	1.00

TABLE D.23 Main Features of Three Model Areas

Name of Model Area	Pressure (m)	Peak Hourly Demand *	Bottom Hourly Demand *
Gordons	65 - 80	1.71	0.55
Boroko	35 - 55	1.53	0.54
Gerehu	23 - 66	1.50	0.73

* Ratio with average hourly demand

TABLE D.24 MAIN FEATURES

Name of Model Area	Pressure (m)	Peak Hourly Demand *	Bottom Hourly Demand *
Model Area Gordonsn	65 - 80	.71	0.55
Model Area Boroko	35 - 55	1.53	0.54
Model Area Gerehu	23 - 66	1.50	0.73

* Ratio to the average hourly demand

TABLE D.25 WATER CONSUMPTION BY CATEGORY (DAILY MAX),

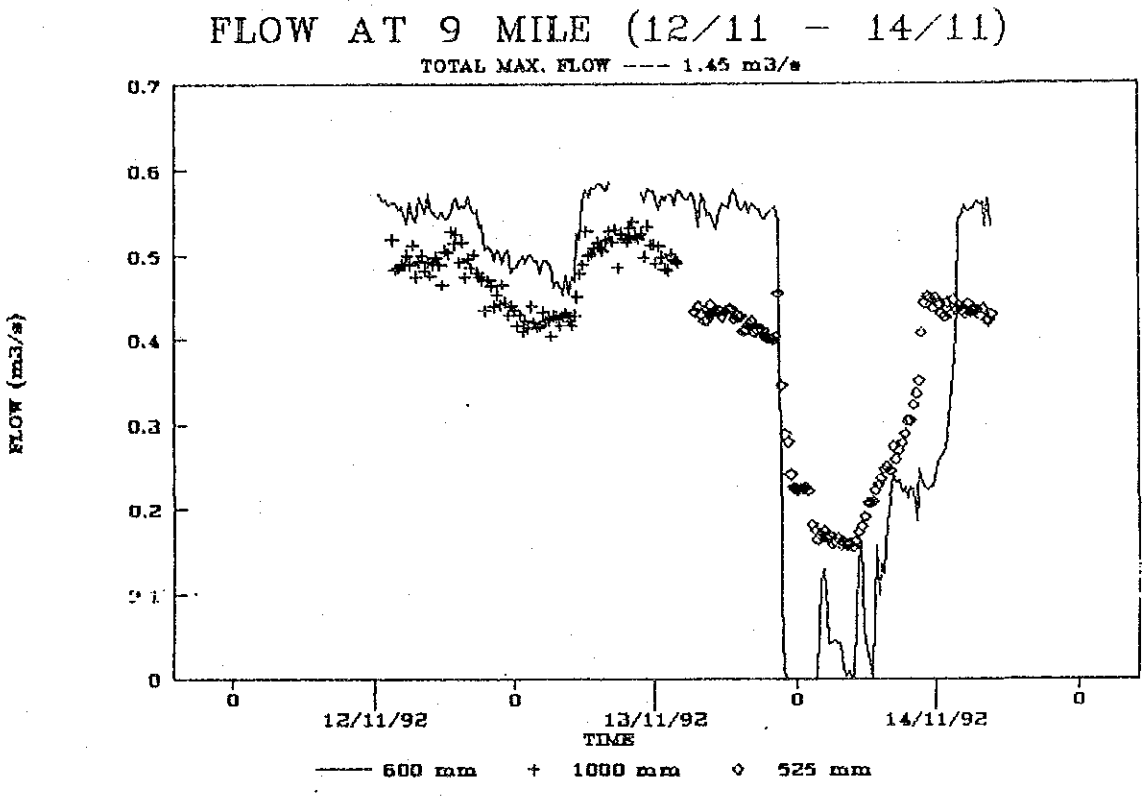
Census Division		Category (m^3/day)				
No.	Name	Residential	Public	Industry	Commercial	Total
80	Gerehu	13,767	253	986	279	15,284
81	Waigani/University	10,012	3,733	0	979	14,723
82	Hohola/Tokalala	19,537	2,867	1,293	1,090	24,787
83	Gordons/Saraga	19,634	2,537	9,444	693	32,307
84	Korobosea/Boroko	17,117	1,293	59	1,196	19,665
85	Kilakila/Kaugere	17,140	470	1,135	314	19,058
86	Hanuabada/Town	16,276	2,828	1,406	1,112	21,623
87	Napanapa/Laloki	1,736	50	117	33	1,937
88	Bomana	4,658	1,393	314	89	6,454
Total		119,877	15,424	14,753	5,785	155,838

