CHAPTER 4 SOCIAL ENVIRONMENT

4.1 Population and Socio-Economic Situation

PNG had its independence in 1975 from Australia and is a member of the British Commonwealth. PNG covers an area of 460 thousand km^2, and has an estimated population of about 5 million in 2000. Australia is the top donor supplying 50% of official development assistance for PNG. It is about 25 billion yen (about US$210 million). Japan is the second largest donor following Australia with good friendship. PNG is also a member of APEC since 1993, and economic activities of Chinese capitals coming from Malaysia, Singapore and Indonesia are recently very common. An estimated per capita GNP in 1996 was US$1,150 and US$890 in 1998 (World Development Indicators). Agriculture remains the major sector of the economy, employing over 80% of the labour force living in the rural area. Economic re-structuring was held in 1990 and 1995 with recommendation from World Bank and IMF, and introduction of value added tax (VAT) increased incomes for the PNG Government. At the same time privatisation of government-owned commercial entities (Air Niugini, PNG Banking Group, other Commercial Statutory Agencies in public services including PNGWB) was recommended and the PNG Government is seeking the implementation.

4.2 Organization for Administration in Water Sector

The following organizations are relevant to the administration of water sector in PNG. It is difficult to express that the administration on water sector is really unified.

a) PNGWB as a counterpart agency of this Study, in charge of water supply and sewerage services on a national level especially for Provincial Towns, District Towns and other rural areas.
b) Water Resources Management Division, Dept. of Environment and Conservation, Water Resources Management Division in charge of water resources management.
c) Eda Ranu in charge of water supply and sewerage in National Capital District (NCD). This is a 100% government owned company to distribute water in the service area, while bulk water supply is done by PNG Water that is a joint venture with foreign capitals.
d) Dept. of Health (DOH), Health Improvement Division mainly in charge of promotion of water supply and sanitation improvement as an organization in health.
e) Local Level Government (LLG) is in charge of existing water supply and sewerage facilities. Especially LLG is authorized to be in charge of water supply in the area under the Organic Law, and there are many small-scale water supply systems under the management of LLG. Concerning development and conservation of water resources, under the Water Resources Act Water Resources Management Division (WRMD) has the function of a regulatory body. The authority regarding water resources development and utilization is also stipulated in the NWSS Act that is the basis for PNGWB. It is not very clear concerning the demarcation of the authority between WRMD and PNGWB on this point. However, there is no inconvenience practically so far because of this unclear demarcation. Therefore, it seems that the clarification has not been tried yet.

4.3 Water Supply Services

The PNGWB was established to cover water supply and sewerage services in all the Provincial Towns in the country, and currently covers 11 Provincial Towns. The Eda Ranu was set up exclusively to service water supply and sewerage in National Capital District (NCD) and working accordingly. In case of rural communities, promotions of water supply and sanitation have been done by Dept. of Health, Health Improvement Division. However, the number of the villages receiving water supply is still very limited. None of these organizations are able to provide exact information and data on actual situation of rural water supply and water use. Although the District Towns have their importance in the position next to the Provincial Towns, no organization has achieved realizing water supply improvement at the District Towns. When water supply service in PNG is considered improvement in the rural area is essential and District Towns, as the gateway for the rural upgrading, have high priority.

1) Water Supply Service at the Provincial Towns in the Country

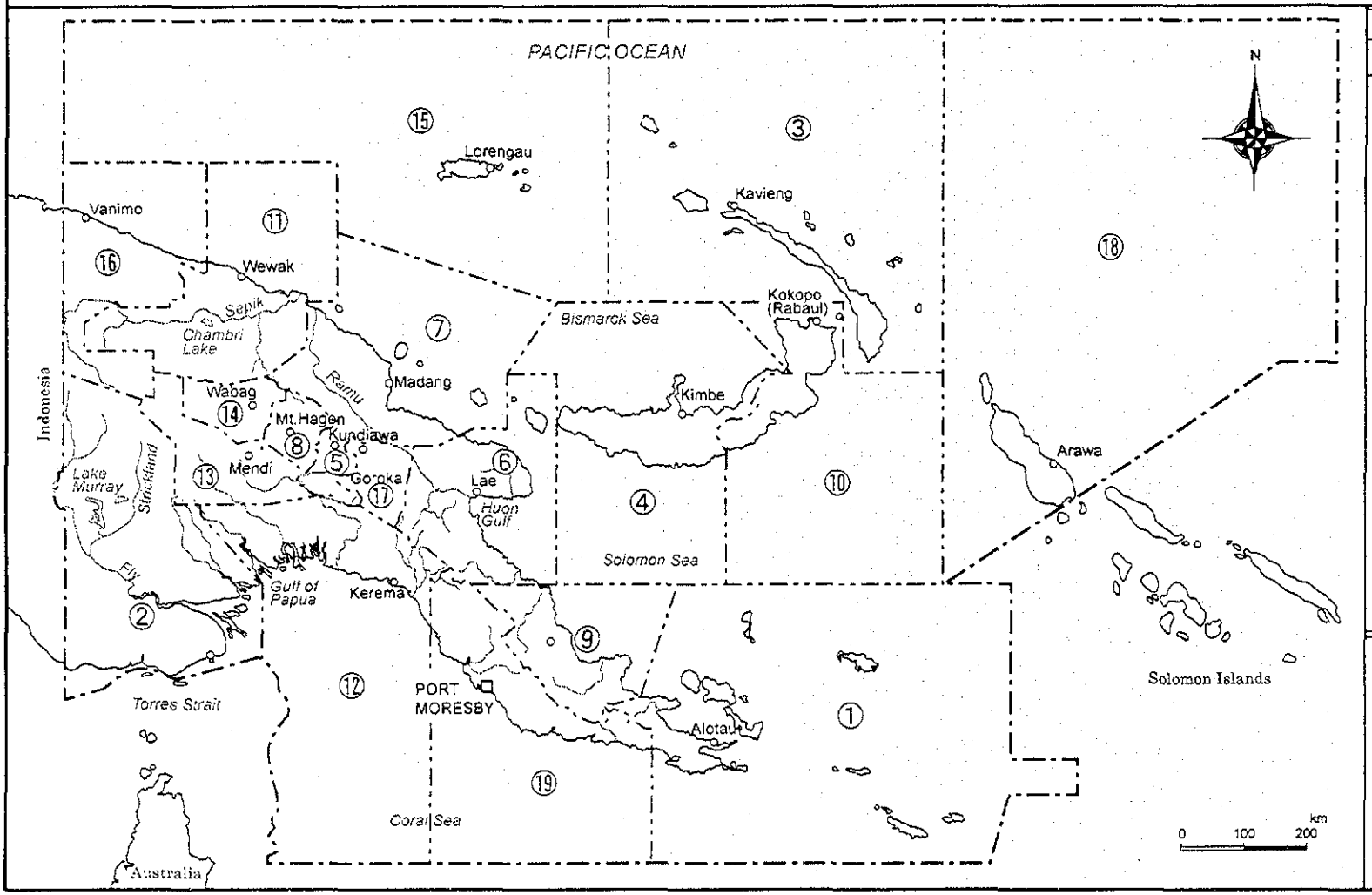
There are 19 Provinces with their Provincial Towns and the NCD. The PNGWB is currently providing services at 11 Provincial Towns.

Table-4.1 Provincial Towns and Organization Providing Water Supply Services in PNG

Provincial Town	Province	Organization Providing Water Supply Services
Alotau	Milne Bay	PNGWB
Daru	Western	PNGWB
Kavieng	New Ireland	PNGWB
Kimbe	West New Britain	PNGWB
Kundiawa	Simbu	PNGWB
Lae	Morobe	PNGWB
Madang	Madang	PNGWB
Mount Hagen	Western Highlands	PNGWB
Popondetta	Oro	PNGWB
Rabaul	East New Britain	PNGWB
Wewak	East Sepik	PNGWB
Kerema	Gulf	LLG
Mendi	Southern Highlands	LLG
Wabag	Enga	LLG
Lorengau	Manus	LLG
Vanimo	Sandaun	No water supply system
Goroka	Eastern Highlands	LLG
Arawa	North Solomon	PNGWB (operation suspended)
Port Moresby	NCD and Central	Eda Ranu/PNG Water

* Port Moresby is the National Capital and formulates the NCD, and simultaneously it is the Provincial town of Central Province. Therefore, there are only 19 provincial towns while 20 Provinces (including NCD) exist.

Fig-4.1 Provincial Towns and Water Supply Services by PNGWB



Province	Town
Water Supply by PNGWB	
①Milne Bay	Alotau
②Western	Daru
③New Ireland	Kavieng
④West New Britain	Kimbe
⑤Simbu	Kundiawa
⑥Morobe	Lae
⑦Madang	Madang
⑧Western Highlands	Mount Hagen
⑨Oro	Popondetta
⑩East New Britain	Rabaul/Kokopo
⑪East Sepik	Wewak
⑫Gulf	Kerema
⑬Southern Highlands	Mendi
⑭Enga	Wabag
⑮Manus	Lorengau
⑯Sandaun	Vanimo
⑰Eastern Highlands	Goroka
⑱North Solomon	Arawa
⑲NCD and Central	Port Moresby

○ Provincial Town
□ National Capital
Boundary of Province
Boundary of State

Water supply services in the Provincial Towns listed below are currently managed by either Local Level Governments or Provincial Administrations and it is planned that the services will be handed over to PNGWB after the facilities are rehabilitated and/or extended which require funding by foreign aids.

Table-4.2 Foreign Aid Agency for Funding on Water Supply Services

Provincial Town	Province	Foreign Aid Agency for Funding
Kerema	Gulf	ADB
Mendi	Southern Highlands	ADB
Wabag	Enga	ADB
Lorengau	Manus	JICA
Vanimo	Sandaun	AusAID

2) NWSS Act and Organic Law

The PNGWB was established based on the NWSS Act the enacted in 1986. As a Commercial Statutory Authority (CSA) it is in a position to manage the water supply and sanitation services of the whole country. Department of Works (DOW) used to be in charge of the water supply and sewerage services before the legislation of NWSS Act, and PNGWB succeeded from DOW. The water supply and sanitation service is the essential need for the residents' living conditions under various environments of the country. The Organic Law legislated and its amendment both enacted in 1995 lay down the status and functions of local autonomous bodies and have relevance with NWSS Act. Therefore, it was discussed whether the responsibility to provide water supply service will be under Provincial Governments (PG) and/or Local Level Governments (LLG) at the regional level or under PNGWB. However, it is recognized that NWSS Act which stands for national interest has the prevailing status to the Organic Law. The PNGWB is responsible as a supervisor and an implementing agency of the water supply and sanitation service of the whole country including urban and rural areas. The PNGWB has not been involved in the water supply service in the District Towns, other smaller urban communities and rural areas as compared with the ones for Provincial Towns.

3) User Pay Policy

So-called "USER PAY POLICY" is an important policy of the PNG Government concerning the water supply service. A pay water supply service had not settled in the PNG before NWSS Act.

Long time and ceaseless efforts were required under the support of the foreign aid organization, specially ADB to let PNGWB establish itself well and obtain the current financial status which is independent and healthy. In the residential area of low-income group, commonly called as "Settlement" in the Provincial Town where water is supplied, the fee collection is difficult and not practised, while neither the concept of the policy nor the water supply service have reached rural areas. This shows the difficulty to spread the "USER PAY POLICY". In the District Towns the cost sharing of the water supply service is hardly performed by the whole area.

4) PNGWB as Commercial Statutory Authority (CSA)

The PNGWB is a provider of public service. However, it is not possible to participate directly in the water supply and sanitation service on a non-commercial basis due to its status as CSA. This restriction is effective to sustain healthy financial conditions as the provider of the water supply and sanitation service to the public. At the same time, this restriction is one of the reasons why the spreading of the water supply service in the whole country was not accomplished. In addition, PNGWB is under the supervision of the Minister for Privatisation and Corporatisation and listed as one of the CSA for privatisation in the future. However, the water supply coverage in PNG is still low, and the difficulty to make the water supply service commercially viable is a reality. Therefore, currently privatising PNGWB is not appropriate yet considering such a facts. In case that PNGWB is privatised, it is predicted that PNGWB will not be able to contribute much to the improvement of small and medium-sized local urban and rural water supply.

5) Management system for District Town Water Supply

As a result of Study and analysis as mentioned above, the best way to achieve improvement of water supply in District Town must be the direct management by PNGWB.

The number of District Towns in the country is almost the same as the number of Open Electorate (election district for member of parliament) that count 89 in the whole country. Among them the areas covered by satisfactory water supply service are very limited. Water supply service of most District Towns has not only the problems of the facility but also the problems of the institutional framework and financial affairs. Therefore, a provision of satisfactory water supply services for these District Towns shall be a target that PNGWB should achieve in the future.

The PNGWB is supposed to play the role of promoter and facilitator to achieve the higher coverage under the NWSS Act. On the other hand, the District Town water supply service has vulnerable commercial viability. In the Corporate Plan for 1999 to 2003, PNGWB is indicating its view on their business development positively with the background that they have been making the surplus since 1997. In this Corporate Plan, together with extension of urban water supply services in Provincial Towns, promotion of rural water supply is clearly stated. The problem is that it is not easy to maintain the income-expenditure balance break-even because of the small scale of these District Town water supply services. It is a question on how to balance the two essential functions that PNGWB has, i.e., "To advocate provision of water supply service to the public" and "To protect its financial health as the self-contained CSA being managed independently".

On the other hand, the Study Area includes 6 District Towns and the number of customers receiving water supply service in these areas are assumed to hardly exceed 200 in each area. The scale of these water supply services is small. However, there is a possibility that several thousand to 10,000 numbers of customers in total can be newly acquired if about 200 numbers of customers as the average are secured in all District Towns (80 places or more). District Town water supply service is not only a public mission but also a potential market for the future of PNGWB subject to solution of the financial balance problem of these small water supply systems.

Tbale-4.3 Number of Customers in the Study Areas

Provincial Town	Number of Existing Customers			
	Domestic	Commercial & Industrial	Institutional	Total
Popondetta	779	53	44	876
Daru	870	37	50	957
Sub-Total	1,649	90	94	1,833
District Town	Number of Expected Customers			
	Domestic	Commercial & Industrial	Institutional	Total
Mutzing	160	3	7	170
Finschhafen	243	7	15	265
Bereina	176	2	10	188
Kwikila	170	3	9	182
Kupiano	837	3	14	854
Oro Bay	158	2	5	165
Sub-Total	1,744	20	60	1,824

* Number of domestic customers will actually be less than the above-mentioned number because it is

assumed that one contract will cover more than two households in the rural area and the settlement. In case of Kupiano because of the big rural population in the area, it seems that the number of actual customers will be around 500 or less.

4.4 Water Resources Development Situation

Department of Environment and Conservation (DEC), Water Resources Management Division is concerned with water resources management including river water, lakes, ponds and groundwater. When the survey of water resources is started, reporting to this office on the survey is necessary as well as reporting of the survey results. Considering groundwater development, permission based on the official form is required for drilling and pumping.

On the other hand, DEC manages the measurement of river discharge at certain gauge stations constantly. Therefore, PNGWB can work together with them and request the measurement of river discharge at the sites such as Binaturi intake station, Popondetta intake point, and other concerned intake points since the official records of river discharge for intake at these points are not available.

4.5 Water Supply, Health and Sanitation

The UNICEF's reports indicate that only 28% of the population in PNG had access to safe drinking water in 1997, and 22% of the population had adequate sanitation facility. On the other hand, Ministry of Health reported in the National Health Plan, 2001-2010 that about 30% of the population in the country has access to safe drinking water in 2000, and 22% of the same has adequate sanitation facility. Other relevant information for water supply in 2000 is showing that about 60% of the urban population is supplied with water while only 20% of the rural population is covered. The above figures are very low compared with the water supply coverage ratio in other countries in the Pacific Region. Because of this kind of situation, the PNG Government planned to improve the coverage of water supply to 50% in 2010.

CHAPTER 5 PRESENT SITUATION OF STUDY AREA

5.1 Climate and Hydrology

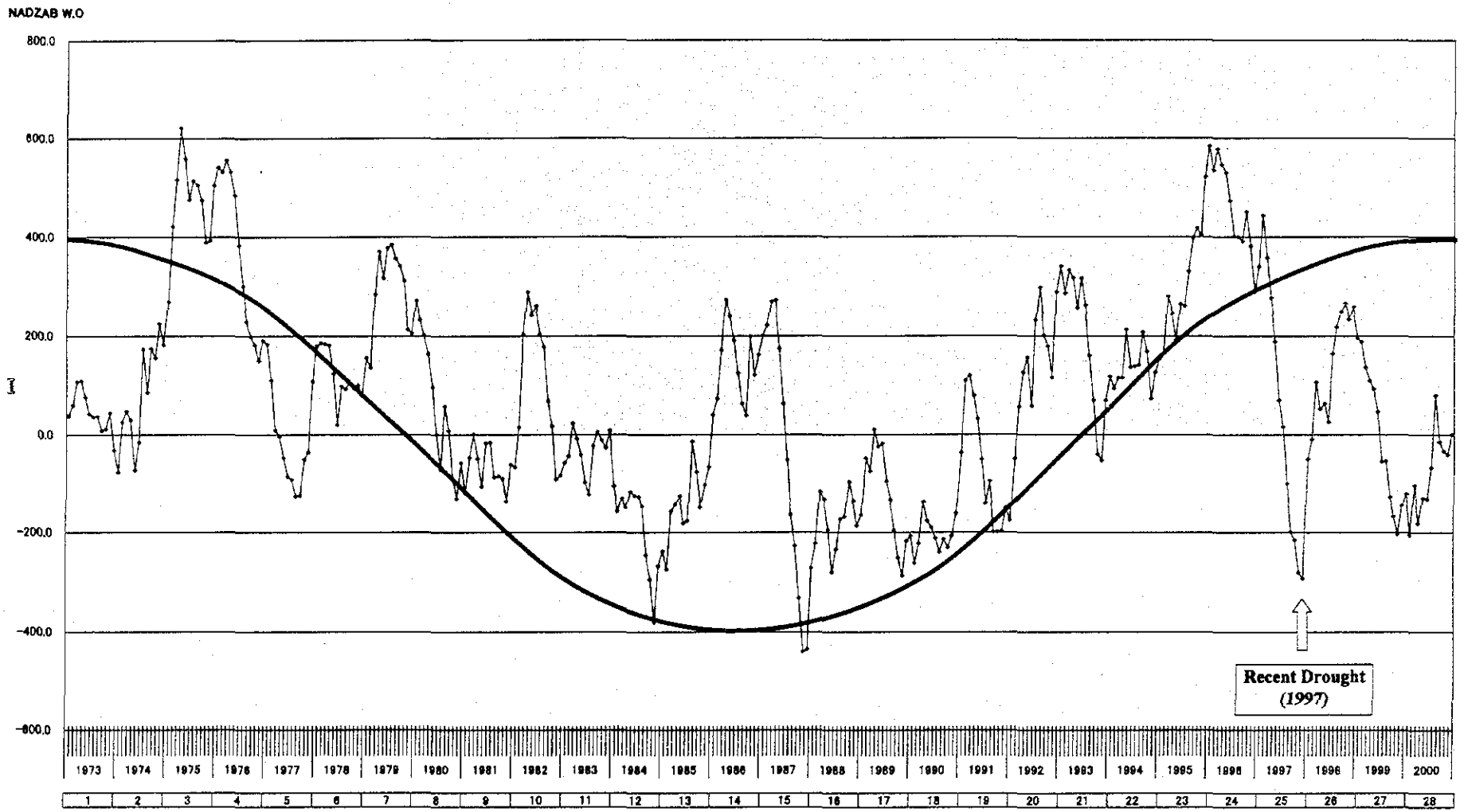
PNG is located in the tropical rainforest climate with a mean annual rainfall of 2,000mm to 3,500mm for the Study Area. There are two seasons of rainy and dry in a year. It was reported that the major drought was faced in 1997- 1978 which was probably more severe than those of 1973-74, 1977, 1980-81, 1984, 1987, 1991, 1993 droughts brought by the El Niño in the last century. Generally, they say the El Niño occurs in a 5 to 7 years cycle. The monthly rainfall data was collected from Nadzab station in Lae and the rainfall pattern for the recent 28 years from 1973 to 2000 was analysed. It clearly shows the drought in 1997 as seen in Fig.-5.1 and the drought continues to contribute to the shortage of rainfall till 2001.

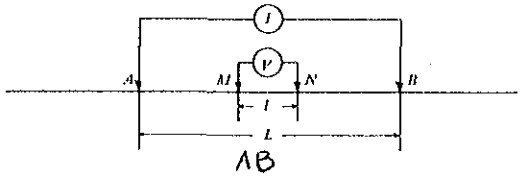
5.2 Geophysical and Hydrogeological Survey

Geophysical and hydrogeological survey was carried out in order to assess the distribution and potential of groundwater to be developed. In this survey, both Schulamberger and Wenner methods were applied (Fig.-5.2). In addition, geomagnetic survey method, namely EM method was introduced in Popondetta and Daru depending on the topographical and geological conditions. These data were used to select drilling points and target depths. (Fig.-5.3 to 5.6).