TABLE D.26 RATIO OF EACH CATEGORY DEMAND TO RESIDENTIAL DEMAND (1990)

Census Division		Category				
No.	Name	Residential	Public	Industry	Commercial	Total
80	Gerehu	1	0.018	0.072	0.02	1.11
81	Waigani/University	1	0.373	0	0.098	1.471
82	Hohola/Tokalala	1	0.147	0.066	0.056	1.269
83	Gordons/Saraga	1	0.129	0.481	0.035	1.645
84	Korobosea/Boroko	1	0.076	0.003	0.07	1.149
85	Kilakila/Kaugere	1	0.027	0.066	0.018	1.112
86	Hanuabada/Town	1	0.174	0.086	0.068	1.329
Average			0.1232	0.1262	0.0499	
87	Napanapa/Laloki	1	0.029	0.067	0.019	1.116
88	Bomana	1	0.299	0.067	0.019	1.386
Total		1	0.129	0.124	0.048	1.3

TABLE D.27 TOTAL WATER DEMAND (DAIY MAX)

Census Division		Year (m^3/day)					
No.	Name	1990	1995	2000	2005	2010	2015
80	Gerehu	15284	18880	19612	23973	29504	31291
81	Waigani/University	14724	17978	18413	22117	27170	30482
82	Hohola/Tokalala	24787	31009	32677	40877	46337	46363
83	Gordons/Saraga	32306	44087	49707	51822	52576	52746
84	Korobosea/Boroko	19665	23245	22500	22508	22513	22515
85	Kilakila/Kaugere	19058	23716	24803	30867	36347	36371
86	Hanuabada/Town	21623	25241	24954	28995	32429	32452
87	Napanapa/Laloki	1937	5745	10725	20006	33495	63926
88	Bomana	6453	11531	16202	24297	33683	51141
Total		155837	201432	219593	265462	314054	367287



TITLE

TRUNK MAINS FLOW AT 9 MILE

Fig. No.

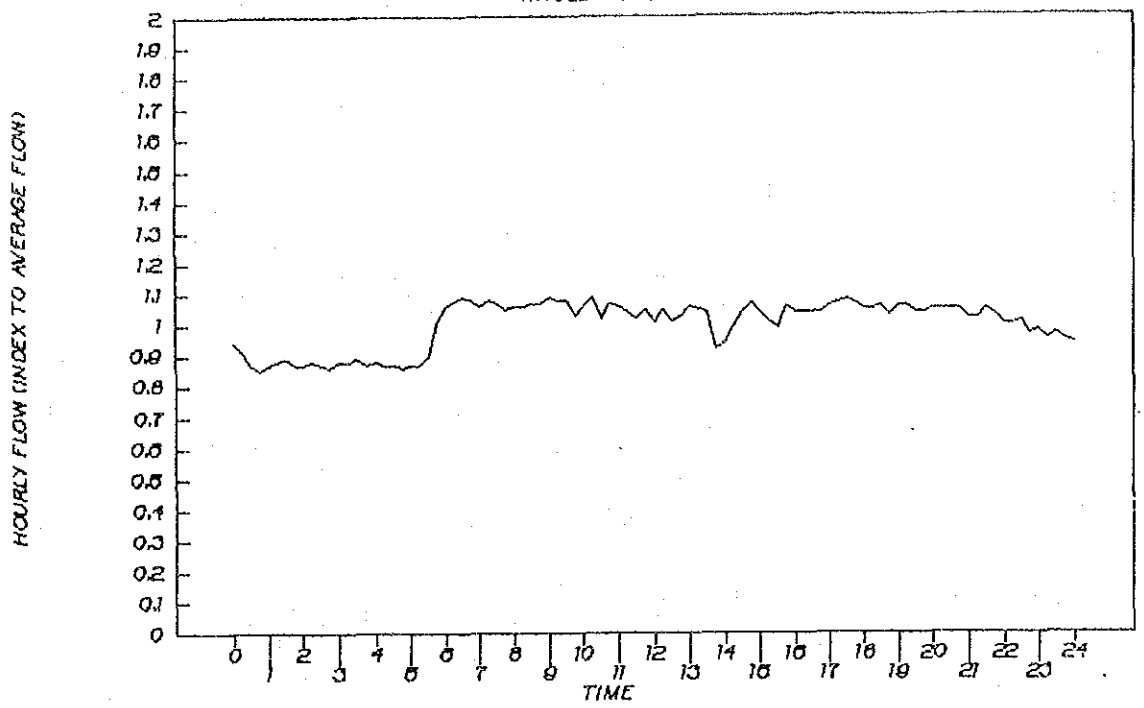
D.1

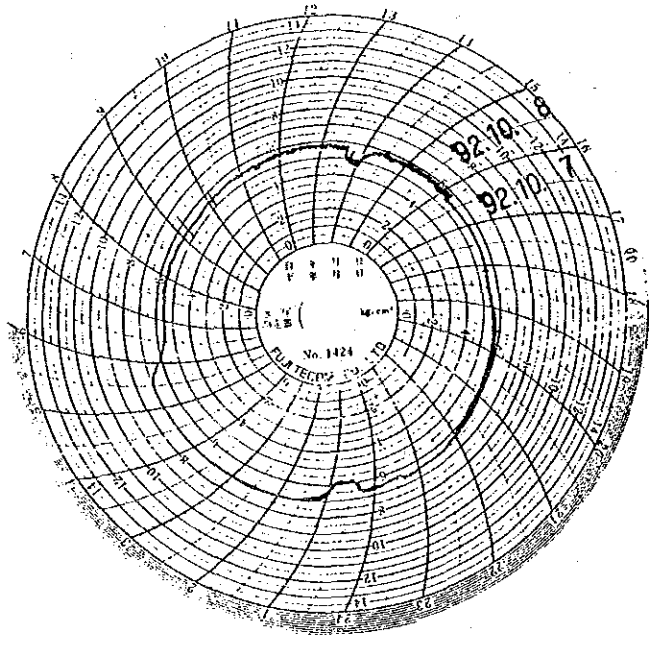
PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

DAILY DEMAND CURVE

WHOLE GEREHU





TITLE

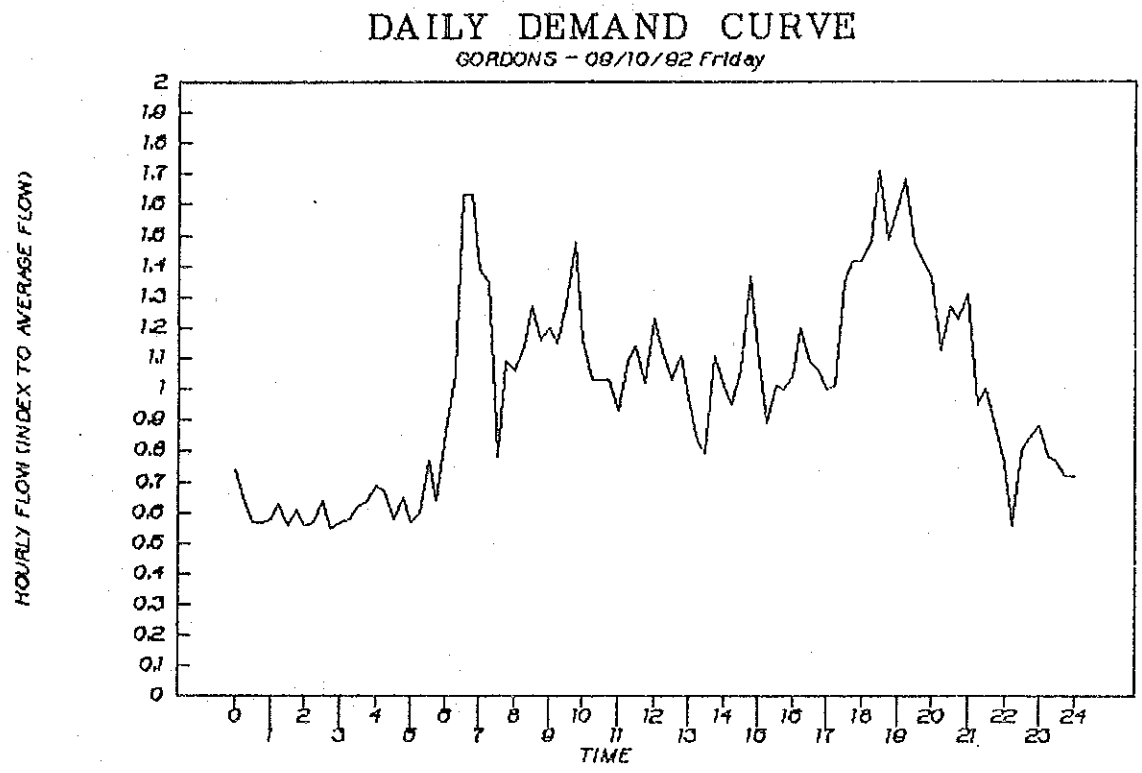
FLOW INTO ENTIRE GEREHU AREA

Fig. No.