1) Popondetta is located 17 km to the north of from Lamington Volcano (1,679 m in elevation). This area shows generally high earth resistivity (45 to 10,000Ω-m) which is a characteristic of volcanic regions. Geoelectric prospecting was conducted mainly in the town of Popondetta and at the foot of Lamington Volcano, and the underground down to 130m below the ground level was analysed. The analysis shows that the stratum with 85 to 362Ω-m in earth resistivity could be productive. Groundwater is expected at 30m below the ground level in the northeast to the southeast areas from the Town. Based on the above survey, in these areas, two drilling points were selected at 1.0 km from the Town where a drilling rig can access. The target aquifer depth was 100m each.
2) Daru is a small island, north-south 4 km and east-west 6 km, with the highest altitude at 12m. PNG Geological Survey, which investigated the groundwater potential in the past, reported that the area is affected by the intrusion of saline water. Geophysical survey was carried out to identify the areas suffering from the saline water and the depth of the intrusion, so that the potential of potable groundwater can be identified. Judging from earth resistivity, the areas affected by saline water are situated in the north-west to the south of the island. These areas show very low earth resistivity of 2 to 8Ω-m. These depths are 8m to 24m, and especially, the north-west of the island is 40m in depth.

Fig.-5.1 Rainfall Pattern at Lae in Recent 28 Years (1973-2000)

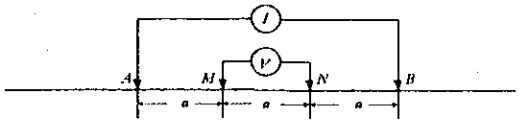




Schlumberger Array, $\rho a = \frac{L^2 - l^2}{4l} \frac{V}{I}, \quad L \geq 5l$

A,B : Current electrode, M,N : Potential electrode

L : spacing of Current electrode, l : spacing of Potential electrode



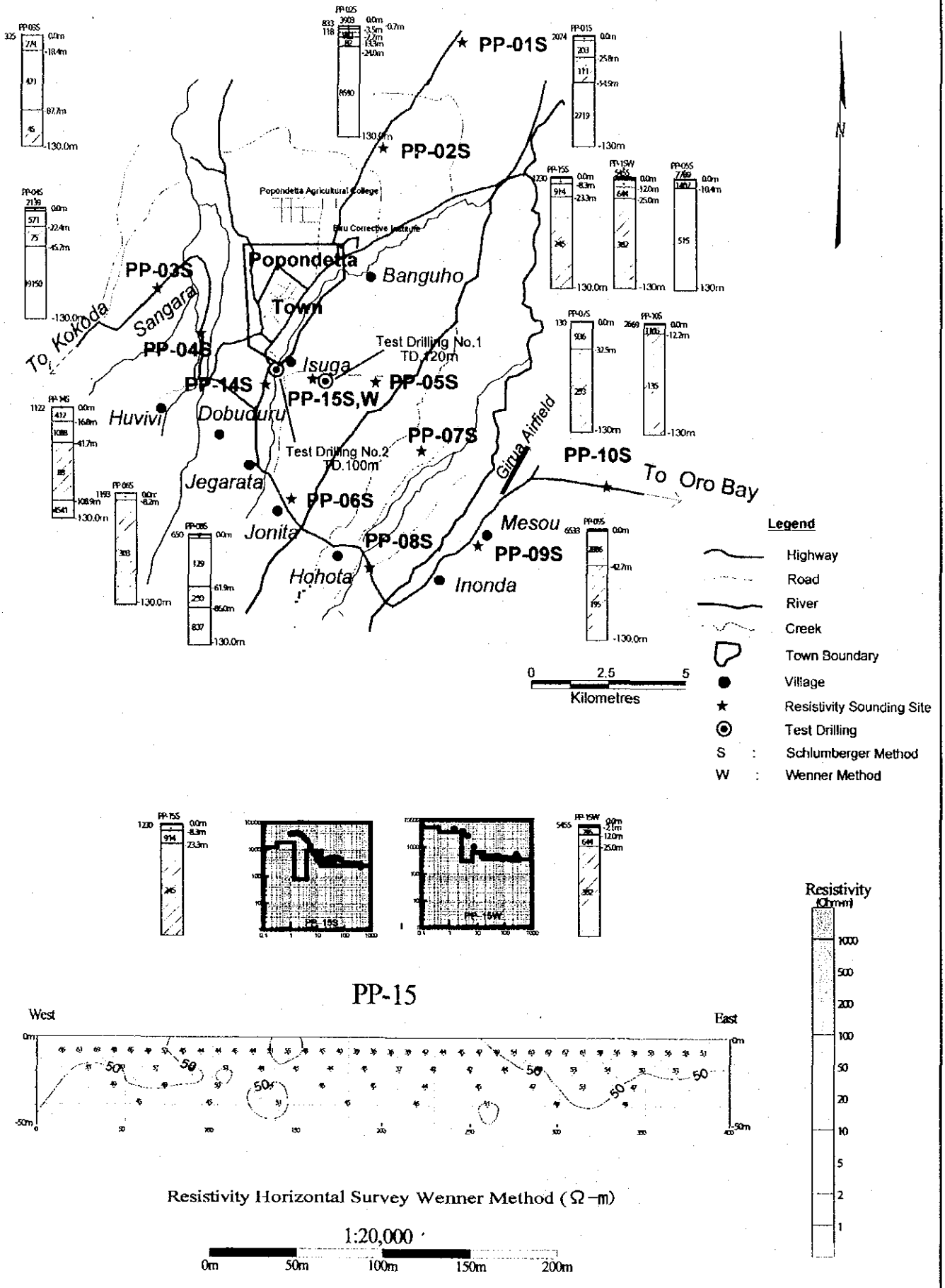
Wenner Array, $\rho a = 2\pi \frac{V}{I} a$

a : Electrode spacing

Figure 4-3-2 Electrode Array in Vertical Electrical Survey

Fig.-5.2 Electrode Array in Vertical Electrical Survey

Fig-.5.3 Interpreted Resistivity Sounding in Popondetta



Resistivity Horizontal Survey Wenner Method (Ω-m)

1:20,000

0m 50m 100m 150m 200m

Figure-5.4 VES Curves of Resistivity Sounding in Daru

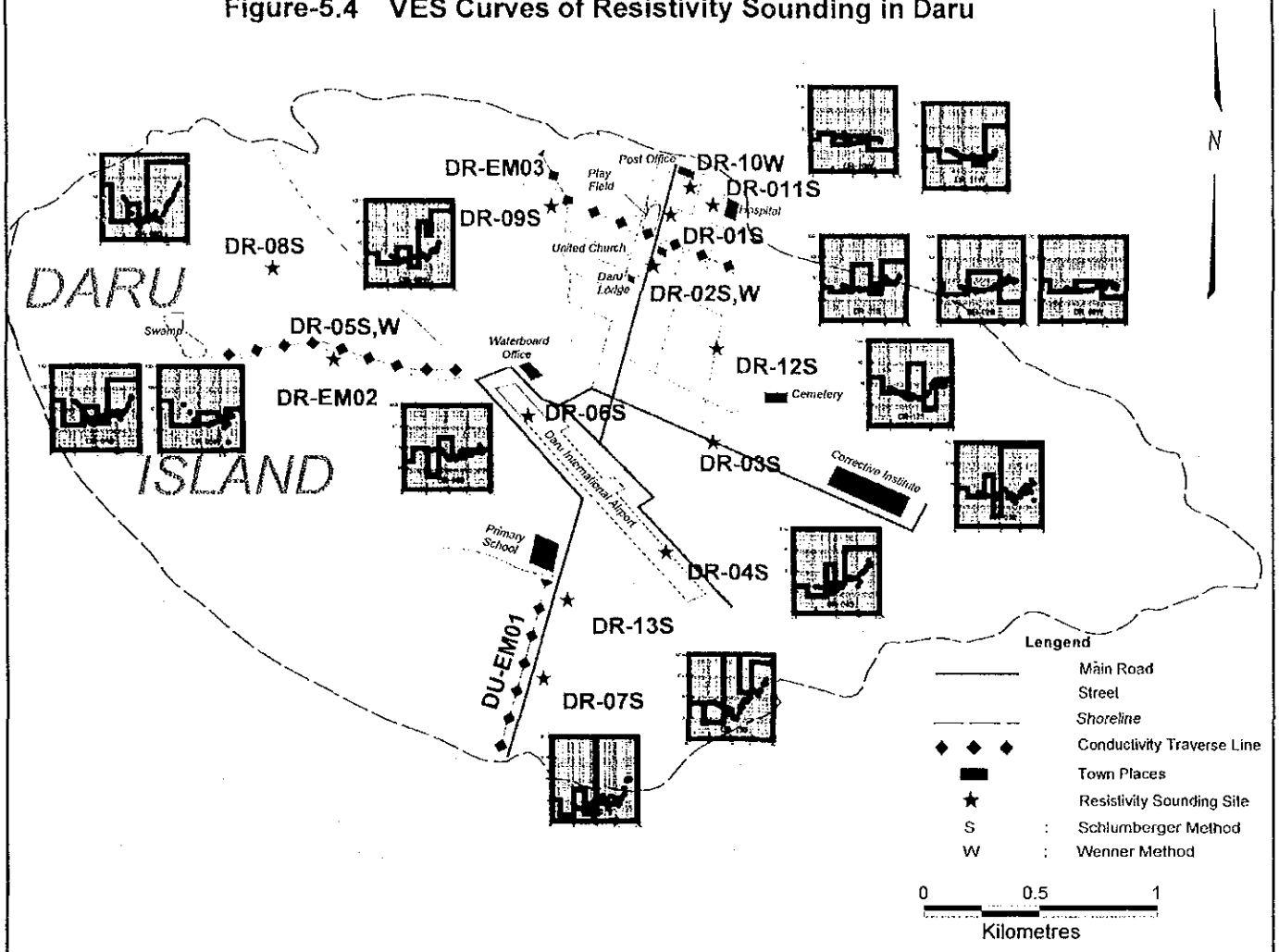
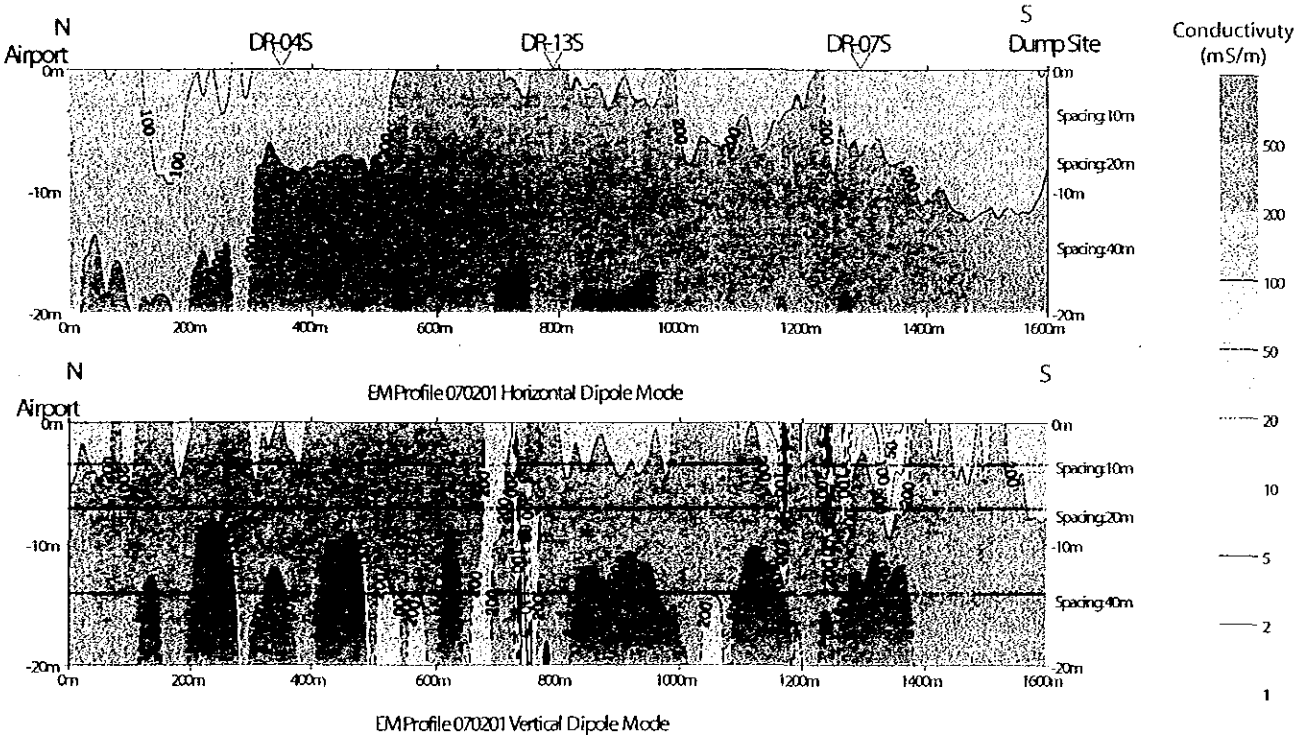


Figure-5.4(2) Condutivity Profile of Electromagnetic Survey between Airport and Dump Site in Daru