D.2

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

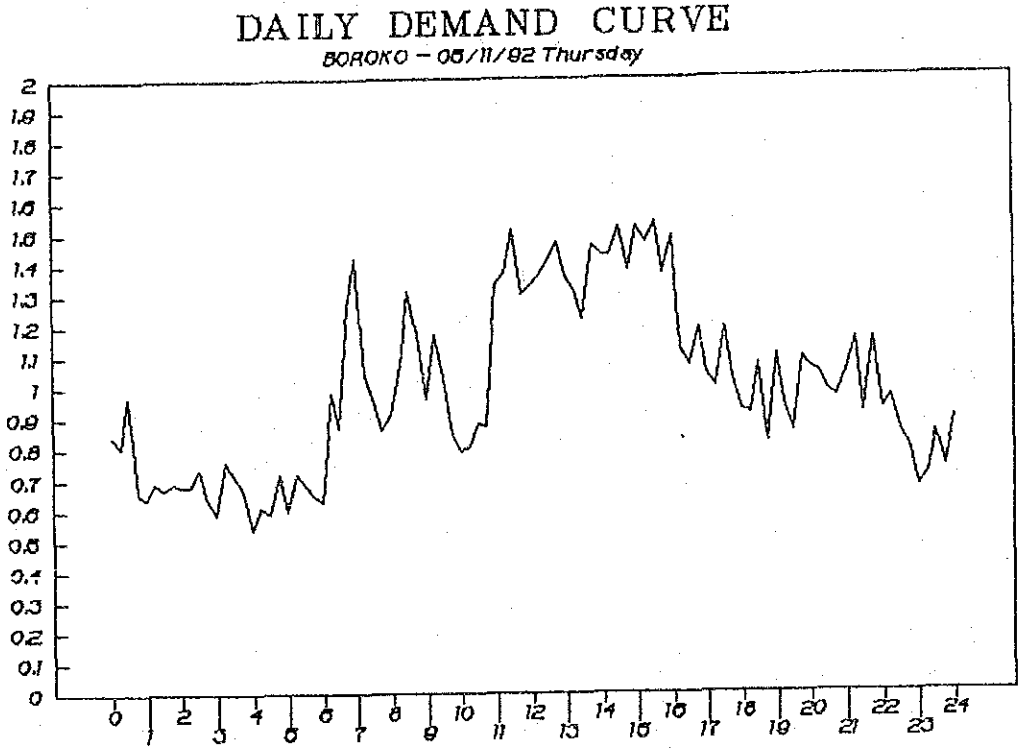
DAILY DEMAND CURVE IN GORDONS MODEL AREA

Fig. No.