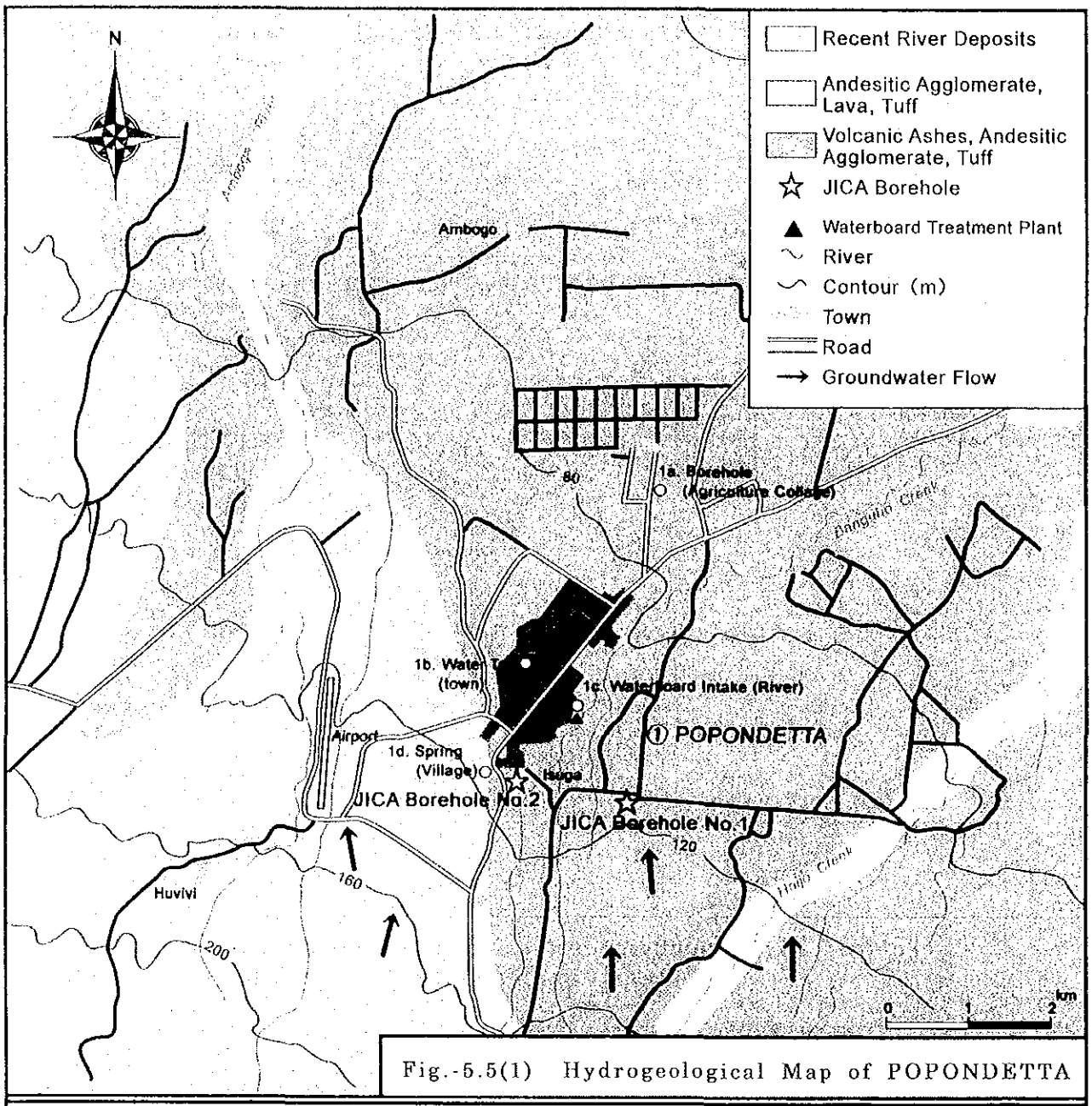


Fig.-5.5(1) Hydrogeological Map of POPONDETTA

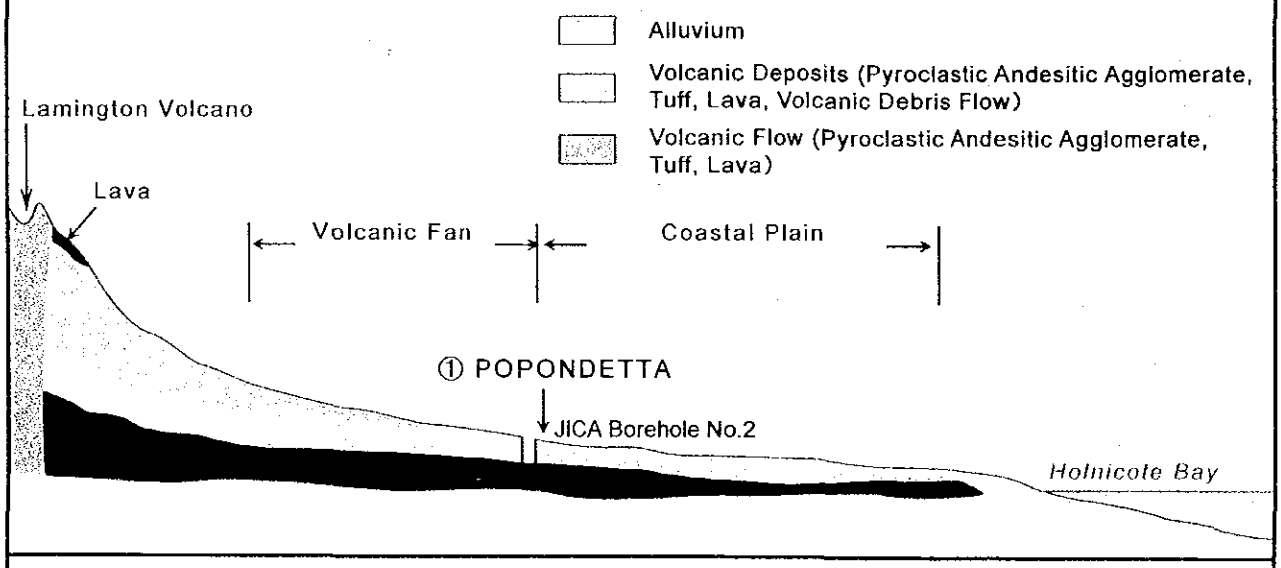


Fig.-5.5(2) Schematic Geological Cross Section Lamington-Holnicote

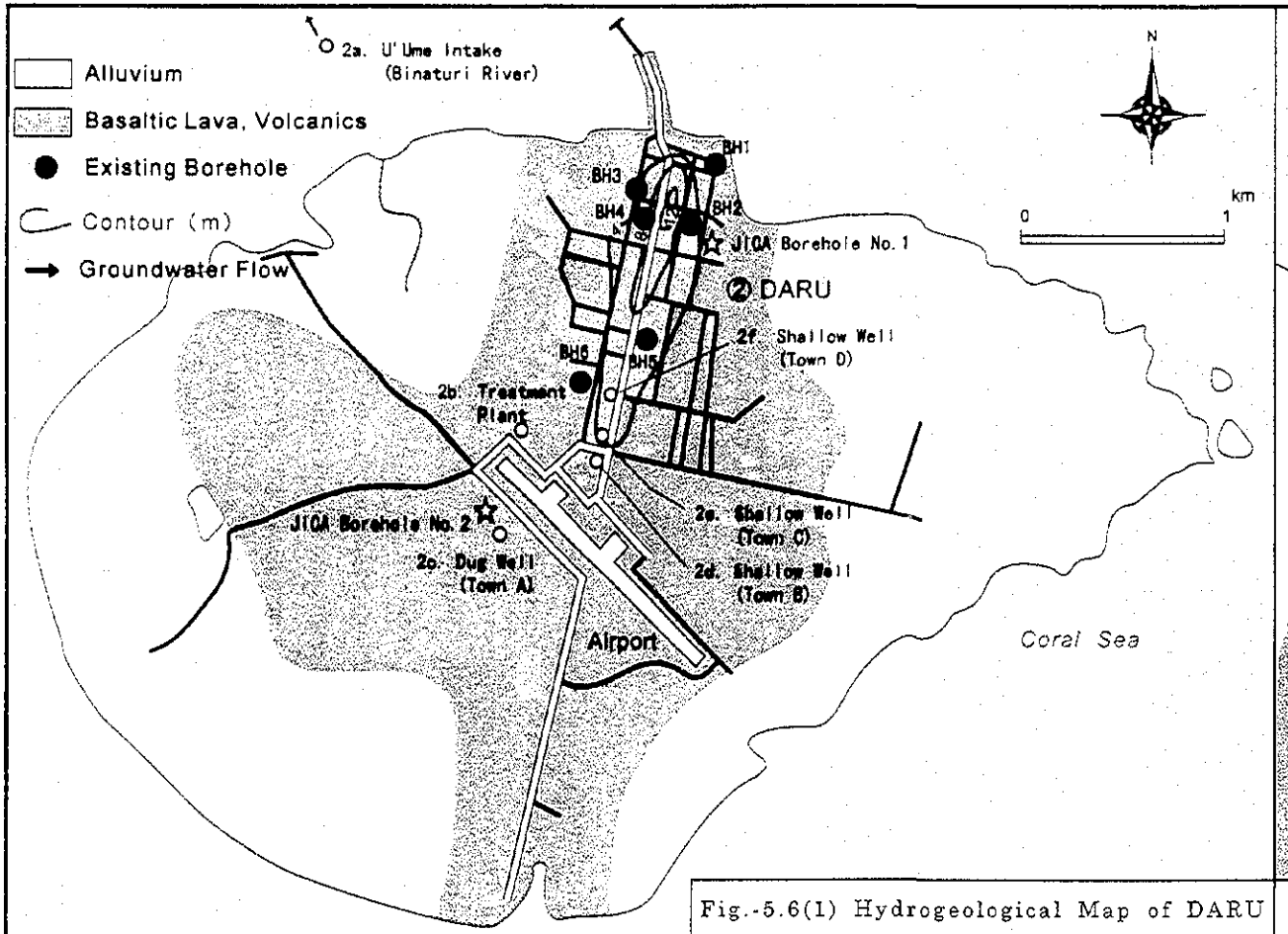


Fig.-5.6(1) Hydrogeological Map of DARU

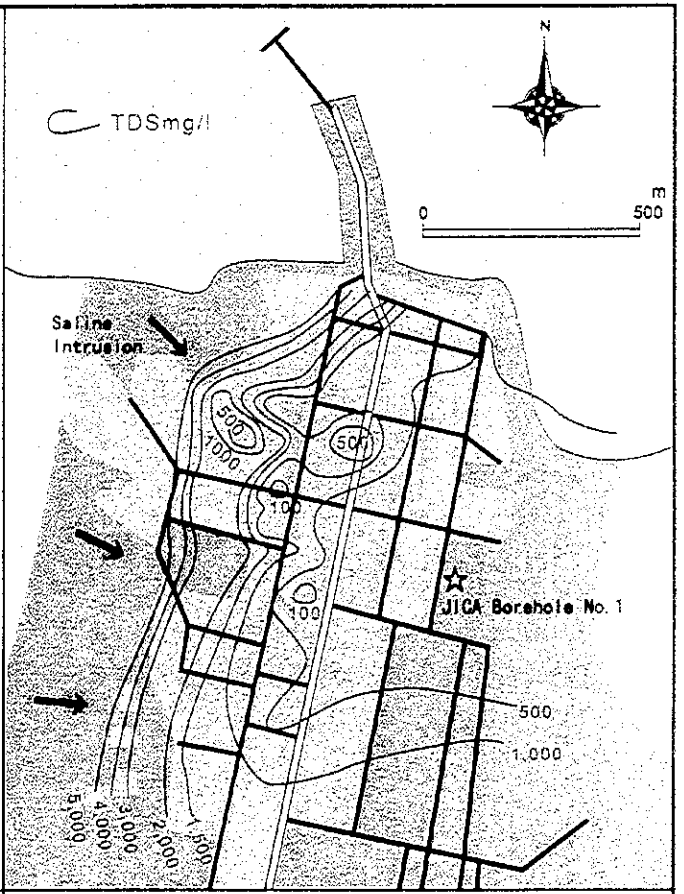
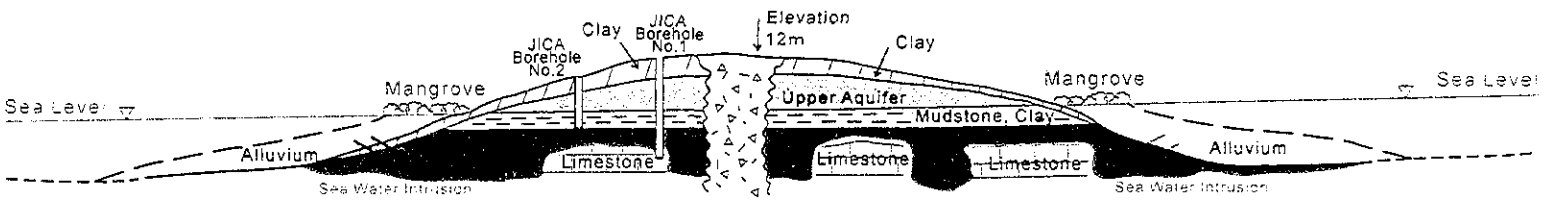


Fig.-5.6(2) Total Dissolved Solids in Upper Aquifer (TDSmg/l)



Data : PNG Geological Survey

Fig.-5.6(3) Geological Cross Section of Daru Island

On the other hand, the relatively high areas in altitude, which are in the north-east of the island and 5m to 10m above the sea level, show relatively high earth resistivity of 18 to 80Ω-m and the depths are 3m to 50m. Since groundwater can be expected in these areas, drilling point No.1 was selected there. Whereas the drilling point No.2 was selected in the south-west of the island where the first 6.9m from the ground level shows a low earth resistivity of 4Ω-m but the stratum below this shows the value of 33 to 282Ω-m where groundwater is expected.

3) Bereina is located in the plain along the coast. North-west of the town is a hilly area where coral limestone is covered by the Quaternary conglomerate. Artesian basin is expected in the town located in the lowland of the coastal plain and the inland. To find a water source that is close to the town and has a confined aquifer, the site for geophysical survey had been selected in the north-east from the town. As hydrogeologically expected, the analysis showed that there might be an aquifer with earth resistivity of 15 to 95Ω-m in the north-east of the town. The aquifer could become thicker (25m to 95m) and deeper toward the direction from the town. The drilling point was selected near the health centre for the ease of the distribution of water and the accessibility. An aquifer is expected to be 30m to 40m deep and 19 to 33Ω-m in earth resistivity.
4) Mutzing is characterized as the centre of agricultural development and located in Markham Valley. The area has thick Quaternary deposit along the tectonic line and is known to have high groundwater potential. Geoelectric survey was carried out to identify the area and the depth of the aquifer in the study area. As a result of the survey, the area showing the earth resistivity of 24 to 282Ω-m is expected to be an aquifer of sand and gravel, and it could be located at 10m to 130m depth. The area is generally sand and gravel stratum showing the smooth geoelectric survey curve of around 100Ω-m. Thus, the drilling point is selected in the town centre where the earth resistivities are 48 to 63Ω-m and the aquifer is expected to be in the strata of 6m to18m and 43m to 122m in depth.
5) The processes from the geophysical, geological and hydrogeological survey to select the drilling point, test drillings were carried out considering the following.
   a. The results of the geophysical survey are analysed considering the geographical, geological and hydrogeological characteristics of each site.
   b. Based on the analyses, the drilling points and the depths are determined.
   c. Priorities for drilling are given to the sites that have accessibilities to mobilise a drilling rig.
   d. Among prospective sites with same groundwater potentials, the site closest to the town is selected to minimise the distance of the distribution pipes installed.
   e. In terms of securing lands, priorities are given to the State Lands. In case a drilling site is selected in a customary land, the owner's permission should be obtained in advance.
   f. Hydrogeological maps show the drilling points for the Study Area.

5.3 Hydrogeological Study

1) Hydrogeological study is done based on the limited existing borehole data, the results of geological survey, water quality analysis, geoelectric prospecting and test drilling.
2) When we consider the groundwater potential, the concept of Specific Capacity (SC) is the most important factor as well as the other factors, namely discharge, drawdown, pumping water level, static water level as follows.
   a. Specific Capacity (m^3/day/m) =
      Discharge of Pumping Test (m^3/day) / Drawdown (m)
   b. Drawdown (m) = Pumping Water Level – Static Water Level
   c. Groundwater Potential (m^3/day) =
      Specific Capacity (m^3/day/m) x Allowable Drawdown (m)
3) The groundwater potentials are calculated as the volume of water taken from a borehole assuming the groundwater is continuously pumped for allowable drawdown.
   The 10 m of allowable drawdown was determined in this study based on the results of the continuous discharge test of the test boreholes, the structure of boreholes, total depth and the static water level. Nevertheless, in Daru, Finshhafen, Oro Bay and other specific areas where the saline water intrusion is reported, the allowable drawdown is reduced to 1 m instead of 10 m so that the saline water intrusion could be minimized.
4) The groundwater potential per borehole in the Study Area including depth of main aquifer was evaluated and summarized in Table-5.1 and the master plan for groundwater development program should be prepared considering the water demand for the target year of 2015.

Table-5.1 *Groundwater Potential Capacity*

Study Area	Borehole Depth (m)	Static Water Level (m)	Pumping Water Level (m)	Depth of Aquifer (m)	Potential Capacity per Well (m^3/day/well)
1. Popondetta	110	7.0	17.0	70-100	850
2. Daru	50	2.5	3.5	20-40	325
3. Bereina	50	6.0	16.0	20-40	751
4. Kupiano	70	2.0	12.0	30-60	350
5. Kwikila	50	4.0	14.0	20-40	470
6. Finschhafen	50	6.0	7.0	20-40	540
7. Mutzing	50	2.0	12.0	30-40	8,640
8. Oro Bay	50	4.0	14.0	20-40	150
9. Oro Bay (Kopure)	50	4.0	14.0	20-40	700

5.4 Basic Information

1) Income Level

The following table is a summary of a survey in relation to the monthly cash income of eight (8) Study Areas. From this data it can be concluded that firstly, income levels are highest in Daru and Popondetta (provincial capitals), and secondly, Kwikila and Mutzing, where transport is comparatively convenient, possess higher levels of incomes than other towns.

Table-5.2 Monthly Cash Income

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Median (K)	742.50	589.50	N/A	654.66	906.25	695.78	924.75	956.58
Average (K)	790.63	1,654.11	N/A	700.86	994.65	1,427.69	1,734.11	1,212.92
Informal Residents/ Villagers								
Median (K)	283.50	90.00	189.59	237.50	408.33	159.75	696.50	394.65
Average (K)	797.04	176.43	337.91	349.43	486.10	236.93	928.45	432.01

2.66Kina=1US$ (Aug. 2000)

2) Land Use

Land in PNG is classified into two (2) categories based on form of ownership: Customary Land and Alienated Land. Alienated Land is the land that is alienated from Customary Land or removed from custom and is largely owned by the PNG government. However, 99% of national land is Customary Land and the rules and principals of customary land tenure are in accordance with native customs rather than those set out in any formal documentation. Therefore, state intervention in customary land tenure is very limited. It is thought, on the one hand, such an ambiguous situation seems to have conserved traditional culture and personal identity. However, on the other hand, it has also prevented the utilization of Customary Land and presented obstacles for perhaps more desirable objectives such as development projects. Although the government has tried to promote the registration of Customary Land to solve such issues, no significant progress appears to have been made.

Facilities for the JICA Pilot Project have been constructed on State Land in consideration of the above-mentioned situation. For example, although facilities for a Water Vending Project in Daru had planned to be constructed in an informal residential area, the location was changed to State Land because all informal residential areas are thought to be on Customary Land. An

exceptional case was the installation of communal taps in villages. In this case, the landowners coincide with the beneficiaries from the communal taps and thus willingly allowed the installation to progress.

Land is a very sensitive issue in PNG and any issue relating to it should be paid with careful attention. Even State Land is not always free from disputes and there are some cases where trials relating to land ownership or compensation are still evident. In fact, even some of the surveyed sites are still engaged in trials. In general though, it would be impossible to utilize Customary Land for the benefit of those who have nothing to do with its ownership. And in practice, such a project as is indispensable to utilize Customary Land is very difficult, unless certain direct benefits for its owners are sure and obvious.

3) Social Status and Working Conditions for Women (Gender Consideration)

There are very rich and complex cultural traditions in PNG and it may not be accurate to say that the social status of women has been traditionally lower than that for men. However, at present, it may be fair to say that the social status of women may be at a disadvantage to that of men. As shown in following Table-5.3, various social indicators in relation to gender support this assertion. Furthermore, although there is no objective data available, it is thought that domestic violence and rape are widespread.

Table-5.3 Selected Social Indicators in Relation to Gender

	Male	Female
Life Expectancy at Birth	55.4	57.3
Adult Literacy Rate	71.4%	56.0%
Combined primary, Secondary and Tertiary Gross Enrolment Rate	42%	35%
Seat in Parliament by Gender	90.7%	9.3%

(Source; Human Development Report 2000

In addition, it is also possible to point out that the unfair land tenure system may be a factor that prevents women from starting their own businesses. It is believed that women were the traditional owners of land tenure in places where matrilineal heirship was common. However, all rights in relation to land are held by men at present, and women appear to have been relegated to witnesses, even where traditionally matrilineal heirship is predominant. Today, land is considered to be important collateral for making loans, thus women seem to be treated discriminately from an economical point of view.

Table-5.4 Responsibility for Fetching Water

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Adult Male	0%	13%	N/A	9%	24%	25%	20%	7%
Adult Female	92%	98%	N/A	88%	84%	97%	95%	86%
Boy	0%	2%	N/A	0%	11%	6%	3%	0%
Girl	12%	16%	N/A	3%	11%	9%	5%	11%
Informal Residents/ Villagers								
Adult Male	29%	17%	32%	10%	20%	63%	22%	7%
Adult Female	93%	96%	98%	90%	67%	100%	100%	93%
Boy	0%	4%	0%	7%	7%	5%	0%	0%
Girl	14%	13%	18%	14%	20%	8%	15%	25%

In the survey, it has been observed that the voice of women was limited in meetings, and committee members for the Pilot Project tended to consist of only men.

As results of the survey and questionnaires show, the responsibility of fetching water is predominantly borne by adult women. In addition, the majority of participants in the informal sector from informal residents/villagers are women and it is inferred that a considerable amount of income is generated by them. The income from informal sector activities is also able to be disposed of by women. From field observations, daily domestic duties like preparation of meals are carried out by women, thus the water supply service should be closely related with their daily life and it is thought that the needs for water by women is keener than that of men. Therefore, it is considered that women are a more appropriate stakeholders and should play the main role of maintaining communal water taps. Although it would be difficult to expect women to lead activities as a chairperson of the Water Management Committee considering the social context of PNG, the benefit should be high to promote the positive participation of women. In practice, the Water Management Committee organized for the period of the Pilot Project has given certain attention not to exclude women from its membership

4) Current Water Usage and Satisfaction

Formal residents depend on water taps for drinking and cooking in Mutzing, Finschhafen, Daru and Popondetta, where there are water supply facilities that seem to work constantly. The formal residents use water tanks mainly in Bereina, Kwikila and Kupiano, where there are either no water supply facilities or they do not work well. As for informal residents/villagers, wells and rivers are the main sources of water except in Daru and Finschhafen.

As for the availability of water through the year for formal residents, it seems that water availability is stable in Daru and Popondetta, where PNGWB operate services, and next to them are Mutzing and Finschhafen, where there are working water supply facilities. Towns like Bereina, Kwikila and Kupiano, where water tanks are the main source of water, seem to be the least stable. In the case of informal residents/villagers, their main water sources are rivers and wells and their feelings about the availability of water sources throughout the year is generally better than that of formal residents. Although it is understandable that it is possible to fetch water more constantly from rivers and wells compared to rainwater, rainwater in tanks would be of preference over rivers and wells considering the quality and workload involved in fetching water. Many informal residents/villagers feel that their water source is dirty. Therefore they are not satisfied with existing water sources.

Table-5.5 Water Availability throughout The Year

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents							
49%	42%	N/A	12%	5%	6%	81%	99%
Informal Residents / Villagers							
79%	80%	82%	28%	27%	80%	93%	93%

Table-5.6 Water Source Problem (Dirty)

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents							
85%	49%	N/A	27%	30%	31%	79%	60%
Informal residents / Villagers							
64%	80%	56%	66%	47%	70%	78%	68%

Yet, many formal residents in Mutzing, Finschhafen, Daru and Popondetta also feel that their water source is dirty, even though water supply facilities are equipped and functioning. Therefore there is some gap between the present situation and what is desired. As the extent of this gap differs depending on site, it will be necessary to inquire as to why they consider their water source dirty in more details as a public water supply service.

Table-5.7 Main Water Sources for Drinking and Cooking

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
House Connection	60%	60%	N/A	0%	0%	3%	92%	89%
Public Faucet	17%	11%	N/A	0%	0%	0%	2%	1%
Rain Water Collection Tank	6%	18%	N/A	100%	89%	94%	7%	4%
Neighbours Rain Water Tank	0%	11%	N/A	0%	3%	0%	0%	0%
Public Rain Water Tank	0%	0%	N/A	0%	0%	3%	0%	1%
Dug Well	6%	0%	N/A	0%	0%	0%	0%	0%
Neighbours Dug Well	6%	0%	N/A	0%	0%	0%	0%	0%
Public Well	0%	0%	N/A	0%	8%	0%	0%	1%
River Stream, Spring	6%	6%	N/A	0%	0%	0%	0%	1%
Informal residents/villagers								
House Connection	7%	16%	0%	0%	0%	0%	71%	21%
Public Faucet	0%	40%	0%	0%	0%	0%	27%	11%
Rain Water Collection Tank	0%	8%	4%	35%	53%	13%	0%	7%
Neighbours Rain Water Tank	0%	4%	0%	0%	13%	0%	0%	0%
Public Rain Water Tank	0%	0%	0%	0%	0%	0%	0%	0%
Dug Well	36%	0%	0%	14%	0%	0%	0%	4%
Neighbours Dug Well	0%	0%	0%	21%	0%	0%	2%	4%
Public Well	43%	0%	0%	45%	13%	0%	0%	21%
River Stream, Spring	14%	44%	96%	3%	20%	88%	0%	32%

5) Awareness for Water Supply Service

A. Expectation for Water Supply Service

As shown in Table-5.8 below, almost 100% of households hope to join a water supply service and there should not be any obstacles to paying water charges.

In the case of starting a new water supply service at the surveyed sites, it is thought that each household of formal residents can make a contract with PNGWB (as is the case in other provincial towns where PNGWB operates) because most formal residents are public servants and have a staple income source. However, as water charges have been provided free of charge in the past and are considered to be to poor and inadequate, it is uncertain how a change will affect the willingness of people to pay for the services in the future.

It is considered that water supply services for informal residents/villagers will require different conditions. Most do not have stable income sources and their monthly cash income is lower than that of formal residents.

Table-5.8 Willingness to Join Water Supply Service

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano
Formal Residents					
100%	96%	N/A	97%	97%	100%
Informal Residents/ Villagers					
100%	100%	100%	100%	100%	100%

When communal taps were introduced to informal residents/villagers as a part of the Pilot Project, it was observed that those informal residents/villagers tended to limit their water usage to save on water charges. Thus, if such a limitation is applied too strictly, the benefit of the water supply service may not be fully realized. On the other hand, if water is used carelessly, large water charges may bring about serious problems for sustainable use. In any case, continual monitoring of communal tap usage will be required.

B. Willingness and Ability to Pay

As results from a survey conducted in Daru and Popondetta show, where PNGWB is operating water supply services, the most frequent range of actual payments for water by formal residents is from K5 to K10. In the case of informal residents/villagers in Daru, although the most frequent level is no payment, distribution is spread evenly from K5 to K30. In the case of informal residents/villagers in Popondetta, about 70% do not pay water charges and are considered to be excluded from the water supply services.

As the result of a survey regarding the willingness to pay for water supply services in six (6) District Towns show, K10 is an acceptable level for over 50% of residents, and around K5 to K10 is acceptable for informal residents/villagers.

Considering that the average monthly cash income of formal residents ranges from K700 to K1,660 (mean: K590 to K910), K10 is thought to be an amount both possible and willing to be paid.

Table-5.9 Willingness to Pay for Water Supply Services

	Mutzing		Finschhafen		Oro Bay		Bereina		Kwikila		Kupiano	
Formal Residents												
Less than K2	6%	100%	0%	100%	N/A	N/A	0%	100%	0%	100%	0%	100%
-K4	9%	94%	2%	100%	N/A	N/A	16%	100%	3%	100%	6%	100%
-K6	26%	85%	26%	98%	N/A	N/A	34%	84%	43%	97%	31%	94%
-K8	3%	59%	5%	72%	N/A	N/A	6%	50%	3%	54%	3%	63%
-K10	44%	56%	44%	67%	N/A	N/A	28%	44%	27%	51%	47%	59%
Over K10	12%	12%	23%	23%	N/A	N/A	16%	16%	24%	24%	13%	13%
Informal Residents / Villagers												
Less than K2	0%	100%	32%	100%	34%	100%	4%	100%	0%	100%	20%	100%
-K4	7%	100%	8%	68%	14%	66%	4%	96%	7%	100%	20%	80%
-K6	14%	93%	36%	60%	24%	52%	39%	93%	33%	93%	53%	60%
-K8	7%	79%	4%	24%	6%	28%	0%	54%	0%	60%	0%	8%
-K10	36%	71%	12%	20%	16%	22%	46%	54%	40%	60%	8%	8%
Over K10	36%	36%	8%	8%	6%	6%	7%	7%	20%	20%	0%	0%

As for informal residents/villagers, average monthly cash income ranges from K180 to K800 (mean: K90 to K410), thus K10 is thought to be rather expensive for supplying water services at some lower cash income sites. The water charge for communal taps installed by the Pilot Project has fixed a monthly flat rate of K5 per household (informal residents/villagers). Through discussions with beneficiaries, payments of K5 appear both possible and willing to be paid. However, for sites like Oro Bay, Finschhafen and Kupiano, where average cash income is lower than Pilot Project sites, it is doubtful that K5 can be paid. Although actual consumption of water for each communal water tap has not yet been measured, according to beneficiaries, a minimum monthly water charge by PNGWB of K3.5 for 12,000L is thought to be adequate per household. If it is certain that the required amount per household is less than K5, water supply services by PNGWB through communal water taps is thought to be realistic and sustainable.

6) Willingness to Participate in The Affairs of Maintenance

In the first field survey, over 80% of people at most sites have expressed willingness to participate in maintenance work and bear the required costs for water supply and sewage facilities. However, after water supply facilities were renovated and enhanced through the Pilot Project, the willingness to repair water related facilities like water pipes and taps inside each house at a user's own expense show a different tendency. The percentage willing to bear the cost was 67.7% in Bereina, but 4.0% in Mutzing and 25.4% in Kwikila. It is thought that this level of willingness is not very high.

As for formal residents in district towns, most are public servants and live in official residences,

therefore it would be difficult to expect them to realistically participate in maintenance. However, it is agreed that the responsibility for maintaining the water supply facilities from main facilities to meter boxes at each house is borne by PNGWB and maintenance of interior facilities in official residences is borne by authorities concerned. Thus the above-mentioned factor is not so crucial for water supply services operated by PNGWB.

As for informal residents/villagers, over 90% expressed willingness to participate in maintenance and bear the required costs in the first field survey. In addition, those concerned reached the consensus that daily maintenance including required costs will be borne by them through the process of implementing the pilot project. Although it will be required to monitor the operation and maintenance of communal taps hereafter, it is thought that their willingness is high and the promotion of communal taps through participation is a realistic option.

Table-5.10 Willingness to Participate in Maintenance

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano
Formal Residents					
94%	91%	N/A	97%	100%	88%
Informal Residents/ Villagers					
100%	92%	98%	93%	93%	100%

Table-5.11 Willingness to Bear The Cost of Maintenance

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano
Formal Residents					
80%	82%	N/A	88%	92%	56%
Informal Residents/ Villagers					
100%	88%	98%	93%	100%	98%

5.5 Health Situation

1) Condition of Medical Services

In Bereina and Kupiano, supply of water and electricity is not stable so in-patients are not allowed, although wards are attached to all medical institutions except Finschhafen. In Kwikila, although water facilities of the town do not work, the health centre has an independent water well. In the case of Finschhafen, full-time doctors work at a hospital operated by a missionary organization in the neighbourhood, and serious sick persons or patients necessary to be hospitalised are thought to be treated there.

According to hospital/clinic records, patients with malaria are most common, while those with skin diseases, diarrhoea, or pneumonia are the next more prevalent.

Expenses for treatment are not standardized, and fees are not collected at some institutions. Even if fees are collected, circumstances differ among places. Some staff have admitted that a reason that fees are not properly collected is that there is a fear of creating trouble with some patients.

Although it cannot be said that people are satisfied with the poor conditions of the institutions, they do not seem to think it is that important to collect fees. This may be because medicine is distributed by the central government.

5.6 Situation Regarding Sanitation

1) Sanitary Customs

As to sanitary customs, results of a survey concerning boiling water for drinking and washing hands after visiting toilets are described below.

In general, the percentage of people that boil drinking water is not very high; formal residents are more careful with drinking water than informal residents. There are some sites where informal residents hardly display a custom of boiling drinking water. Considering most residents use rivers and/or wells as source of water, it should be of concern that people do not boil water for drinking.

Table-5.12 Custom of Boiling Water

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Always	0%	11%	N/A	27%	18%	13%	14%	8%
Sometimes	24%	60%	N/A	48%	47%	59%	63%	81%
Not usual	76%	29%	N/A	24%	34%	28%	24%	11%
Informal Residents/ Villagers								
Always	0%	0%	0%	14%	7%	0%	10%	0%
Sometimes	21%	24%	14%	48%	53%	50%	56%	36%
Not usual	79%	76%	86%	38%	40%	50%	34%	64%

Table-5.13 Washing Hands after Visiting Toilets

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Always	25%	24%	N/A	61%	79%	34%	31%	26%
Sometimes	67%	76%	N/A	36%	21%	66%	69%	72%
Not usual	7%	0%	N/A	3%	0%	0%	0%	1%
Informal residents/villagers								
Always	7%	28%	4%	17%	40%	3%	24%	0%
Sometimes	86%	72%	88%	59%	53%	93%	73%	93%
Not usual	7%	0%	8%	24%	7%	5%	2%	7%

Washing hands after visiting toilets is more customary than boiling drinking water. However, according to information gained from a workshop at Mutzing, people understand the importance of washing hands but they do not necessarily practice it. It is explained that there are no facilities available to wash hands near toilets and as villagers need to carry water from wells and/or rivers, washing hands is difficult to practice. Since lifestyle customs of informal residents/villagers at other sites is similar to Mutzing, it is considered that the results of the questionnaires considerably reflect hope rather than reality.

In a survey involving questionnaires, questions regarding whether villagers at the Study Areas think diarrhoea is a preventable disease were conducted. While most residents consider it preventable, informal residents at some sites do not. As to education regarding health and sanitation, the survey shows that informal residents have less experience than formal residents. This conveys that the educational opportunities for these issues are necessary, especially for informal residents/villagers.

2) Sanitation Facilities

At the surveyed sites, formal residents have flush toilets and/or private pit latrines, and households with no toilets represent 8% at most sites. Daru is an exceptionally flat coral island, where the groundwater level is high, so pit latrines cannot be constructed. Thus the main form of toilet is a bucket toilet.

As to informal residents, there are some sites where more than 90% of households do not use toilets such as Oro Bay, Bereina, Kupiano. On the other hand, there are other sites where almost all households have toilets such as Mutzing, Popondetta. Although reasons for the extreme difference among the sites is not clear, there is a datum that households without a toilet comprise 14.1% countrywide. Thus, it is a serious situation that more than 90% of households do not use toilets. In PNG, where there are continual outbreaks of water-borne diseases like typhus, it is important to spread sanitary facilities in order to minimize the chances of such outbreaks occurring.

Table-5.14 Sanitation Facilities

Private Flush Toilet	9.1%
Shared Flush Toilet	2.5%
Traditional Pit Latrine	69.1%
Improved Pit Latrine	1.8%
Bucket Toilet	0.5%
Closet Over Sea	2.8%
No Toilet	14.1%

(Source: Papua New Guinea Demographic and Health Survey 1996)

CHAPTER 6 GROUNDWATER DEVELOPMENT AND EVALUATION

6.1 Test Drilling

Test drillings were carried out to evaluate the groundwater potential, which were predicted by the geophysical surveys. The Study Areas were located in 8 areas of 4 Provinces. Most were accessible by road except Daru Island and Finschhafen.

1) Selection of Drilling Contractors

After comparing the quotations for the test drilling submitted by drilling contractors stationed in PNG, three (3) drilling companies were selected as follows.

a) The four areas of Bereina, Kwikila, Kupiano and Daru drilled by Central Drillers Ltd having office in Port Moresby, National Capital District
b) The three areas of Popondeatta, Oro Bay and Finshhafen drilled by New Britain Drillers having office in Kokopo, Eastern New Britain Island
c) The one area of Mutzing drilled by Paradise Drillers having office in Lae, Morobe Province

These companies had to have the advantage of mobility to each site. Since there was no geoelectric logging company in PNG, an Australian firm and another third world country firm were considered and in the end a Thailand company, Siam Tone was selected based on cost performance.

The field surveys for the selection of the drilling sites were affected by the unusually prolonged rainy period. The survey in Kupiano was delayed for more than a month because a bridge to the site was washed away by a flood. The drilling started for Bereina in the late June 2000 by Central Drillers, Port Moresby.

The three drilling contractors completed their drilling works. However there were large differences in their outfit, such as capacity of drilling machine, supporting machine and equipment for drilling, drilling method and technique between each company.

(1) Potential aquifers were not developed properly due to lack of skills and techniques in

drilling fluids control. Generally materials like bentonite and/or polymer were used to protect drilling bore from collapsing during mud circulation drilling. However in PNG the drillers are familiar with polymer but not with bentonite. Polymer was not effective enough to stop the collapse of loose sands and cobbles from the inside of the water well. Although bentonite was used under the supervisor's suggestion, it did not work well.

(2) Moreover, the collapse of the water well cannot be prevented by the injection of bentonite after the collapse started. Therefore, bentonite must be used from the beginning in the areas which consist of sand, gravel and cobbles. The drilling was successful in Popondetta because New Britain Drillers had the ability to manage such a situation. Meanwhile, the other two drilling Contractors are yet to reach such capabilities.

(3) Where the boreholes were successfully drilled, geophysical well loggings of potential aquifers could not be completed as expected due to caving in and boreholes, which were not vertically straight after drilling. On the other hand, the result of some of geophysical well loggings were not satisfactory enough to identify aquifer depth due to technical problems encountered with the logging probe during well logging. Such a problem may have occurred during transit of the logging equipment to the various sites.

6.2 Results of Test Drilling

In accordance to the request of the PNG Government, a Groundwater Development Study was conducted for Water Supply Systems with the intention to avoid the failure of water supply systems as experienced during the last drought (1997-98) brought about by the last El Niño. The *Groundwater development included geophysical survey, hydrogeological study and test drilling* which were carried out from April 2000 to September 2000, and the results of test drillings at the Study Areas are shown in Table-6.1 .

Table-6.1 Results of Test Drilling

Study Area	Drilled Depth (m)	Completion Depth (m)	Static Water Level (m)	Discharge m^3/d	Specific Capacity $m^3/d/m$	Groundwater Potential $m^3/d/w$ (Allowable Drawdown 10m)
Popondetta No.1	126	120	7.3	536	85.9	Successful
Popondetta No.2	106	100	6.9	544	87.6	850 $m^3/d/w$
Daru No.1	80	64	2.6	353	250	Saline Water Problem
Daru No.2	42	35	2.1	320	400	3,250 $m^3/d/w$
Bereina	36	28	5.4	290	75.1	Successful 751 $m^3/d/w$
Kupiano	62	36	1.4	53	7.7	Small Discharge 77 $m^3/d/w$
Kwikila No.1	100	74	2.3	88	15.7	Successful
Kwikila No.2	44	31	3.7	216	47.0	470 $m^3/d/w$
Finschhafen No.1	40	13	4.0	43	Small	Successful
Finschhafen No2	37	36	5.9	540	540	5,400 $m^3/d/w$
Mutzing No.1	82	62	2.0	864	Clashed	Successful
Mutzing No.2	83	60	2.0	432	864	8,640 $m^3/d/w$
Oro Bay No.1	54	50	7.0	43	Small	Unsuccessful due to loose boulders however abundant groundwater was confirmed.
Oro Bay No.2	12	Boulders	1.5	864	Abundant	
Oro Bay No.3	6	Boulders	1.5	864	Abundant	
Total	910	709				

1) Test boreholes were drilled at each Study Area to confirm the groundwater potential for water supply and in total there were eight (8) sites test drilled. The results of test drilling at seven (7) sites were successful in terms of their use as sources for water supply systems while the test drilling at Oro Bay was unsuccessful. The measured discharge could only cater for a hand pump. Two additional boreholes were tested at Oro Bay but drilling was unsuccessful due to technical problems, as the mud circulation-type drilling machine could not be drill through the loose boulders. There is, however abundant groundwater around Kopure village, as this was encountered between the depths of 10 to 20m.

2) Two boreholes were drilled on Daru Island and a high potential of groundwater was confirmed but salinity of the water is a problem. During the Phase II of the Study from January 2000 to

July 2001 the Study Team monitored BH Daru #2 (total depth of 42m, static water level 2m) and observed freshwater with a thickness of 20 m and it's suitable quality for drinking under stable conditions. The borehole therefore can be utilized as a supplementary water source for Daru at pumping rate of approximately 325 m^3/day subject to the test pumping for water quality changes within allowable drawdown of 1m to 2m.

3) The above successful test boreholes at the seven (7) sites can be utilized as a new water source for water supply systems in the future. Bereina, Kwikila and Mutzing were selected for the Pilot Project and test boreholes at these three sites were used as water sources of the new water supply systems. The discharge of test boreholes at Kupiano is not good enough for production well comparing with groundwater potential in the area. Therefore, Kupiano water supply system should be a production well drilled in the future.

4) In Popondetta, where the potential of groundwater had not been identified in the past studies, two successful test drillings revealed there were several aquifers with a high potential of groundwater at depths between 70 and 120 m. Based on these results, it was concluded that these boreholes could be used as production wells with yields at about 850 m^3/day/well. Though these were designed as test boreholes with a diameter of 6 inches that produce about 350 m^3/day/well due to the limitation in submersible pump capacity. Therefore, we recommend drilling new production wells with a diameter of more than 8 inches due to large water demands for Provincial Town of Popondetta.

Table-6.2 Evaluation of Groundwater Potential of the Study Area

(Test Drilling : ◎ Successful, × Unsuccessful)

(Groundwater Potential : ◎ Production ○ Groundwater Potential Confirmed but Need to Saline Water Problem)

Study Area	Test Drilling	Groundwater Potential	Study Results
Popondetta	◎	◎	Abundant groundwater potential (850m^3/day/well) was confirmed, and test boreholes shall be utilized as production boreholes. However, the inner diameter of test boreholes is ϕ 143mm, therefore groundwater discharge is 350 m^3/day due to pump capacity. When we need discharge of 850 m^3/day we should drill the production borehole with ϕ 200mm of inner diameter.
Daru	◎	○	Abundant groundwater potential (3,250 m^3/day/well) was confirmed, however chloride content of 700mg/l was reported by the water quality analysis. Through the follow up study in 2001 groundwater quality was measured by depths. Freshwater was found in the depths of more than 30m due to flowting water based on the concept that the Ghyben-Herzberg (H=42h). We should consider the saline water intrusion in future, however we may get water at about 325 m^3/day/well with 1m drawdown due to very high potential. We recommend to pumping test with careful water quality changes at the site.
Bereina	◎	◎	Abundant groundwater potential (751 m^3/day/well) was confirmed, and the test borehole was used for production of Pilot Project. There is no problem of water quality.
Kupiano	◎	○	The test hole was drilled out of town about 3 km away due to the saline water and contamination. Groundwater was found with small discharge of 77 m^3/day/well, and therefore we could not use it as production well.
Kwikila	◎	◎	Abundant groundwater potential (470 m^3/day/well) was confirmed, and the test borehole was used for production of Pilot Project.
Finschhafen	◎	◎	Abundant groundwater potential (5,400 m^3/day/well) was confirmed and it is possible to use it as a production well. However, water quality especially for saline intrusion should be considered due to being near the sea coast.
Mutzing	◎	◎	Abundant groundwater potential (8,640 m^3/day/well) was confirmed, and the test borehole was used for production of Pilot Project.
Oro Bay	×	◎	The first test hole was drilled at about 2 km away from the coast to avoid saline water but water discharge was small. The second and third borehole was tested near the village, however it could not be drilled deeper due to loose boulders.

6.3 Groundwater Quality Analysis

Each of the test boreholes had groundwater samples collected from the boreholes after the pumping test. National Agricultural Research Institute (NARI) in Port Moresby and National Analysis Laboratory (NAL) in Lae did the water quality test under the responsibility of well drilling contractors. Table-6.3 shows the results of groundwater quality at the eight test drilling sites namely as Popondetta, Daru, Bereina, Kupiano, Kwikila, Finschhafen, Mutzing and Oro Bay. The Guidelines for drinking water quality, second edition, WHO 1993 and Public Health (Drinking Water) Regulation, 1984 as the PNG drinking water standard were considered and will be released in July 2001.

1) With regard to the water qualities of the test boreholes from which the water qualities were analysed for drinking water purposes and for the characteristics of groundwater. As far as the 19 elements, which are described in the PNG Water Standard, are concerned, all of the parameters except for iron, chloride and TDS are satisfied for all of the Study Areas.

   The concentrations of iron do not meet the standard value (0.3 mg/l) in two sites: Popondetta #2, (0.54 mg/l) and Oro Bay, (0.71 mg/l). For the other components, the values of chloride and total dissolved solids (TDS) did not meet the standard value of 250 mg/l and 1000 mg/l, respectively at Daru #1, (700 mg/l and 1940 mg/l) and Daru #2, (700 mg/l and 2402 mg/l). In Popondetta, the tested water had a high concentration of Aluminium, which could have originated from the drilling mud.

2) To evaluate the characteristics of groundwater in the Study Areas the results are also shown in tri-linear diagrams in Fig.-6.1.

3) Analyses of The Physical Parameter of Groundwater.
   The 6 physical parameters of water temperature, pH, Electric Conductivity (EC), turbidity and colour and odours & tastes were analysed as general characteristics of groundwater at the drilling sites by the drilling supervisor of the Study Team and PNGWB (Table-6.4)

Table-6.3 Water Qualities of Drilled Boreholes in the Eight Sites

Site	No.	Water source	Date of Year 2000	Weather	Air Temp °C	Physical Parameters						Elements								
						W. temp*1 °C	pH	EC mS/m	Turb*2	Colour	Odour & taste	Cd mg/l	Hg mg/l	Se mg/l	Pb mg/l	As mg/l	Cr mg/l	F mg/l	Ba mg/l	Zn mg/l
Detection limit												0.001	0.001	0.001	0.001	0.001	0.001	0.1	0.001	0.01
1.Popondetta	#1	Borehole	30-Aug	Fine	32.0	27.8	7.6	25.7	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.1	0.018	<0.01
	#2	Borehole	25-Aug	Fine	31.6	28.7	7.1	27.1	0	0	Acceptable	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.1	0.022	<0.01
2.Daru	#1	Borehole	29-Sep	Fine	32.5	28.8	8.1	330.0	0	0	Salty	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.3	0.048	0.01
	#2	Borehole	5-Oct	Cloudy	35.5	29.5	8.3	340.0	0	0	Salty	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.0	0.044	0.01
3.Bereina	#1	Borehole	27-Jul	Fine	33.3	29.0	8.5	58.2	0	0	Acceptable	<0.001	0.001	<0.001	<0.001	0.004	<0.001	0.6	0.010	<0.01
4.Kupiano	#1	Borehole	27-Jul	Cloudy	32.4	29.4	7.7	110.0	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.9	0.024	0.01
5.Kwikila	#1	Borehole	6-Nov	Fine	31.5	28.8	7.4	101.5	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.2	0.020	0.01
6.Finschhafen	#2	Borehole	10-Oct	Rain	32.2	28.5	7.9	31.2	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.6	0.004	0.01
7.Mutzing	#1	Borehole	8-Oct	Fine	33.5	28.2	7.4	25.5	0	1	Acceptable	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.1	0.003	<0.01
8.Oro Bay	#1	Borehole	3-Sep	Fine	31.8	28.7	6.9	24.6	1	0	Acceptable	<0.001	<0.001	<0.001	0.001	<0.001	0.002	0.1	0.016	<0.01
Guidelines/Standards for Drinking Water Quality																				
WHO (1993)						-	-	-	5NTU	15TCU	Acceptable	0.003	0.001	0.01	0.01	0.01	0.05	1.5	0.7	3
PNG (1984)						-	6.5-9.2	-	25 units*5	50 units*6	Unobjectionable	0.01	0.001	0.01	0.1	0.05	-	1.5	-	15
Japan (1993)						-	5.8-8.6	-	2	5	Acceptable	0.01	0.0005	0.01	0.05	0.01	0.05	0.8	-	1

NB

*1: *Water temperature*, *2: *Turbidity*, *3: *Total coliform*, *4: *Standard plate count*, *5: Jacksons turbidity units, *6: on the Platium-cobalt scale, *7: COD 10mg/L

*8: WHO

All water intended for drinking: E. coli or thermotolerant coliform bacteria must not be detectable in any 100ml

*9: PNG

(i) There shall be no E. coli in any sample of 100 ml.(ii) If E. coli is absent, no sample shall contain more than 3 coliform organisms per 100 ml.

*10: JPN

SPC: shall be less than 100 in any 1ml sample.