D.3

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

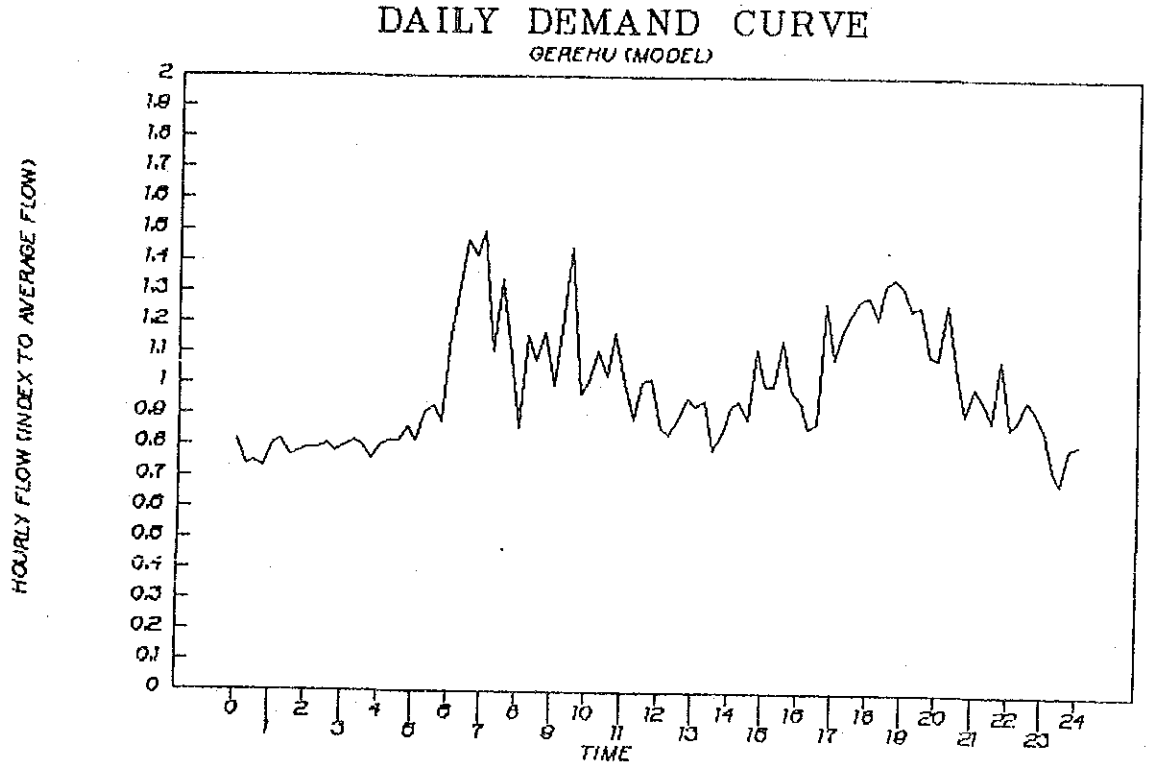
DAILY DEMAND CURVE IN BOROKO MODEL AREA

Fig. No.

D.4

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

DAILY DEMAND CURVE IN GEREHU MODEL AREA

Fig. No.

D.5

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

APPENDIX E

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

LEAKAGE

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APPENDIX E LEAKAGE

E.1 SUPPLIED AMOUNT

It has long been believed that one of the main causes of water shortage in NCD is high leakage. This seems to be true because water pressures in the water supply system is generally high for delivering the treated water altitudes as high as 80 m, while most other areas are located at 30 - 50 m, altitude in the valley. Nevertheless, no quantitative data was available to verify this phenomenon. Hence, leakage measurement was conducted during the Study period to obtain the current leakage level and to decide to what level leakage can be reduced.

The most reliable method to find the leakage amount is to subtract the total consumed amount from the total supplied amount, although the difference includes the leakage amount as well as unmetered, unbilled amounts.

At the Mt.Eriama treatment plant raw water, filtered water, sludge and backwash water are all metered. These results can normally be used to check meter calibration. However, all three sludge meters and two filter flow meters are not working and the No.3 sedimentation tank has no flow meter for sludge, so such checks cannot be made presently. Raw water meter for Bomana was installed on November 13, 1992. This "installation gives total inflow amount into the Mt.Eriama treatment plant. The other inflow from Rouna 1/3 head pond has been measured. The total inflow in November was about 1.45 m^3/s or 125 mld.

Instead, portable flow meter recorders were used to estimate the total water supplied to the system. Firstly, the flow meters were mounted on the two outlet pipes - 600 mm and 525 mm - located along the steep hill at the outlet of the treatment plant. These locations are convenient because only two parallel pipe exist so that the sum of the flow gives the total output from the plant. However, the results yielded a remarkably low flow presumably due to the open flow, condition in the pipe. Flow in the pipe must be fully pressurized.

The second location was at Gerehu off-take where three parallel pipes exist and one pipe branches off. The off-take is located at 9-Mile, some 3 to 4 km from the treatment plant. Although there is some consumption between them the sum of the four flows give the approximate total output. Simultaneous measurements which give a more accurate flow could not be made since only two flow meters were available. Also, the flow in the 450

mm pipe could not be measured. Measurements of the three remaining pipes were conducted successively. The results are shown in Table E.1. The average flow was as given below;

600 mm 0.5485 m^3/s
525 mm 0.4646 m^3/s
250 mm 0.0418 m^3/s

Out of the four pipes, the 525 mm pipe branches off and goes to Gerehu, Waigani and Tokarara areas. On the other hand, the remaining three pipes go down to Town area through Boroko and Korobosea areas. The three pipes are interconnected to each other in some places enabling the flow in the 450 mm pipe to be estimated. However, during the measurement, more appropriate points were found by closing valves as shown in Fig. E.1.

Fig. E.1 delineates the pipes and the new measurement points. When the valve at xx is closed, the following linear relation can be established;

9 Mile	Gerehu off-take
600 mm	600 mm
1000 mm	525 mm
525 mm	450 mm + 250 mm

The amount of flow in the 600 mm pipe at 9 Mile is similar to the Gerehu off- take as shown in Table E.2. Also the flow in the 1000 mm pipe at 9 Mile is similar to the flow in the 525 mm pipe at Gerehu off-take. The flows at 9 Mile are given in Table E.3 with average flow as given below;

1000 mm 0.4779 m^3/s (41 mld)
600 mm 0.5420 m^3/s (47 mld)
525 mm 0.4280 m^3/s (37 mld)
TOTAL 1.4479 m^3/s (125 mld)

The three pipes flows give a combined flow of 1.45 m3/s or 125 mld. This value corresponds reasonably with the inflows to the treatment plant (refer to Tables E.4 to E.5). Therefore, the total amount supplied to the NCD area is estimated at 1.45 m3/s as of November, 1992.