Total Coliform: must not be detectable in any sample.

continued

Site	No.	Elements										Compounds & Others						Bacteria	
		Fe mg/l	Cu mg/l	Na mg/l	Mn mg/l	Cl mg/l	Ni mg/l	Sb mg/l	B mg/l	Mo mg/l	Al mg/l	CN mg/l	NO_2 mg/l	NO_3 mg/l	SO_4 mg/l	TOC mg/l	TDS mg/l	Total Coli[*3]	SPC[*4]
		0.01	0.001	1	0.001	1	0.001	0.001	0.1	0.01	0.01	0.01	0.01	1	1	0.1	1	1	1
1.Popondetta	#1	<0.01	0.005	16	0.010	6	<0.001	<0.001	0.1	<0.01	0.57	<0.01	<0.01	<1	11	1.7	200	0	0
	#2	0.54	0.006	5	0.002	4	<0.001	<0.001	0.1	<0.01	1.60	<0.01	<0.01	<1	10	2.8	230	0	0
2.Daru	#1	<0.01	<0.001	408	0.002	700	<0.001	<0.001	<0.1	<0.01	0.06	<0.01	<0.01	1	11	5	1940	0	0
	#2	<0.01	<0.001	399	0.011	700	<0.001	<0.001	<0.1	<0.01	0.03	<0.01	<0.01	1	10	5	2402	0	0
3.Bereina	#1	0.20	<0.001	66	0.045	20	<0.001	<0.001	0.1	<0.01	0.01	<0.01	0.37	1	7	1.9	437	0	0
4.Kupiano	#1	0.01	0.001	88	0.004	30	<0.001	<0.001	0.1	<0.01	0.04	<0.01	0.03	<1	4	3	745	0	0
5.Kwikila	#1	<0.01	<0.001	66	0.184	11	<0.001	<0.001	<0.1	<0.01	<0.01	0.01	0.01	<1	10	1.4	440	0	0
6.Finschhafen	#2	0.08	0.005	6	0.001	2	<0.001	<0.001	<0.1	<0.01	0.65	<0.01	<0.01	<1	10	3.2	260	0	0
7.Mutzing	#1	<0.01	0.007	16	0.030	4	<0.001	<0.001	<0.1	<0.01	0.57	<0.01	0.04	2	16	3.9	190	0	0
8.Oro Bay	#1	0.71	0.008	6	0.020	2	<0.001	<0.001	<0.1	<0.01	0.69	<0.01	0.02	<1	3	4.8	110	0	0
Guidelines/Standards for Drinking Water Quality																			
WHO (1993)		0.3	2	200	0.5	250	0.02	0.005	0.5	0.07	0.2	0.07	3	50	250	-	1000	*8	
PNG (1984)		1	1.5	-	0.5	1000	-	-	-	-	-	0.05	-	45	-	-	-	*9	
Japan (1993)		0.3	1	200	0.05	200	0.01	0.002	0.2	0.07	0.2	0.01	10		-	*7	500	*10	

References
1: WHO (1993), "Guidelines for drinking water quality, second edition, volume 1"
2: http://www.who.int/ (April 2001)
3: "Public Health (Drinking Water) Regulation 1984, No. 8 of 1984"
4: Nihon Kankyo Kanri Gakkai (1996), "Guidebook for new water standards"

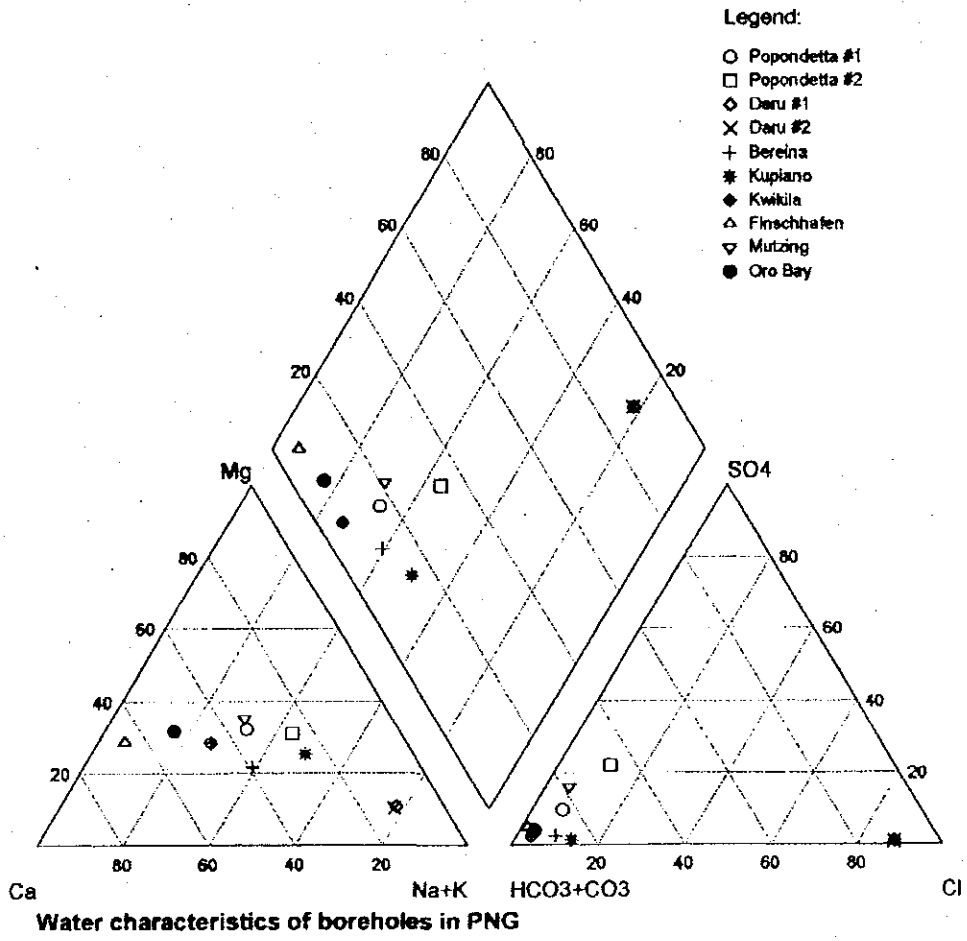


Fig.-6.1 Groundwater Characteristics of Test Boreholes in Study Area

Table-6.4 Water Qualities of Drilled Boreholes in the Eight Sites (parameters relating to geological characteristics)

Site	No.	Water Source	Date of Year	Physical Parameters						Parameters representing Geological Characteristics								Hardness & Others					Non-metals	
				W. temp*1	pH	EC	Turb*2	Colour	Odour & taste	Na	K	Ca	Cl	Mg	HCO_3	CO_3	SO_4	Acid	T-Alka.	T-Hard	TDS	L I*3	NH_4	T-P
			2000	°C		mS/m				mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1.Popondetta	#1	Borehole	30-Aug	27.8	7.6	25.7	0	0	acceptable	16	5.3	18	6	10	120	<1	11	5.6	120	87	200	-0.3	<0.01	0.21
	#2	Borehole	25-Aug	28.7	7.1	27.1	0	0	acceptable	5	5.2	4	4	3	38	<1	10	7.6	38	20	230	-2.0	0.01	0.63
2.Daru	#1	Borehole	29-Sep	28.8	8.1	330.0	0	0	salty	408	12.9	53	700	30	141	1.7	11	<5.0	143	257	1940	0.6	0.47	<0.05
	#2	Borehole	5-Oct	29.5	8.3	340.0	0	0	salty	399	10.2	55	700	28	142	2.6	10	<5.0	145	252	2402	0.8	0.52	<0.05
3.Bereina	#1	Borehole	27-Jul	29.0	8.5	58.2	0	0	acceptable	66	4.8	60	20	20	331	1.4	7	48.0	333	231	437	1.4	0.09	0.31
4.Kupiano	#1	Borehole	27-Jul	29.4	7.7	110.0	0	0	acceptable	88	1.4	39	30	24	329	2.1	4	<5.0	331	197	1	0.5	<0.01	<0.05
5.Kwikila	#1	Borehole	6-Nov	28.8	7.4	101.5	0	0	acceptable	66	0.4	100	11	38	510	1.3	10	48.0	511	406	440	0.7	0.08	0.17
6.Finschhafen	#2	Borehole	10-Oct	28.5	7.9	31.2	0	0	acceptable	6	1.6	64	2	17	240	<1	10	17.0	240	228	260	0.8	0.01	<0.05
	#1	Dry																						
7.Mutzing	#1	Borehole	8-Oct	28.2	7.4	25.5	0	1	acceptable	16	0.6	16	4	10	100	<1	16	7.2	100	81	190	-0.7	0.01	0.08
8.Oro Bay	#1	Borehole	3-Sep	28.7	6.9	24.6	1	0	acceptable	6	1.3	19	2	7	90	<1	3	5.6	90	76	110	-1.1	<0.01	0.12

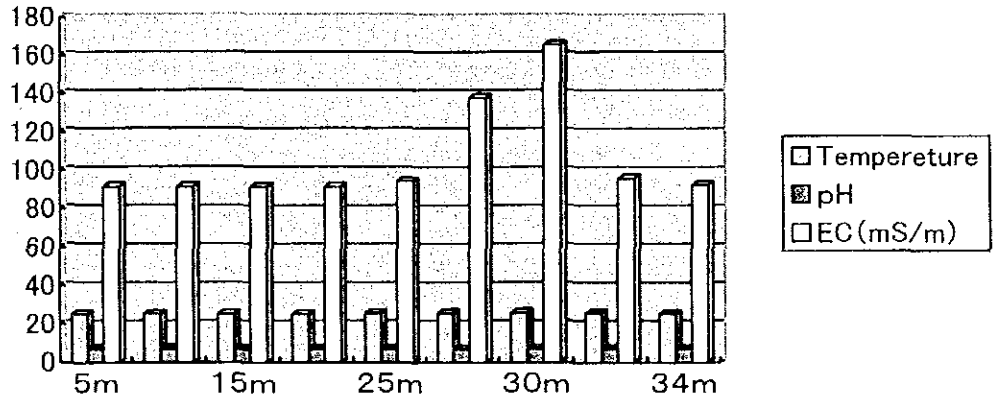
NB
1: Water temperature
2: Turbidity
3: Langelier index

At the same time, the weather and the air temperature were also recorded on the sampling day. All of the 7 sites recorded showed that the groundwater is of suitable quality for water supply except Daru, due to saline conditions affected by seawater. Daru showed a high level of electric conductivity (>330 mS/m, pH 8.1 to 8.3) in 2000. However, the Study Team monitored the Daru borehole (BH DR #02) from January to June 2001, and found the electric conductivity to range from 91.7 to 165.7 mS/m and pH value of 7.2, indicating suitability for drinking water supply.

The completed borehole depth was 35 m, and therefore the upper parts of groundwater are suitable for supplementary water source to Daru Island. The results of water quality monitoring are shown in Table-6.5, as follows.

Table-6.5 Test Borehole Daru No.2 Water Quality Monitoring (18th June 2001)
Borehole Depth: 42.8m, Statistic Water Level: 1.8m

1.Depth (m)	5m	10m	15m	20m	25m	27m	30m	32m	34m
2.Water Temperature (C)	25.3	25.5	25.4	25.3	25.7	25.9	25.9	25.7	25.5
3. pH	7.24	7.23	7.25	7.24	7.23	7.17	7.20	7.25	7.25
4.EC (S/m)	91.7	91.7	91.6	91.7	94.4	138.1	165.7	95.9	92.6



6.4 Water Source of Water Supply System

The test boreholes namely Bereina, Kwikila and Mutzing were evaluated hydrogeologically for water source of water supply system as summarised in Table-6.6.

Table-6.6 Hydrogeological Evaluation of Water Source at 3 Sites

1. Site Name	1. Bereina	2. Kwikila	3. Mutzing
2. Total Depth	36 m	44 m	83m
3. Well Depth	28 m	31 m	60m
4. Static Water Level	5.4 m	3.7 m	2.0 m
5. Pumping Water Level	9.2 m	8.3 m	2.5 m
6. Drawdown	3.8 m	4.6 m	0.5 m
7. Discharge	290 m^3/d	216 m^3/d	432 m^3/d
8. Specific Capacity	76.3$m^3/d/m$	47.0 $m^3/d/m$	864 $m^3/d/m$
9. Groundwater Potential (Allowable Drawdown of 10m)	763 m^3/d	470 m^3/d	8,640 m^3/d

6.5 Improvement of Water Supply Conditions in Daru and Binaturi

1) Daru Water Supply Improvement

There will be installation of Water Vending Units (WVU) in Daru where the PNGWB already has an office. This WVU concept aims at improving water supply conditions for low-income groups in the Town where water venders sell the drinking water by bucket to people who do not have house connections or have a disconnected water supply. Among the low-income group residents there is a certain number of households who have been disconnected from water supply because of no payment of water bills owed to the PNGWB. This is the first trial experiment in Provincial Town water supply by PNGWB to relieve the above-mentioned people who are faced with drinking water problems by installing the Water Vending Units. The details of these components and locations in Daru are shown in Table-6.7 and Fig.-6.2.

Table-6.7 Water Vending Unit in Daru

Daru Water Supply Improvement	Water Vender unit (Public Faucet): 2 units

2) Binaturi River Basin Water Supply and Environmental Survey

a. Binaturi River Basin Water Supply

The Binaturi River Basin Water Supply is aimed at improving their water supply conditions with villagers' participation. The villagers are encouraged to construct their own

water supply facilities namely, rain water collection tanks, hand dug wells with hand pumps and hand augered boreholes with hand pumps in their respective village working together with community organizers arranged by the Study Team for community development. The Study Team supplies the necessary equipment and materials for the construction. Supervisors participate also under the management of the Study Team. On the other hand, villagers provide their own labour and locally available basic materials such as sand and wood. The development plan and work schedule are prepared through discussions with the villagers, and preparation of their own implementation schedule is done through facilitation by community organizers and supervisors. The plan for operation, management and maintenance of water supply facilities and plan for public awareness building and community participation are included in this component of the Study.

b. Environmental Survey in Binaturi River

The environmental survey in Binaturi River is to survey and analyse the impact of saline water intrusion on environment conditions of river basin of Binaturi where the intake of pump station for water supply to Daru Town is located. The Environmental Survey in Binaturi River consists of the following two main items and the scope of works are shown as follows;

(1) Hydrological Survey

(2) Environmental Study including Water Quality Analysis

This work was done by the Unisearch, which is a local consultant with academic backgrounds. Unisearch composes of the researchers from the University of Papua New Guinea. The field survey was conducted in December 2000 and the results of the study were presented in a seminar held in June 2001 at Boze village, Binaturi river basin. The followings are the summary of their study results.

(1) From chemical and Electric Conductivity (EC) data, it was established clearly that the salt front was positioned below Kunini village, 10 km upstream of Binaturi river mouth as shown in Fig.-6.2. Dissolved salt levels, as indicated by the EC values, were quite high 4,140 mS/m near the mouth of the river and dropped to the level of almost pure freshwater at 60.2 mS/m in Kunini village.

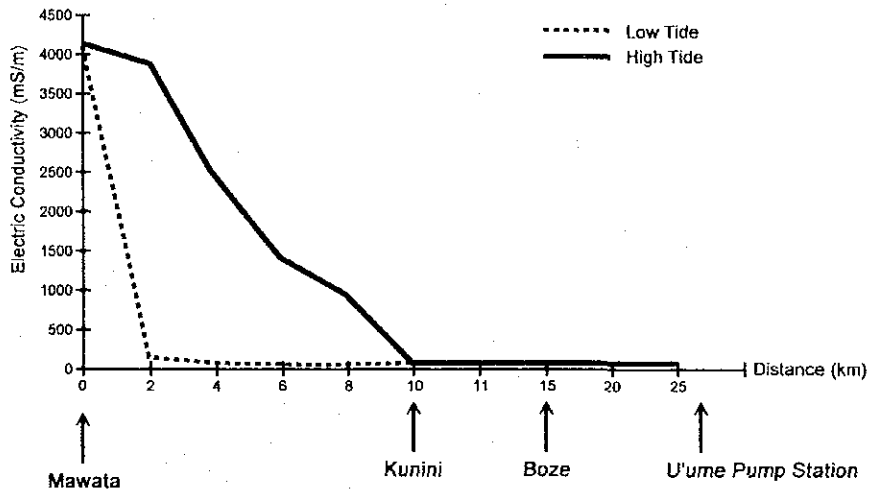
(2) The river water at Kunini had a tinge of saltiness (EC= more than 100 mS/m) during high tide and so water collection for drinking purposes was postponed until low tide. Fig.-6.4 shows the difference of EC between high tide and low tide. The EC values at

Boze village remained close to 30 mS/m for both high and low tides.

(3) The correlation between the difference of vegetation types and salinity of the water would give an indication of the nature of saline water intrusion into fresh water condition along the river system. Kunini is the present boundary of salinity influence to the fresh water condition, and the mangrove distribution which is observed there might be the evidence.

(4) Water extraction of 800 to 1,600 m^3/day pumped from Binaturi River does not contribute to salinity migrations. The percentage extraction at the pump station of U'ume in peak period is estimated at 0.2 to 2.0 % of the river discharge.

(A)



(B)

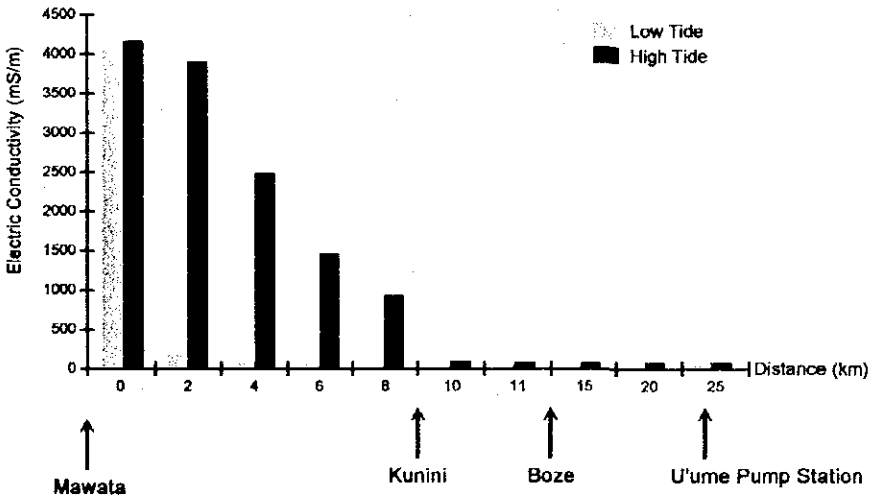


Fig.-6.2 Binaturi River Water Quality Change Influenced by the Tide (December 2001)

CHAPTER 7 WATER SUPPLY MASTER PLAN

7.1 Conditions of Existing Water Supply Facilities

The Study Team surveyed the present condition and the situation of operation and maintenance of existing water supply facilities in the Study Area in 2000. The following matters were checked through the interview with operators for water supply facilities at sites. Method of managing, operation and maintenance of water supply facilities which contains pump and diesel engine generator, etc. and cases of accident in the past and current problems were surveyed. The Study Team executed the survey of the piping route and service area as much as possible in the Study period. The Table-7.1 below indicates the status of the existing water supply system of each Study Area.

Table-7.1 Situations of Existing Water Supply System in 2000

Area	Conditions of Existing Water Supply System	
Popondetta	Operation	24 hours water supplies. Problem on relocation of existing water intake facility and the water treatment plant.
Daru	Operation	18 hours water supplies. Problem of an environmental influence, alternative water source and an existing water source.
Bereina	Non Operation	System non operation since Feb. 2000 due to the breakdown of the existing well pump, generator and etc.
Kupiano	Non Operation	Currently water supply system is non-operation due to breakdown as water intake facilities and conveying pumps.
Kwikila	Non Operation	The water supply stopped since 1994 due to water intake facility's breakdown etc.
Finschhafen	Operation	Water is being supplied without any treatment and chlorination.
Mutzing	Operation	Interrupted supply due to fuel shortage, problem of generator, capacity of existing supply tank. Water supply 3 to 4 times in a day and 1 to 2 hours in one time.
Oro Bay	No Water Facilities	Water supply system is not constructed, yet. Rainwater collecting tank or shallow dug well is used for drinking water supply.

Both of the water supply systems in Popondetta and Daru have respective issues. Though the system has become old and strengthening and expansions of the services are necessary, the existing systems are working and continuously providing water supply services. On the other hand, the water supply systems at 4 District Towns namely Bereina, Kwikila, Kupiano and Mutzing stopped operation due to the trouble and/or damage of water source and/or intake facility in May 2000.

7.2 Present Population and Target Year

1) Present Populations of Study Area

Population of Popondetta is 14,556 persons, and population of Daru is 10,286 persons in year 2000. Table-7.2 shows the current population of study area in 2000.

Table-7.2 Existing Populations in Study Area (2000)

Popondetta			Daru		
Ward	Family	Population	Area	Family	Population
Ward 1(north)	460	3,346	Laru	831	3,832
Ward 2(north-central)	295	3,670	Darawaro	322	1,839
Ward 3(central)	915	3,700	Tamate	377	1,807
Ward 4(south-central)	318	1,740	Karakara	554	2,808
Ward 5(south)	212	2,100			
Total	2,200	14,556	Total	2,084	10,286

Study Area	Residents	Schools.	Health Centre	Villages	Total
Bereina	760	—	70	(*1) 513	1,343
Kupiano	839	982	196	(*2) 5,792	7,809
Kwikila	1,180	1,396	170	(*3) 180	2,926
Finschhafen	900	(*4) 1,249	(*5) 920	(*6) 1,159	4,228
Mutzing	500	830	120	(*7) 650	2,100
Oro Bay	(*8) 231	(*9) 763	126	(*10) 3,105	4,225

(*1) includes Toreno No.1, No.2, Ponepone, Paikua, Kuroapaina, hihive No.1.No.2 and Baukeke
(*2) includes Gavuone and Wanigela
(*3) includes Vade compound, Mr. Braun Compound and Makan Compound
(*4) includes Cegerhaphen High School and Vocational Centre
(*5) Buraun Memorial Hospital
(*6) includes Godowa , Tamuc , Timbulim , Buta Compound, Gingala Village and Bugain Village
(*7) includes Sumpubagin Village, Mutzing Village and Intoap Village
(*8) includes Sub-District Administration and Ijividari District Administration
(*9) includes Eroro Primary/Elementary School and Embogo High School
(*10) includes Eroro, Busega, Kopure, Dombada, Embogo and Bema Village etc

2) Target Year

The target year of the water supply master plan is year 2015 based on the official discussions with PNGWB. This period was divided into three stages in this Study, i.e., up to the year 2005,

up to 2010, and up to 2015. Daily water consumptions were proposed for each Stage, and based on these consumptions the total supply rates were calculated. Table-7.3 shows the Stages targeted in this master plan.

Table-7.3 Target Year of Master Plan to 2015

Target Year	2005	2010	2015
Stage	Stage-I	Stage-II	Stage-III

7.3 Design Criteria

In this master plan, the following criteria were set based on the discussions with PNGWB staffs and engineers regarding the water supply systems in District Towns and Provincial Towns.

1) Population Growth Rate

The census on a national level was carried out in September 2000. However, the result has not been published yet. Therefore, the population growth rates were analysed based on the census carried out in 1980 and 1990. The average population growth rate was 2.3% in Papua New Guinea, and the growth rates in each Province and District are shown in Table-7.4 below.

Table-7.4 Population Growth Rates in Target Provinces and Districts from 1980 to 1990

Province	PGR	District	PGR
Western	2.83 %	Daru	2.21 %
Central	1.93 %	Bereina	1.99 %
		Kupiano	1.99 %
		Kwikila	1.99 %
Morobe	2.15 %	Finschhafen	1.40 %
		Mutzing	2.15 %
Northern	2.24 %	Popondetta	2.46 %
		Oro Bay	2.46 %

Source: Census in 1990

2) Target Population

Target population was calculated after consideration of water supply areas in each stage and the target year of 2005, 2010, and 2015 as shown in Table-7.5.

Table-7.5 Target Populations for Water Supply by Stages

Site	No. of household in 2000	Population in 2000	Target population for water supply		
			2005	2010	2015
Popondetta	2,080	14,556	16,434	18,559	20,961
Daru	1,470	10,286	11,469	12,796	14,277
Bereina	194	1,343	1,483	1,636	1,805
Kupiano	837	7,809	8,621	9,511	10,495
Kwikila	211	2,926	3,197	3,488	3,821
Finschhafen	297	4,228	4,532	4,858	5,209
Mutzing	163	2,100	2,335	2,598	2,888
Oro Bay	467	4,225	4,770	5,387	6,084
Total	5,719	47,473	52,841	58,833	65,540

3) Daily Water Consumption

Based on the results of the social survey and study on the existing facilities a series of discussions was held with PNGWB during the Study in 2000 to conclude the most appropriate quantities of water supplies in the 6 District Towns. The designing was done in accordance with the 3 Stages of the development, Year of 2005, 2010 and 2015 considering present insufficient water supply situation in the Study Area, and focusing on smooth transition of the operation and management system to a more efficient one.

Table-7.6 *Level of Water Consumption*

Levels	Targets	Remarks
Level-A	· Hospital Patient (bed)	The quantity of water supply is twice as much as Level B.
Level-B	· Formal Residents (Town) · Hospital Staffs & Families · High School Staffs & Families	The quantity of water supply is to be 75 lit/c/day until the target year 2015.
Level-C	· School (Boarders)	The quantity was designed between Level B and Level D.
Level-D	· Village · Settlement	The quantity was designed from 45 lit/c/day, necessary as drinking water, to 65 lit/c/day, the quantity including bathing, until the year 2015.
Level-E	· Office · Hospital Out-Patient · School (Day Students)	The quantity is half as much as Level B as it is used only during daytime.

The proposed quantities of water mentioned above are to be achieved in three stages of years 2005, 2010 and 2015.

Table-7.7 Daily Water Consumption (lit/c/day) – Recommended in This Study

Target Year	2005	2010	2015
Level－A	130	140	150
Level－B	65	70	75
Level－C	55	65	70
Level－D	45	55	65
Level－E	33	35	38

The allocations of the quantities of water mentioned above are aimed at sustainable operation systems for the PNGWB and the consumers in the Study Area.

The water supplies for commercial and industrial uses are also described in the PNGWB Design Manual. Nevertheless, they are not suitable to the water supplies in the rural areas including District Towns. Although there are some grocery shops in the 6 District Towns, it is assumed that these scales are rather small to pay special attentions. In addition, large-scale commercial and industrial water users are unlikely to occur in these areas in the near future. Therefore, in these District Towns, commercial and industrial users were not considered.

7.4 Water Demand

In this master plan, the factor for ADF was set as 1.2, while that of PHF was set as1.5. The volume of a water storage tank was designed as a third of the PDF. The criteria for the water supply in District Towns were defined as follows, Table-7.8.

Table-7.8 Selected Criteria for Water Supply in District Town

Daily Flow	[DF]	= [TP] × [DWC]
Average Daily Flow	[ADF]	= [DF] × 1.2
Peak Daily Flow	[PDF]	= [ADF] × 1.2
Average Hourly Flow	[AHF]	= [ADF] ／ 24
Peak Hourly Flow	[PHF]	= ([PDF]／24) × 1.5
Tank Capacity	[TC]	= [PDF] × 1／3

Note : [TP] = Target Population, [DWC] = Daily Water Consumption

Table-7.9 Projected Water Demand for 6 District Towns (lit/day)

Study Area	Demand	2005	2010	2015
Bereina	DF	82,538	103,981	127,167
	ADF	99,046	124,777	152,600
	PDF	**118,855**	**149,732**	**183,120**
Kupiano	DF	109,624	310,127	674,407
	ADF	131,549	372,153	809,289,
	PDF	**157,858**	**446,583**	**971,146**
Kwikila	DF	177,147	205,883	247,184
	ADF	212,576	247,059	296,620
	PDF	**255,091**	**296,471**	**355,944**
Finschhafen	DF	264,417	319,824	376,638
	ADF	317,301	383,789	451,966
	PDF	**380,761**	**460,547**	**542,359**
Mutzing	DF	131,696	165,993	202,265
	ADF	158,036	199,192	242,718
	PDF	**189,643**	**239,030**	**291,262**
Oro Bay	DF	69,071	151,999	395,451
	ADF	82,885	243,614	474,542
	PDF	**99,462**	**292,337**	**569,450**

The tendency of the water consumption in Popondetta and Daru in 2000, which was calculated from sales record of the PNGWB, is shown in Table-7.10, below. The yearly water consumption in Popondetta is 446,800m^3 and Daru is 227,800m^3 in 2000. The industrial water consumption shares 10% of the total water consumption in Popondetta and 8% in Daru. The consumption of the institutional users is 30% of the total water consumption in Popondetta and 10% in Daru.

Table-7.10 Water Consumption of Popondetta and Daru (2000)

Water User	Popondetta		Daru	
	m^3/year	%	m^3/year	%
1) Domestic	280,400	60%	186,200	82%
2) Industrial	44,200	10%	18,400	8%
3) Institutional	140,200	30%	23,200	10%
Total	464,800	100%	227,800	100%

(Sales Statistics of PNGWB)

The amount of the water demand in Popondetta and Daru calculated based on the above-mentioned data is shown in Table-7.11 below according to the master plan target years in consideration of the effective rate of 1.2% of the population increase and the water demand.

Table-7.11 Projected Water Demands in Popondetta and Daru, 2005-2015 (lit/day)

Study Area	Demand	2005	2010	2015
Popondetta	DF	2,014,420	3,087,393	4,404,553
	ADF	2,417,304	3,704,871	5,285,463
	PDF	**2,900,765**	**4,445,845**	**6,342,556**
Daru	DF	1,156,702	1,751,429	2,468,421
	ADF	1,388,042	2,101,715	2,962,106
	PDF	**1,665,651**	**2,522,058**	**3,554,527**

7.5 Groundwater Development Plan

7.5.1 Existing Water Supply Sources and Groundwater Development

Out of eight Study Area seven have existing water supply systems except Oro Bay that does not have any water supply facility. River water is the main water source of the water supply systems at five areas and groundwater at the other two areas. In Popondetta and Daru, the two Provincial Towns that are managed by PNGWB, river water is pumped at the intake point. Water is supplied to the town after treatment and chlorination. According to the operation record in the year of 2000, Popondetta treatment plant produced and supplied about 1,750 m^3/day of water and the volume of pumped water from river was about 1,800m^3/day. On the other hand, Daru treatment plant pumped river water about 1,250m^3/day at the intake point and about 1,000m^3/day was supplied to the town after treatment. Therefore, the production rate between supply and intake are 98%and 80%, respectively as shown in Table-7.12.

Table-7.12 Present Condition of Existing System in 2000 and Expected Groundwater Development in the Study Areas (2 Provincial Towns and 6 District towns)

Study Area	Status of Existing System	Existing Water Source	Water Intake in 2000 (m^3/day)	Water Supply in 2000 (m^3/day)	Water Supply Efficiency
1. Popondetta	Operation	River water	1,800	1,760	98%
2. Daru	Operation	River water	1,250	1,000	80%
3. Bereina	Stopping	Groundwater	Abandon	Abandon	-
4. Kupiano	Stopping	River water	Abandon	Abandon	-
5. Kwikila	Stopping	River water	Abandon	Abandon	-
6.Finschhafen	Operation	River water	380	380 (no treatment)	100%
7. Mutzing	Hourly operated	Groundwater	50	50	100%
8. Oro Bay	No system	Rain water	-	-	-

7.5.2 Groundwater Development Plan

Based on the groundwater potential per borehole in the Study Area, the master plan for groundwater development was prepared considering the water demand for the target year of 2015 as follows. At the same time, Table-7.13 and Fig.-7.1 (1), (2) and (3) illustrate the water demand and groundwater development plan from 2000 to 2015.

1) Considering the eight Study Areas of water demand for target year of 2015, the necessary number of production boreholes were programmed in Table-7.13 as follows. At the same time, test boreholes drilled by JICA during this Study in 2000 were evaluated for groundwater potential to be utilized in the groundwater development plan.

Table-7.13 Groundwater Development Plan, 2000 to 2015

Study Area	Groundwater Potential	Pilot Project 2001	JICA	2005	2010	2015
1.Popondetta	850	-	-	2	2	2
2.Daru	3,250	-	325 x2	JICA	3	3
3.Bereina *	751	432	-	0	0	0
4.Kupiano	350	-	-	1	1	1
5.Kwikila *	470	288	-	1	0	0
6.Finschhafen	5,400	-	300	JICA	1	0
7.Mutzing *	8,640	360	-	0	0	0
8.Oro Bay	150-700	-	-	1	1	0

*) Pilot Project

(Groundwater Potential based on Test Drilling by JICA in 2000: m^3/day/well)

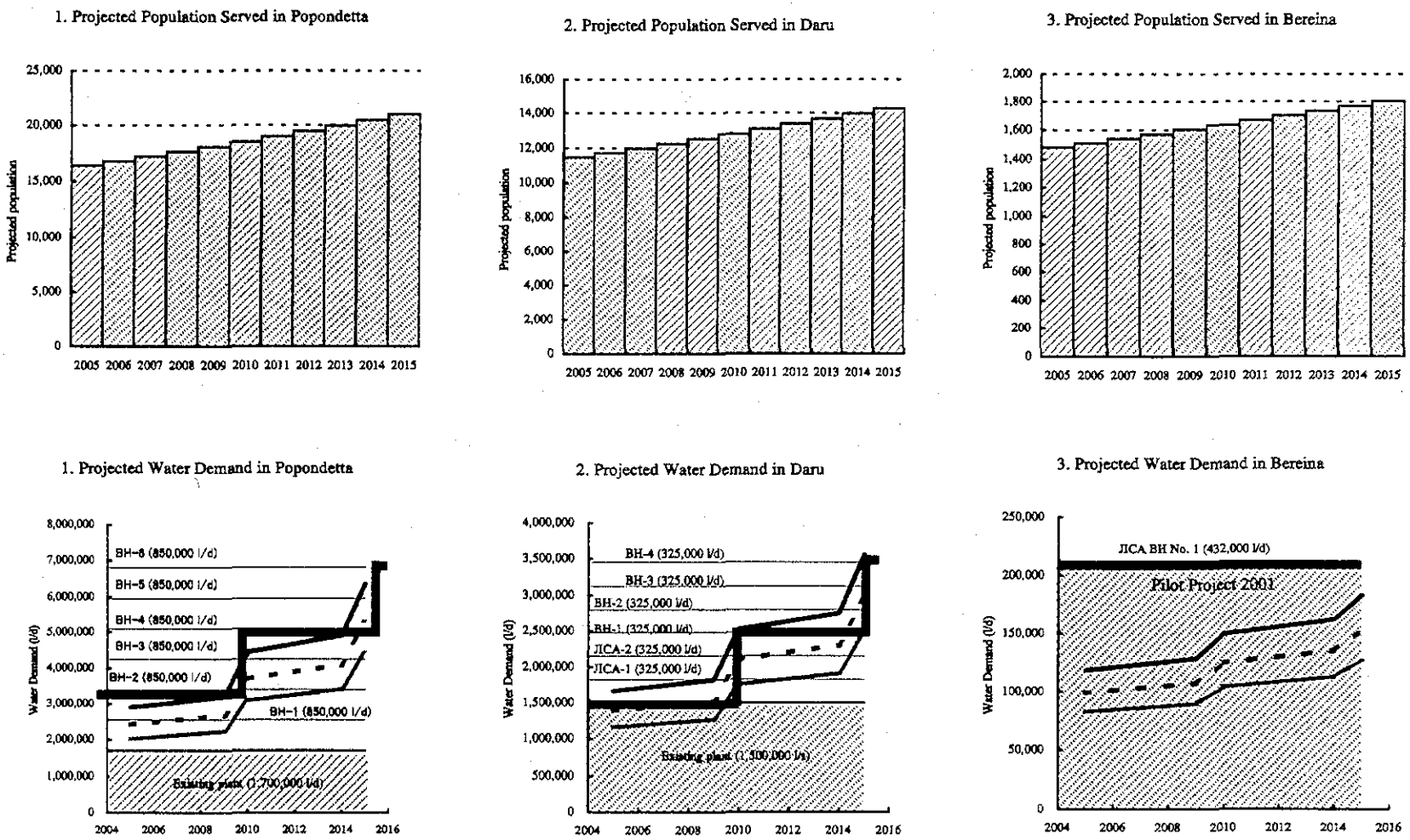


Fig.-7.1 (1) Water Demand and Groundwater Development 2000 - 2015

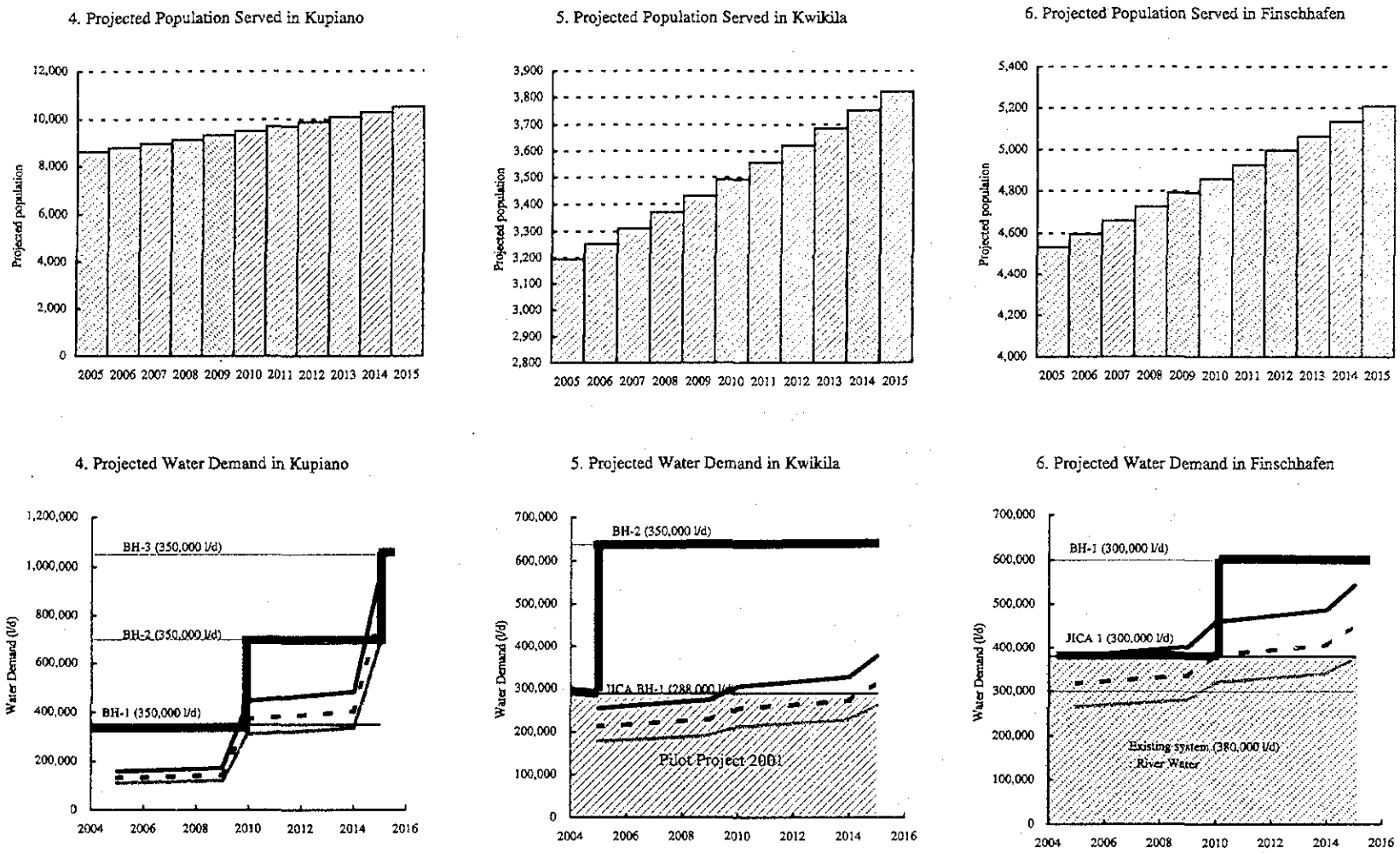


Fig.-7.1 (2) Water Demand and Groundwater Development 2000 - 2015

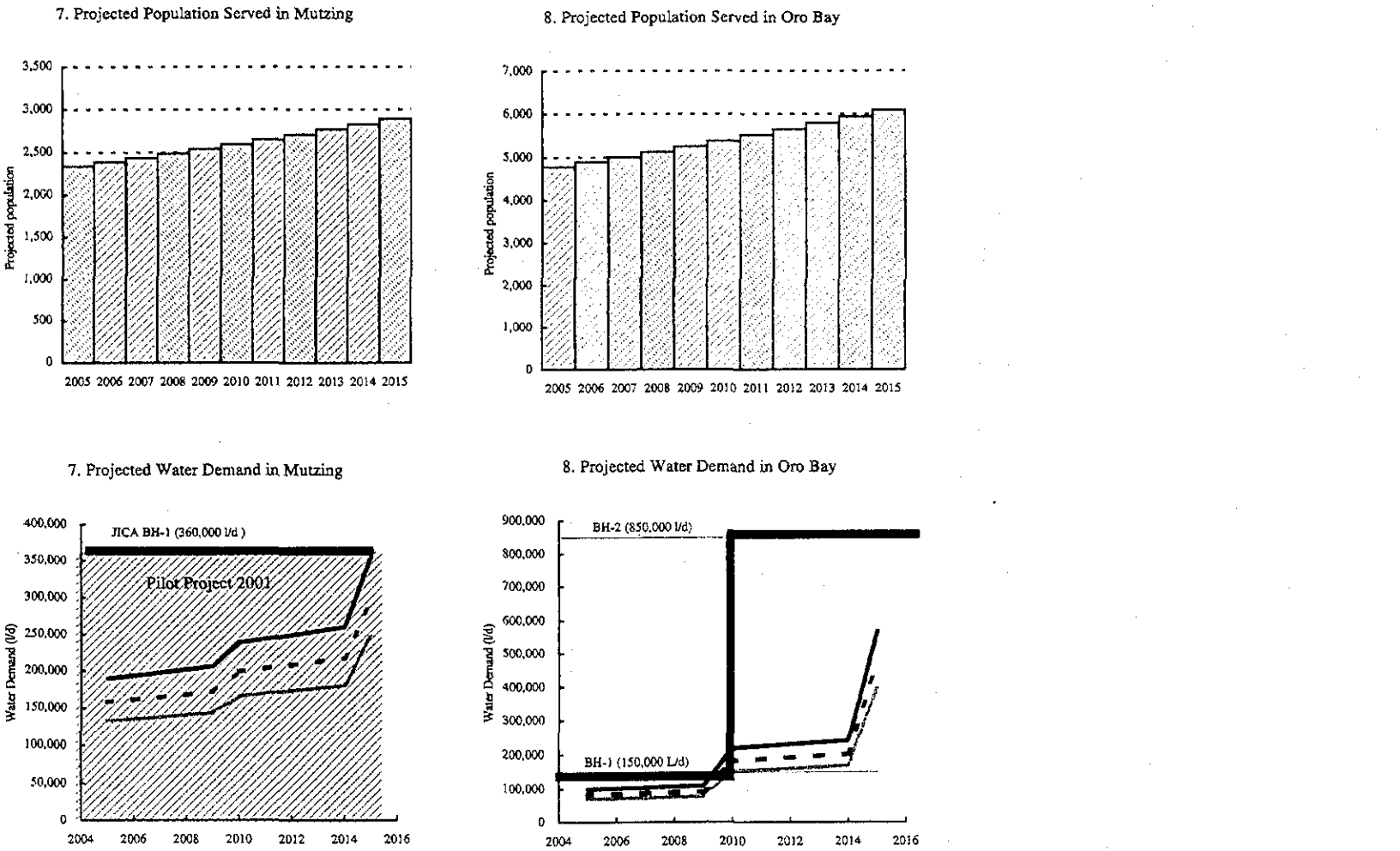


Fig.-7.1 (3) Water Demand and Groundwater Development 2000 - 2015

7.6 Building Codes & Material Standards

1) Building Codes & Standards

As standards of Papua New Guinea, there are the "Building Act", "Building Regulation" and "Papua New Guinea Standard (PNGS)" as following Tables-7.14.