E.2 CONSUMED AMOUNT

An approximate estimate of the proportion of unaccounted water can be derived from water supply bills. This estimate provides a broad assessment of the system efficiency even though the large number of unmetered users (44 % in 1987) in Port Moresby limits the reliability of the estimate.

Metered residential consumption was 26 mld for 11,182 billings while non-residential consumption was 16 mld. Assuming per capita consumption is the same for metered houses and non-metered plus illegally used connections, residential consumption is 69 mld for all the 29,475 house holds in 1990. Further, assuming there is no non-residential consumption besides NCDC's records, total consumption is estimated as 86 mld. The supplied amount is between 115 to 125 mld for long periods. Hence, leakage is estimated to be in the order of 30 percent.

E.3 MODEL AREA

The other method the study team adopted was the setting up of model areas where demand was adequate for 24 hours. The minimum flow at night was measured to estimate leakage.

The procedures adopted for estimating leakage amount were as follows:

1) select candidate areas which can be hydraulically isolated by means of valves, using the NCDC pipe drawings,
2) confirm that pressure and flow are sufficient in the candidate areas.
3) find boundary valves in the area and confirm that all valves are operational,
4) confirm that flow of water can be actually stopped by valves.
5) close all boundary valves except the designated inlet valve, and install a flow meter and a pressure gauge in the inlet pipe,
6) measure for at least 24 hours, including the minimum night flow.

Leakage is governed by many factors such as pressure, pipe material and age of pipe. Model areas were selected to reflect such conditions. The three selected model areas are shown in Figs. E.2 to E.5 The main features are shown in Table E.6.

Gordons

One of the model areas selected for intensive review of water consumption over a relatively short period was Hohola, in sections 68, 69, 70, 74, 75 and 78 at Gordons. These sections, incorporating part of Henao Drive, Gaigo St., Govea St. etc., contains 53 serviced allotments of residential housing and flats.

The residences in this area are all high covenant housing, all with internal plumbing and sewerage. A cursory inspection indicated that the ground was dry and there was no misuse or wastage of water through garden and lawn watering.

The meters were read three times a week through September - October, 1992. A few faulty meters were found and some houses had no meters.

Boroko

This area is also a typical high covenant housing area. This section, Boroko sections 24, incorporates Angau Drive, Kevau Pl. and Mairi Pl. The residences in this area are typical of the well established high covenant housing found throughout Boroko, Korobosea and in parts of Gordons. All houses have full internal plumbing and sewerage.

The meters were read two times a week though November, 1992. The number of faulty meters and houses with no meters was noticeably less. A cursory inspection indicated that the ground was dry and there was no misuse or wastage of water through garden and lawn watering.

Similar to Gordons, the biggest problem was access to meters .

Gerehu

This section incorporates Hohola sections 259 to 264. The residences in this area are typical of the medium to high covenant housing, developed mainly by the National Housing Commission, and found throughout Gerehu, Tokarara, parts of Hohola, Erima, Morata and Kaugere. All houses have full internal plumbing and sewerage.

The meters were read three times a week during September - October, 1992. The number of faulty meters and houses with no meters was noticeably less. A cursory

inspection indicated that the ground was dry and there was no obvious misuse or wastage of water through garden and lawn watering. Access to meters for reading was easier than Gordons and Boroko.

Leakage in the Model Area

The flows and brassiere curves in the three model areas are shown in Table E.7 .

Leakage was measured by 24-hour measurement of inflow and pressure at the three model areas. Leakage ratio ranges from 29 to 41 % in the model areas (refer to Tables E.8 and E.9). Gerehu model area shows the lowest leakage ratio at 29 % while Boroko model area the highest at 41 %, followed Gordons area at 35%.

Age of pipe, contractors' ability to lay pipes etc. will decide the leakage ratio. Besides, the most decisive factor is pressure. The leakage Ratio becomes high when the water pressure is high, which is apparent from the observations.