Table-7.14 Building Standards in Papua New Guinea

Standard	Contents
Building Act	Application Formalities and Permission of Buildings, Administrative guidance, etc.
Building Regulation	General Provisions of Buildings
Papua New Guinea Standard (PNGS 1001～4)	Detailed Codes concerning design of Buildings

PNGS1001 to 1004 related to the building and the structure were published by the "National Standard Council (NSC)" in 1982. The NSC was established under "the National Standard Act 1978" and commenced operations in 1979.

At present, there are no original Papua New Guinea's standards concerning the electric installation. However, it is guided to design based on "S.A.A.Code" or "A.S.S.Specification" which were provided by the Standards Association of Australia.

In designing buildings and facilities in Papua New Guinea, special attentions should be paid for their protections from earthquakes. Recently, quite a number of earthquakes occurred in New Britain Island and Bougainville Island, which are situated in Volcanic Arc Regions. The country has four categories in accordance with the Seismic Zones.
The detailed codes about the anti-earthquake designs are instructed in "PNGS1001-1982 Part4".
In this master plan, the attentions should be paid to construct the buildings and the facilities, especially elevated water tanks, in accordance with the Papua New Guinea's standards.

2) Material Standard

In general, most of the materials for water supplies are imported from Australia and following the Australian Standards. For the water pipes, High Density Polyethylene Pipe (HDPE) and Polyvinyl Chloride Pipes (PVC) are manufactured in Papua New Guinea, while elbows and joints are imported. Valves and pumps are also imported mainly from Australia. Considering the above situation, the following International Standards are applied for the materials.

Table-7.15 Material Standard of The Project

[AS]	Australian Standards	Standards Association of Australia, Standard House
[BS]	British Standards	British Standards Institution, British Standards House
[ASTM]	American Society for Testing and Materials	American Society for Testing and Materials

7.7 Water Supply Plan

1) Design Concept

The water supply facilities were designed considering the factors below.

1) To establish water supply systems that the responsible agency, the PNGWB, can operate, maintain and manage independently.
2) To intend the maximum use of the existing facilities and minimize the time and the costs for the construction.
3) To design the water supply systems, which suit the areas where water supply systems, such as rain water collection systems, already exist.

The master plan consists of Stage-I, II and III in terms of the years for the implementation. In Stage-I, the core facilities such as intake facilities, pump stations and water tanks are installed. While the extensions of the distribution pipelines, the installation of the public faucets, and the renovation of the existing facilities are planned in Stage-II and III.

Table-7.16 Water Supply Master Plan by Stages

Stage and Year		Water Supply Master Plan by Stages
Stage-I	2005	- Construction of intake facilities and pump stations - Construction of water storage tanks - Installation of transmission and distribution lines - Construction of public faucets
Stage-II	2010	- Construction of additional water tanks - Renovation and extension of old lines
Stage-III	2015	- Extension of distribution lines - Extension and renovation of existing lines - Construction of additional public faucets

2) Outline of the Water Supply System

The basic components of water supply systems consist of water source, intake facilities, transmission facilities, distribution facilities and supply facilities. The water supply facilities were designed according to the concept in master plan. The successful test boreholes constructed

in Phase I in 2000 under this Study are utilized as the water sources.

Table-7.17 Components of the Water Supply System

NO	Water Facility	Components		
1	Water Source	Pump Station	Borehole	
2	Intake Facility		Submersible Pump and Pump Pit	
			Power Source	① Power Line (ELCOM)
				② Diesel Engine Generator
				③ Solar Generating System
			Pump House	Pump Control Room
				Chlorination Chamber
			Fence & Gate	① Concrete Block Fence
				② Crimped Wire Fence
3	Transmission Facility	Rising Main Pipe		
		Road Crossing & River Crossing		
4	Distribution Facility	Water Storage Tank		① Ground Water Tank
				② Elevated Water Tank
		Distribution Pipe		
		Road Crossing & River Crossing		
		Rehabilitation of Existing Pipe		
5	Supply Facility	Public Faucet		
		House Connection		

The water supply system of each Study Area is composed of (A) the pump station, (B) the rising main pipe, (C) water storage tank, and (D) the public faucet. And the pump station is divided into (a) borehole and pump pit, (b) pump house and c) power source. When the sunlight is used as a power source, the PV array is set up in the pump station.

3) Power Source of Water Supply System

There are several types of power sources of the water supply facilities such as ① a public electric power, ② diesel engine generator, and ③ renewable energy are enumerated as an alternatives. Considering operation, maintenance and management for the power source of facilities in the Areas the public electric power and/or ELCOM is the most preferable. The diesel generator is used in general where the service of a public electric power is not complete so far.

However, there are a lot of problems where the budget of operation and the maintenance expense

is not enough. In such a case, the water supply hours is limited due to the lack of the fuel cost, and in such a case, the superannuating of the diesel engine generator is assumed to be a cause and the water supply stops intermitting.

The solar pump system was introduced as a renewable energy in the master plan of this project in consideration of the restriction of the power source and the electric power circumstances by such the locale though the use of the force of the wind was also considered.

4) Solar Generating System

In 6 District Towns, there are no stable power supply services from ELCOM except Kwikila and Mutzing to obtain the electric power with transmission line from Port Moresby and Lae, respectively. The diesel engine generator is assumed to be a power source in Bereina and the non-full time water supply is forced from the lack of fuel cost for the power expense. In this master plan, the solar generating system is introduced in consideration of the restriction of the local electric power circumstances.

To introduce the solar generating power for pump, the amount of insolation of 4.1kw/m^2/day or more is needed in general. It is important to set up the duration of pumping hours, which is restricted to sunshine hours. In this Study, 6 hours (from 9 to15 o'clock) as the operation hour is assumed under the consideration of the Design Flow and the capacity of the water storage tank in the sites.

The amount of the insolation in Lae in August is 3.8 kw/ m^2/day. However, it is assumed that August is the rainy season, and the amount of insolation is below the average of the required insolation of 4.1kw/ m^2/day during this time. Therefore since this is raining period, rainwater collection can be used, to compensate for this shortage.

Moreover, in case a large pump output of 6.0kw or more is needed, it becomes disadvantageous to use a solar pump system. A community with a population of 1,000 to 2,000 is ideally suited for the introduction of the solar generating pump system. Therefore, the solar generating pump system of rated output 3.7 or 5.5kw is ideally suited for setting up water supply system in Stages.

7.8 Water Supply Systems

1) Water Supply Systems in 6 District Town

The water supply system at 6 District Town is composed of the (A) pump station, (B) the water storage tank, and (C) the public faucet. There are existing water supply facilities neither of five Study Area other than Oro Bay. In the master plan, the water supply system including effective use for existing facilities in a possible range was examined. The outline of the water supply systems and the proposed facilities according to each Stage at 6 District Town is shown as follows.

2) Water Supply System in Bereina

The water supply has stopped intermittently because of the shortages of the fuel cost and breakdowns of the diesel engine generator of the town operated by District office. Although there are eight villages around Station, pipeline is not extended to these eight villages. Dug wells or the rainwater tanks have been used by villagers because the water supply service dose not reache these villages.

Table-7.18 The Master Plan of Bereina

BEREINA		Area	Facilities
STAGE-I	2005	Station Toreno No.1, No.2 Ponepone Paikwa, Baukeke Karoapaina Hihive No.1, No.2	・Borehole & Pumping House No.1 ・Solar Generating System ・Water Storage Tank (80m^3, H:15m) ・Distribution Pipeline (2.8km) ・Public Faucet (9)
STAGE-II	2010	Station	・Water Storage Tank Rehabilitation (45m^3, H:15m)×2 ・Distribution Pipeline (1.3km)
STAGE-III	2015	Station	・Distribution Pipeline (2.2km)

Therefore, the plan of the pump station where the solar power generating system is adopted as power source for the water supply was considered in Stage-I and the distribution pipeline for eight villages and the installations of public faucets were planned.

The construction of raising main pipeline from the pump station should be planned in Stage-II. New construction and the rehabilitation of distribution pipeline which runs from east to west in Bereina Station are considered in Stage-II. In Stage-III, new construction and rehabilitation of branch pipeline from the main distribution are also considered.

3) Water Supply System in Kupiano

Kupiano is located in the center of Abau District in Central Province and the population is about 2,000 people. However, total population together with Gavuone (about 2,500 people) in the downstream of the Marshall lagoon and Wanigala (about 3,300 people) in the upstream of the Marshall lagoon became 7,800 people. The target population of the year 2015 will be more than 10,000 people in the Study Area.

Table-7.19 The Master Plan of Kupiano

Stage		Area	Facilities
STAGE-I	2005	Kupiano	• Borehole & Pumping House • Solar Generating System • Water Storage Tank Rehabilitation ($180m^3$) • Water Storage Tank ($30m^3$ ×2) • Rising Main Pipeline (5.0m) • Distribution Pipeline (2.1km)
STAGE-II	2010	Gavuone	• Borehole & Pumping House • Solar Generating System • Water Storage Tank ($200m^3$) • Rising Main Pipeline (2.2km) • Distribution Pipeline (3.4km) • Public Faucet (6)
STAGE-III	2015	Wanigela	• Borehole & Pumping House (in Kupiano) • Solar Generating System • Water Storage Tank ($200m^3$) • Rising Main Pipeline (7.0km) • Distribution Pipeline (0.7km) • Public Faucet (5)

The pump station was planned at a place where is 3km away from the Kupiano Town due to the groundwater potential area, and the construction of the distribution pipeline and the ground water tank ($180m^3$) was planned in Stage-I.

Gavuone will be one of the water supply areas in Stage-II. The second pump station is planned in a place where is about 1.3km away from the pump station of Kupiano constructed in Stage-I, and it is assumed to be connected with the rising main pipeline to the first pump station by rising main pipeline. Elevated water tank ($200m^3$) for the water supply to Gavuone is arranged on the east side of Kupiano town.

The water supply system of Wanigala of Stage-III also assumes the composition same as Gavuone. Therefore, the third pump station, elevated water tank ($200m^3$), and five public

faucets are arranged.

4) Water Supply System in Kwikila

The water supply area of Kwikila is divided into three of ① Station, ② Kwikila High School, and ③ Vocational Training School. There are two boreholes originally in Kwikila High school, and the water supply is done although it is insufficient in the volume of water. Because the public water supply had stopped for a long term around Station and the Vocational Training School area, there was lot of water leaks in each place, and it was judged that effective use for existing piping was not easy. Existing pipeline is gradually substituted in each Stage of the master plan.

The new establishment of the pump station and the construction of rising main pipeline to each water supply area and the new establishment of ground water tank ($60m^3 \times 2$) were planned in Stage-I. Moreover, the installation of a public faucet is planned in order to supply the water for the Compound in east side of the Station.

Table-7.20 The Master Plan of Kwikila

Stage		Area	Facilities
STAGE-I	2005	*Station* High School Vada Compound Mr.Broun Compound Makan Compound Vocational Centre Community School	・Borehole & Pumping House No.1 ・Water Storage Tank ($60m^3 \times 2$) ・Rising Main Pipeline (2.6km) ・Distribution Pipeline (2.0km) ・Public Faucet (1)
STAGE-II	2010	Central High school Vada Compound Mr.Broun Compound	・Borehole & Pumping house No.2 ・Rising main Pipeline (0.5km) ・Water Storage Tank Rehabilitation ($45m^3 \times 2$)
STAGE-III	2015	Makan Compound	・Distribution Pipeline (3.2km)

In Stage-II, new borehole and to the second pump station composed of the pump pit and the pump operation room, etc. are planned in order to deal with the water demand until 2015 which is the target year of 2015, and a rising main pipeline from the pump station will be connected with the rising main pipeline prepared in Stage-I. The rehabilitation concerning the water tank of the Kwikila High School should be done in Stage-II. And the existing distribution pipeline is planned to substitute almost completely in Stage-III. The total extension of pipeline for substitution becomes about 4.3km.

5) Water Supply System in Finshhafen

In Finschhafen, as for the water supply area is divided into three areas ① from Station (Gagidu) to Gingala to Gingala, ② from Gingala to Bugain through the Dregerhafen High School, ③ from Broun Hospital to Station (Gagidu), along the road which runs in the coastline of Langemark Bay. The total extension of pipeline of the master plan reaches about 15km along the road and the target population in 2015 that becomes about 4,700 people.

Because the amount of discharge from the river is less than the amount of the water demand, and water supply without chlorination, the pump station is constructed in the Station of Finschhafen (Gagidu), and existing pipeline about 7.4km is substituted for Gingala located in the south of Gagidu in Stage-I. Moreover, the distribution pipeline is planned in Buta Compound, DCA, and Gingala, etc. , and a public faucet are planned to set up.

Table-7.21 The Master Plan of Finschhafen

Stage		Area	Facilities
STAGE-I	2005	Station (Gagidu) Buta Compound DCA Gingala Village	• Borehole & Pumping House No.2 • Water Storage Tank (60m^3×2) • Rising Main Pipeline (0.2km) • Distribution Pipeline (7.4km) • Public Faucet (3)
STAGE-II	2010	Bugain Village High School	• Distribution Pipeline (4.8km) • Public Faucet (2)
STAGE-III	2015	Vocational Centre Broun Hospital Godowa Village Tomuc Village Timblim Settlement	• Borehole & Pumping House No.1 • Rising Main Pipeline (0.1km) • Water Storage Tank (60m^3, H:15m) • Distribution Pipeline (9.9km) • Public Faucet (2)

The distribution pipeline should be renewed from Gingala to further Bugain Village at the position of about 4.8km in the south in Stage-II, and public faucets will be arranged in Buki Village and Dreger High School located on the way. The second pump station should be in the Butaweng Creek upstream, and water storage tank (50m^3) are planned to construct in Stage-III. The installation of branch pipeline for Godowa Village and Tomuc Village located along to the distribution pipeline also considered and public faucets in these villages are planned in Stage-III.

6) Water Supply System in Mutzing

The power line of ELCOM was extended from Lae to Mutzing in June, 2001. Now it is

available to get 24-hour power supply in Mutzing. Because the existing pipeline is limited only inside of Station the water supply area in Mutzing has been expanded into three areas ① Station internal, ② Mutzing Village, Sampubangin Village in the east side of the Station, and ③ Markham Valley High School on the west side of the Station.

Water pressure from existing taps where locate in the surrounding area away from the Station is insufficient. Because, the height of an existing elevated water tank is not high. And, the diameters of existing pipeline are small. Therefore, an elevated water tank 15m in height and the update of existing pipeline are necessary.

The pump station composed of a pump operation room and an elevated water tank, etc. is planned in Stage-I. The amount of the water demand in 2015 which is the final target year is covered by the amount of water supply from this pump station in Mutzing. Moreover, the rising main pipeline and the distribution pipeline to the villages namely Mutzing Village and Sampubagin Village, and Markham Valley High School that are new water supply areas are considered.

Table-7.22 The Master Plan of Mutzing

Stage		Area	Facilities
STAGE-I	2005	Station Sampubagin Village Mutzing Village Intop Village Markham valley High School	・Borehole & Pumping House No.1 ・Rising Main Pipeline (0.6km) ・Water Storage Tank ($80m^3$)×15m ・Distribution Pipeline (2.4km) ・Public Faucet (1)
STAGE-II	2010	Station	・Water Storage Tank Rehabilitation ($30m^3$) ・Rehabilitation of Existing Pipeline

The present Mutzing is Sub district town of Kaiapit District in Morobe Province. Mutzing is a relay point on Highlands Highway to face directions of Madang and Goroka. Therefore, the development of Mutzing is expected as a heartland of the surrounding area. In Stage-II, rehabilitation or new construction works of existing water tanks and existing pipeline are planned in preparation for the increase of the water demand in the target year of 2015.

7) Water Supply System in Oro Bay

As for the water supply area of Oro Bay is divided, even Eroro Mission and Kopure Village are

divided three areas such as ①from Wharf to Fisheries office, ②from north side of Fisheries office to Kopure Village through Ijivitari District Administration, ③from north side of Eroro Mission Embogo High School.

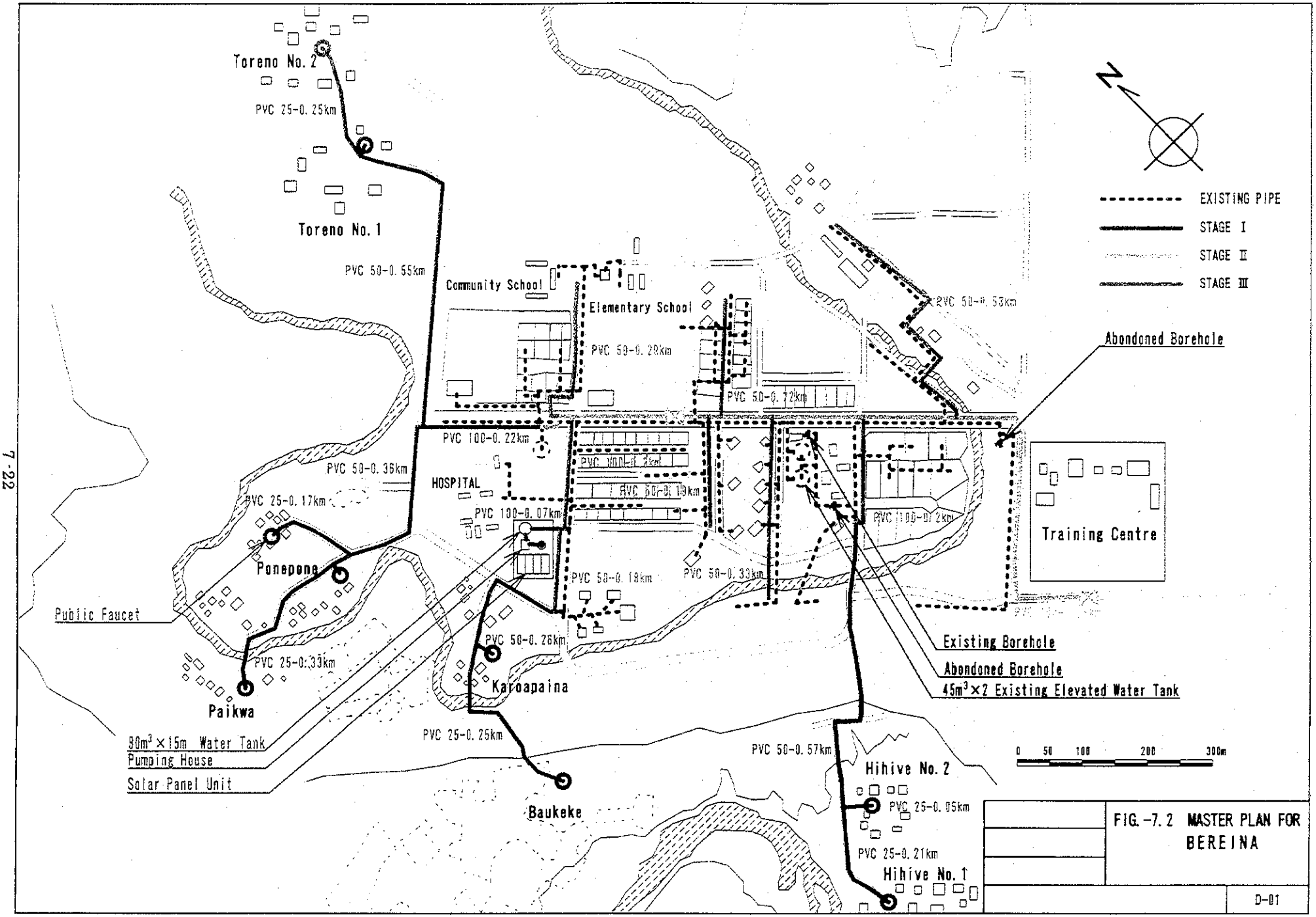
All the water supply facilities in the master plan are planned as new construction of water facilities because there are no existing water supply systems in Oro Bay. The solar generating system is introduced as a power source of the water supply facilities because there is no public power service from ELCOM.

Table-7.23 The Master Plan of Oro Bay

Stage		Area	Facilities
STAGE-I	2005	Sub-Dist. Administration Health Centre Marine Compound Beama Village Mobil Oil Depot	· Borehole & Pumping House No.1 · Solar Generating System · Water Storage Tank (80m^3) · Distribution Pipeline (5.2km) · Public Faucet (4)
STAGE-II	2010	Ijividari Dist. Administration Kopure Village Eroro Village Eroro Mission Basego Village Ijivitali Dist Office	· Borehole & Pumping House No.2 · Solar Generating System · Water Storage Tank (80m^3) · Distribution Pipeline (7.2km) · Public Faucet (4)
STAGE-III	2015	Embogo Village Embogo High School Dombada Village	· Distribution Pipeline (7.0km) · Public Faucet (3)

In Stage-I, the pump station and water storage tank are planned at a position away from Beama Village about 1km inland side. Moreover, the distribution pipeline about 2.1km, which encloses Oro Bay from Wharf to Fisheries office, is planned. Total three public faucets are arranged in Wharf, Health Centre, and Fisheries office.

The construction of the second pump station and water tank was planned to Kopure in Stage-II. Moreover, distribution pipeline about 7.7km is arranged from Kopure to north side of Fisheries office and public faucets in 4 places namely Kopure Village, Eroro Mission, Basego Village and Ijivitari District Administration are arranged. The range from north side of Eroro Mission to Embogo High School becomes a water supply area in Stage-III. Four public faucets are arranged in Embogo Village, Dombada Village, Eroro Village, and Embogo High School.