TABLE E.1 FLOW AT GEREHU OFF-TAKE (1/2)

(m^3/s)

	P600	P525	P250	P600	P525	P250	P600	P525	P250	P600	P525	P250	
TIME	09/11/92	09/11/92	09/11/92	10/11/92	10/11/92	10/11/92	11/11/92	11/11/92	11/11/92	12/11/92	12/11/92	12/11/92	
00:00				0.4850	0.4300		0.4506		0.0367	0.4937	0.4414		00:00
15				0.4796	0.4252		0.4599		0.0364	0.4790	0.4256		15
30				0.4736	0.4297		0.4680		0.0373	0.4886	0.4101		30
45				0.4644	0.4163		0.4611		0.0368	0.4970	0.4252		45
01:00				0.4910	0.4040		0.4656		0.0352	0.4862	0.4254		01:00
15				0.4680	0.4339		0.4644		0.0365	0.4877	0.4288		15
30				0.4763	0.4131		0.4608		0.0370	0.4904	0.4076		30
45				0.4862	0.4195		0.4659		0.0365	0.4880	0.4300		45
02:00				0.4722	0.4343		0.4710		0.0351	0.4961	0.4140		02:00
15				0.4775	0.4240		0.4590		0.0366	0.5066	0.4236		15
30				0.4668	0.4031		0.4680		0.0362	0.4913	0.4172		30
45				0.4763	0.4142		0.4722		0.0365	0.5048	0.4165		45
03:00				0.4820	0.3989		0.4850		0.0357	0.5078	0.4026		03:00
15				0.4901	0.4211		0.4760		0.0352	0.4973	0.4245		15
30				0.4925	0.4104		0.4608		0.0361	0.5045	0.4213		30
45				0.5230	0.4101		0.4704		0.0362	0.5030	0.4181		45
04:00				0.5464	0.4186		0.4527		0.0365	0.4904	0.4250		04:00
15				0.5470	0.4031		0.5149		0.0361	0.4988	0.4345		15
30				0.5649	0.4309		0.5119		0.0363	0.4967	0.4266		30
45				0.5682	0.4124		0.5060		0.0358	0.5114	0.4243		45
05:00				0.5655	0.4106		0.5368		0.0348	0.5473	0.4211		05:00
15				0.5748	0.4313		0.5440		0.0362	0.5547	0.4279		15
30				0.5874	0.4501		0.5428		0.0372	0.5718	0.4462		30
45				0.5889	0.4886		0.5443		0.0382	0.5802	0.4738		45
06:00				0.5918	0.5023		0.5526		0.0389	0.5862	0.4948		06:00
15				0.5868	0.4934		0.5574		0.0401	0.5981	0.5164		15
30				0.5927	0.5196		0.5535		0.0410	0.5951	0.5164		30
45				0.6113	0.5176		0.5553		0.0398	0.5999	0.5221		45
07:00				0.6041	0.5039		0.5688		0.0409	0.5981	0.5167		07:00
15				0.5939	0.5027		0.5643		0.0426	0.6086	0.5228		15
30				0.6011	0.5192		0.5514		0.0440	0.5963	0.5246		30
45				0.6032	0.5199		0.5778		0.0449	0.6065	0.5301		45
08:00				0.5963	0.5075		0.5799		0.0448	0.5874	0.5151		08:00
15				0.5832	0.4834		0.5700		0.0460	0.5898	0.5256		15
30				0.5909	0.5021		0.5694		0.0587	0.5996	0.4916		30
45				0.5895	0.5085		0.5784		0.0446	0.5886	0.5148		45
09:00				0.5715		0.0450	0.5730		0.0608	0.5781	0.5180		09:00
15	0.5969	0.5000		0.6071		0.0466	0.5754		0.0450	0.5918	0.5918		15
30	0.5987	0.5000		0.5784		0.0455	0.5691	0.3438		0.6104	0.4982		30
45	0.6131	0.5119		0.5871		0.0602	0.5790	0.3551		0.5892			45
10:00	0.6032	0.5235		0.5954		0.0448	0.5772	0.3298					10:00
15	0.6029	0.5053		0.5945		0.0667	0.5691	0.3399					15
30	0.5951	0.5210		0.5942		0.0441	0.5661	0.3202					30
45	0.5966	0.4929		0.5951		0.0438	0.5598	0.3212					45
11:00	0.5769	0.5226		0.5835		0.0423	0.5781	0.3533					11:00
15	0.5760	0.5100		0.5904		0.0442	0.6011	0.3335					5
30	0.5787	0.5098		0.5918		0.0445	0.5721	0.3679					30
45	0.5918	0.5171		0.5909		0.0424	0.5889	0.4325					45
12:00	0.5793	0.5148		0.5742		0.0432	0.5805	0.4594					12:00
15	0.5862	0.5030		0.5712		0.0411	0.5760	0.4872					15

TABLE E.1 FLOW AT GEREHU OFF-TAKE (2/2)

(m^3/s)

	P600	P525	P250	P600	P525	P250	P600	P525	P250	P600	P525	P250	
TIME	09/11/92	09/11/92	09/11/92	10/11/92	10/11/92	10/11/92	11/11/92	11/11/92	11/11/92	12/11/92	12/11/92	12/11/92	
12:30	0.5921	0.4920		0.5718		0.0403	0.5871	0.4850					12:30
45	0.5751	0.4991		0.5691		0.0409	0.5700	0.5021					45
13:00	0.5802	0.4900		0.5823		0.0414	0.5763	0.4904					13:00
15	0.5874	0.5046		0.5835		0.0511	0.5924	0.4991					15
30	0.5730	0.4824		0.5904		0.0480	0.5763	0.5224					30
45	0.5847	0.4697		0.5679		0.0464	0.5790	0.4799					45
14:00	0.5826	0.5105		0.5670		0.0525	0.5904	0.5164					14:00
15	0.5918	0.4799		0.5688		0.0439	0.5853	0.5018					15
30	0.5781	0.4980		0.5568		0.0489	0.5742	0.5018					30
45	0.5898	0.4813		0.5688		0.0653	0.5649	0.4797					45
15:00	0.5673	0.4802		0.5682		0.0438	0.5739	0.5176					15:00
15	0.5814	0.4770		0.5799		0.0434	0.5667	0.5012					15
30	0.5778	0.4777		0.5658		0.0427	0.5906	0.4740					30
45	0.5877	0.5023		0.5784		0.0425	0.5625	0.5119					45
16:00	0.5865	0.4923		0.5793		0.0417	0.5763	0.4866					16:00
15	0.6002	0.4900		0.5643		0.0418	0.5673	0.5087					15
30	0.5868	0.4779		0.5883		0.0432	0.5826	0.4605					30
45	0.5874	0.4665		0.5892		0.0420	0.5598	0.4729					45
17:00	0.5927	0.4970		0.5814		0.0402	0.5625	0.4594					17:00
15	0.5793	0.5032		0.5751		0.0422	0.5574	0.4352					15
30	0.5766	0.4952		0.5820		0.0415	0.5769	0.4311					30
45	0.5679	0.4888		0.5607		0.0393	0.5721	0.4345					45
18:00	0.6005	0.5053		0.5808		0.0417	0.5826	0.4421					18:00
15	0.5951	0.4959		0.5960		0.0405	0.5823	0.4409					15
30	0.6029	0.5244		0.5766		0.0385	0.5844	0.4323					30
45	0.5972	0.4886		0.5796		0.0413	0.5841	0.4701					45
19:00	0.6026	0.5137		0.5541		0.0406	0.5670	0.4578					19:00
15	0.5658	0.5158		0.5335		0.0395	0.5760	0.4783					15
30	0.5817	0.4984		0.5380		0.0578	0.5604	0.4710					30
45	0.5778	0.5021		0.5532		0.0396	0.5778	0.4783					45
20:00	0.5766	0.4959		0.5556		0.0388	0.5784	0.4824					20:00
15	0.5700	0.4996		0.5574		0.0394	0.5634	0.4948					15
30	0.5685	0.4907		0.5392		0.0386	0.5568	0.4993					30
45	0.5586	0.4767		0.4988		0.0392	0.5697	0.4904					45
21:00	0.5538	0.4763		0.4907		0.0383	0.5655	0.4701					21:00
15	0.5221	0.4589		0.4434		0.0573	0.5610	0.4724					15
30	0.5084	0.4599		0.4356		0.0377	0.5598	0.4788					30
45	0.5054	0.4676		0.4312		0.0383	0.5413	0.4708					45
22:00	0.5036	0.4496		0.3896		0.0367	0.5305	0.4350					22:00
15	0.4931	0.4555		0.3767		0.0370	0.5051	0.4688					15
30	0.4931	0.4704		0.4138		0.0369	0.4868	0.4521					30
45	0.4754	0.4345		0.4321		0.0371	0.5009	0.4505					45
23:00	0.4775	0.4512		0.4650		0.0368	0.4874	0.4466					23:00
15	0.4856	0.4526		0.4626		0.0357	0.5108	0.4519					15
30	0.4949	0.4341		0.4686		0.0349	0.4937	0.4373					30
45	0.4874	0.4332		0.4614		0.0356	0.4901	0.4370					45
24:00	0.4850	0.4300		0.4506		0.0367	0.4937	0.4414					24:00
No.	59	59	0	96	36	60	96	58	38	40	39		0
Average	0.5667	0.4878	0.5427	0.4504	0.0431	0.5434	0.4520	0.0395	0.5424	0.4595	0		Average