Toreno No. 2
PVC 25-0.25km
Toreno No. 1
PVC 50-0.55km
Community School
Elementary School
PVC 50-0.28km
PVC 50-0.53km
Abondoned Borehole
PVC 50-0.72km
PVC 100-0.22km
PVC 100-0.2km
PVC 50-0.36km
HOSPITAL
PVC 50-0.19km
PVC 25-0.17km
PVC 100-0.07km
PVC 100-0.2km
Training Centre
Ponepone
PVC 50-0.18km
PVC 50-0.33km
Public Faucet
PVC 50-0.26km
PVC 25-0.33km
Karoapaina
Existing Borehole
Abondoned Borehole
45m³×2 Existing Elevated Water Tank
Paikwa
80m³×15m Water Tank
Pumping House
Solar Panel Unit
PVC 25-0.25km
PVC 50-0.57km
Hihive No. 2
PVC 25-0.05km
PVC 25-0.21km
Hihive No. 1
Baukeke
EXISTING PIPE
STAGE I
STAGE II
STAGE III
0 50 100 200 300m
FIG.-7.2 MASTER PLAN FOR BEREINA
D-01

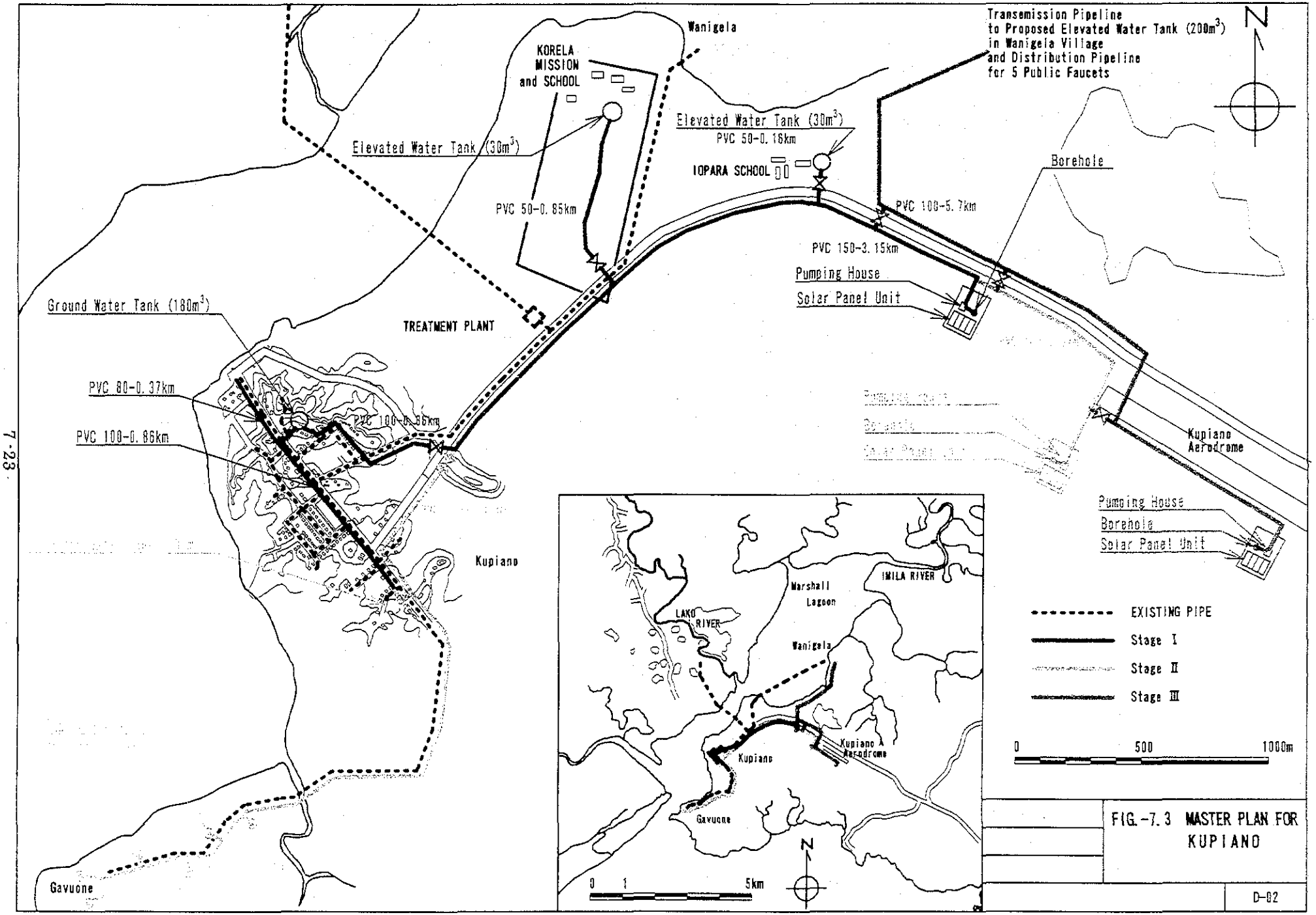


FIG.-7.3 MASTER PLAN FOR KUPIANO

D-02

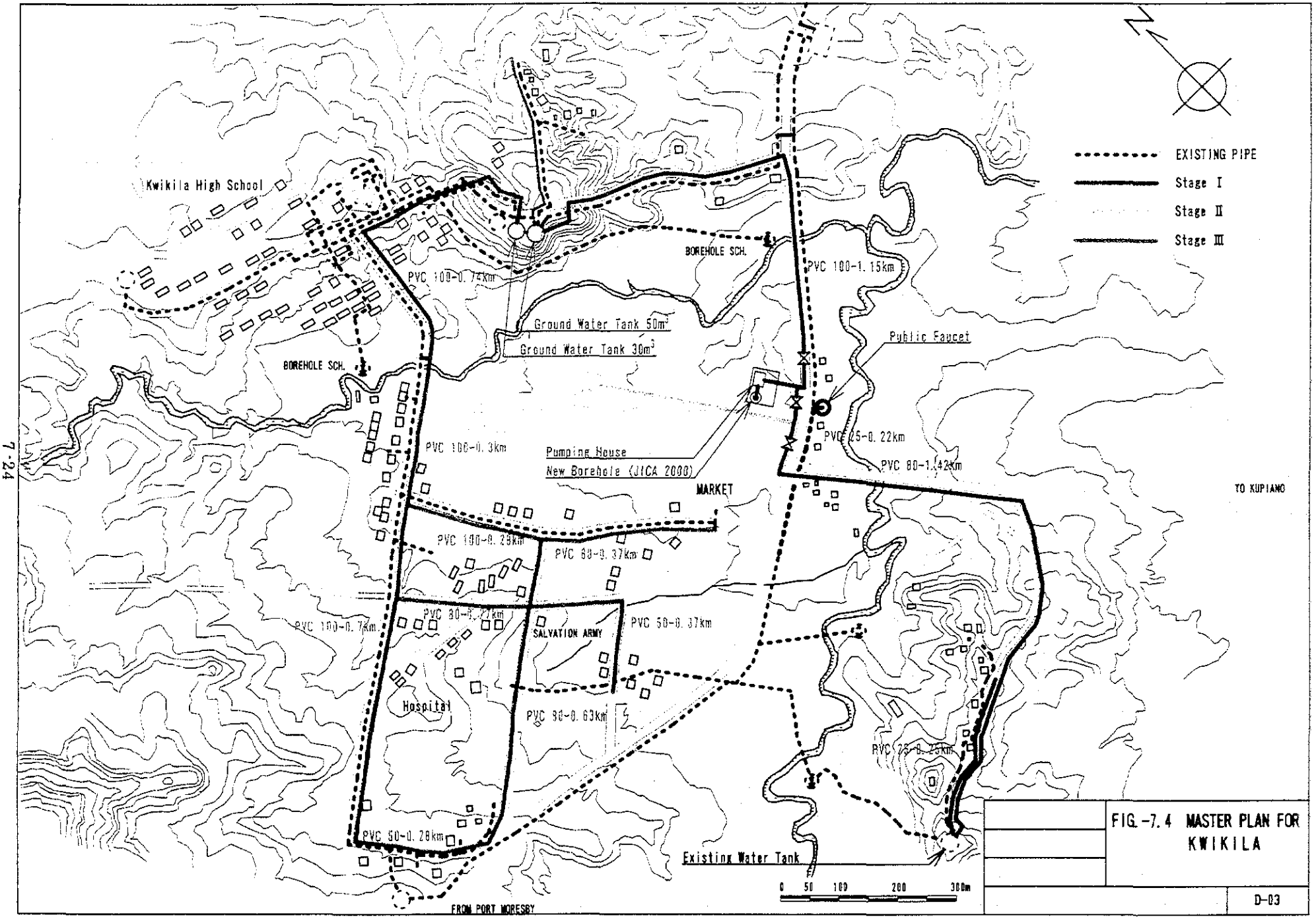


FIG.-7.4 MASTER PLAN FOR KWIKILA

D-03

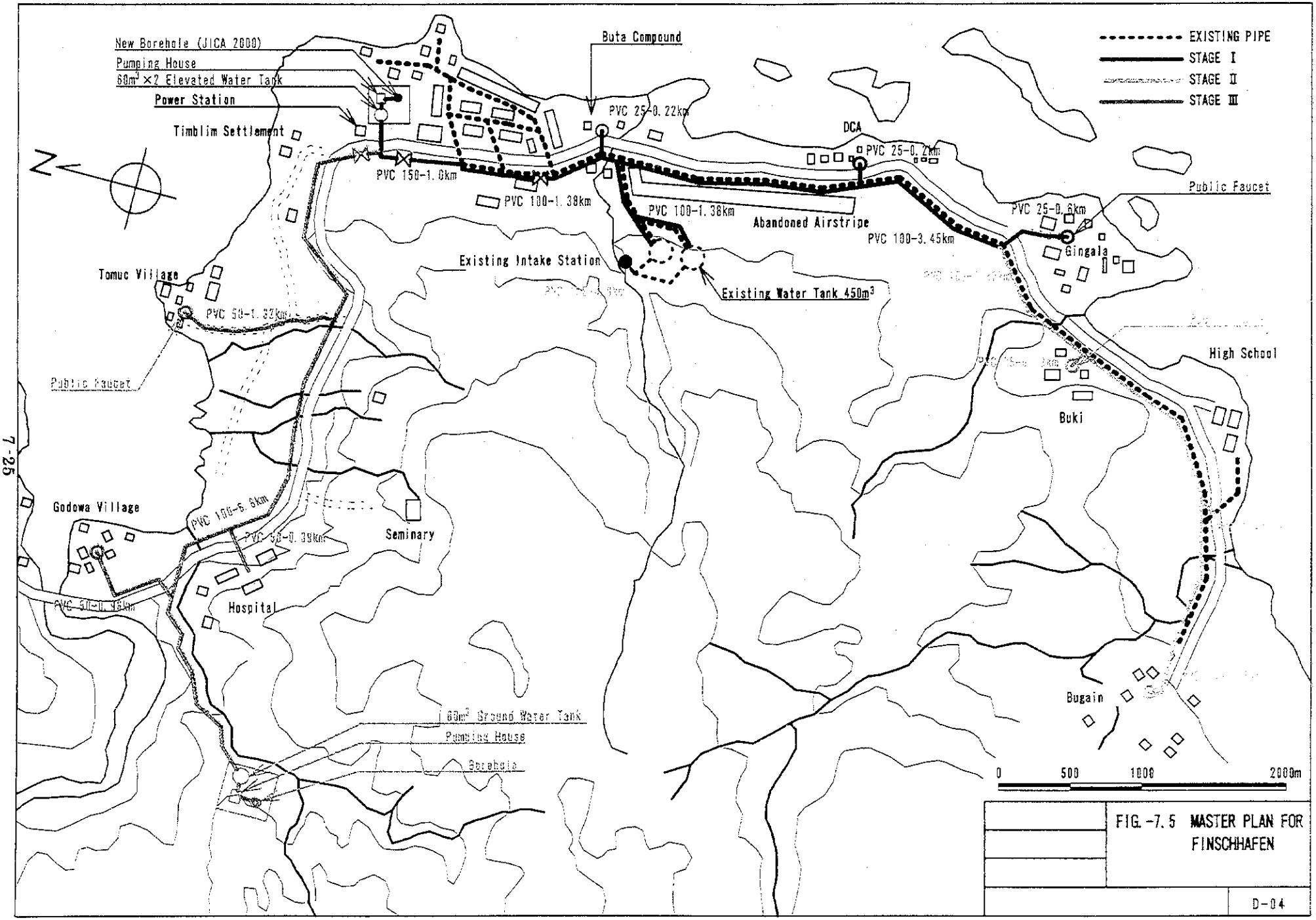
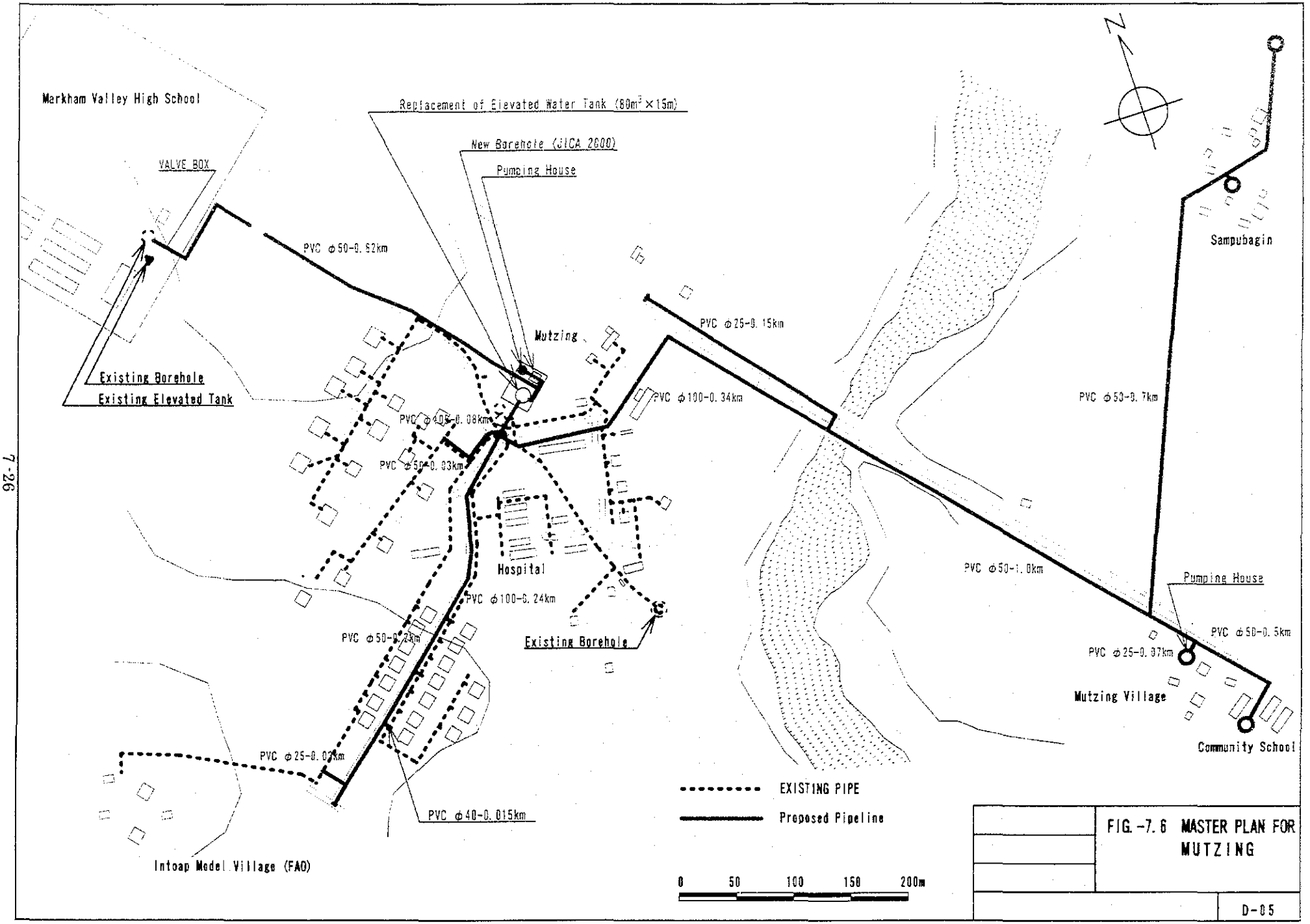
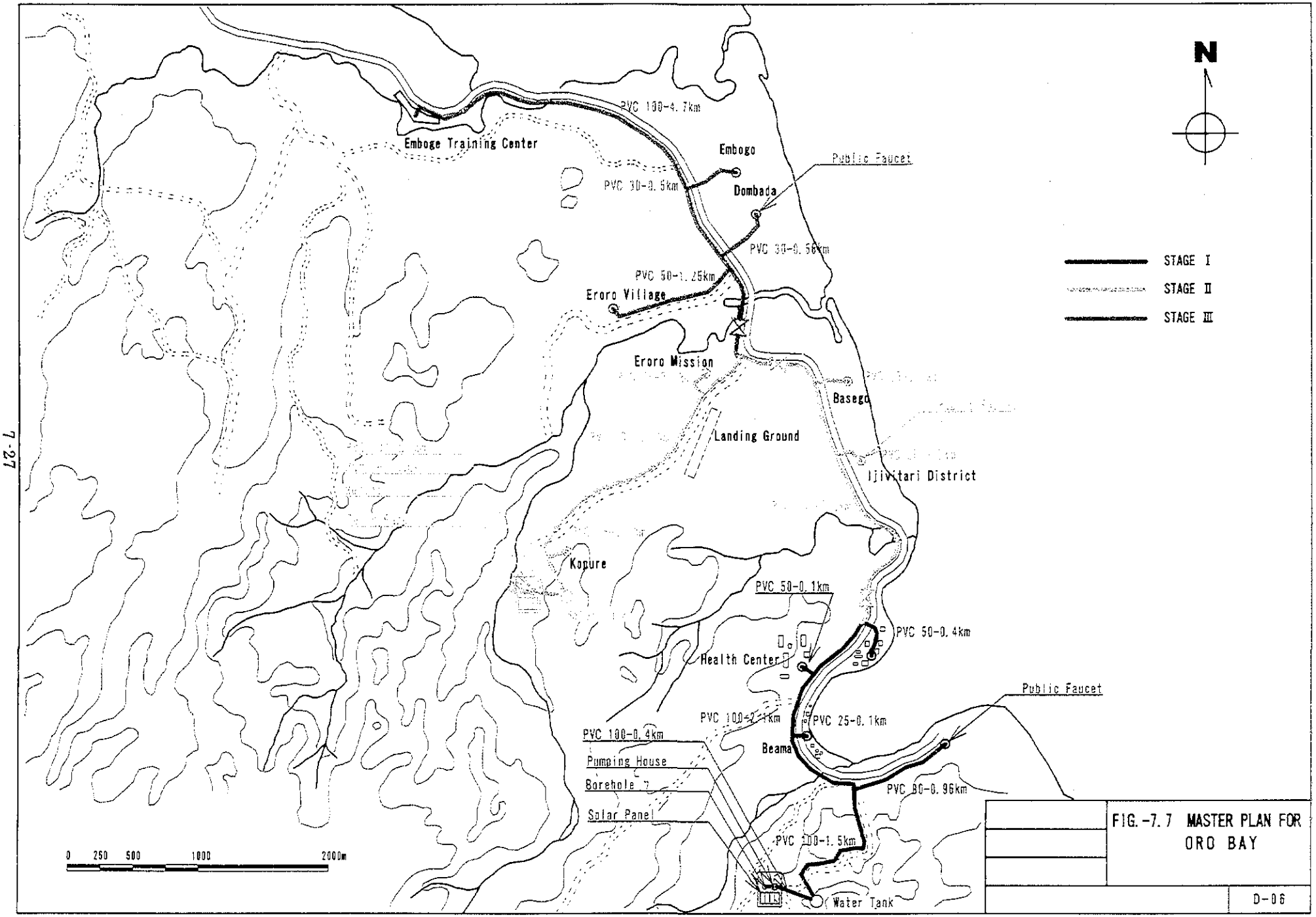


FIG.-7.5 MASTER PLAN FOR FINSCHHAFEN

D-04


Markham Valley High School
Replacement of Elevated Water Tank (80m³×15m)
New Borehole (JICA 2000)
Pumping House
VALVE BOX
PVC φ50-0.92km
Existing Borehole
Existing Elevated Tank
Mutzing
PVC φ25-0.15km
PVC φ100-0.34km
PVC φ40-0.08km
PVC φ50-0.03km
PVC φ50-0.7km
Sampubagin
Hospital
PVC φ100-0.24km
PVC φ50-1.0km
Pumping House
PVC φ50-0.5km
PVC φ50-0.2km
Existing Borehole
PVC φ25-0.07km
Mutzing Village
Community School
PVC φ25-0.02km
PVC φ40-0.015km
Intoap Model Village (FAO)
EXISTING PIPE
Proposed Pipeline
0 50 100 150 200m
FIG.-7.6 MASTER PLAN FOR MUTZING
D-05


N
PVC 100-4.7km
Emboge Training Center
Embogo
Public Faucet
PVC 30-0.5km
Dombada
PVC 30-0.56km
PVC 50-1.25km
Eroro Village
Eroro Mission
Basego
Landing Ground
Ijivitari District
Kopure
PVC 50-0.1km
PVC 50-0.4km
Health Center
Public Faucet
PVC 100-2.1km
PVC 25-0.1km
PVC 100-0.4km
Beama
Pumping House
Borehole
Solar Panel
PVC 80-0.96km
PVC 100-1.5km
Water Tank
STAGE I
STAGE II
STAGE III
0 250 500 1000 2000m
FIG.-7.7 MASTER PLAN FOR ORO BAY
D-06