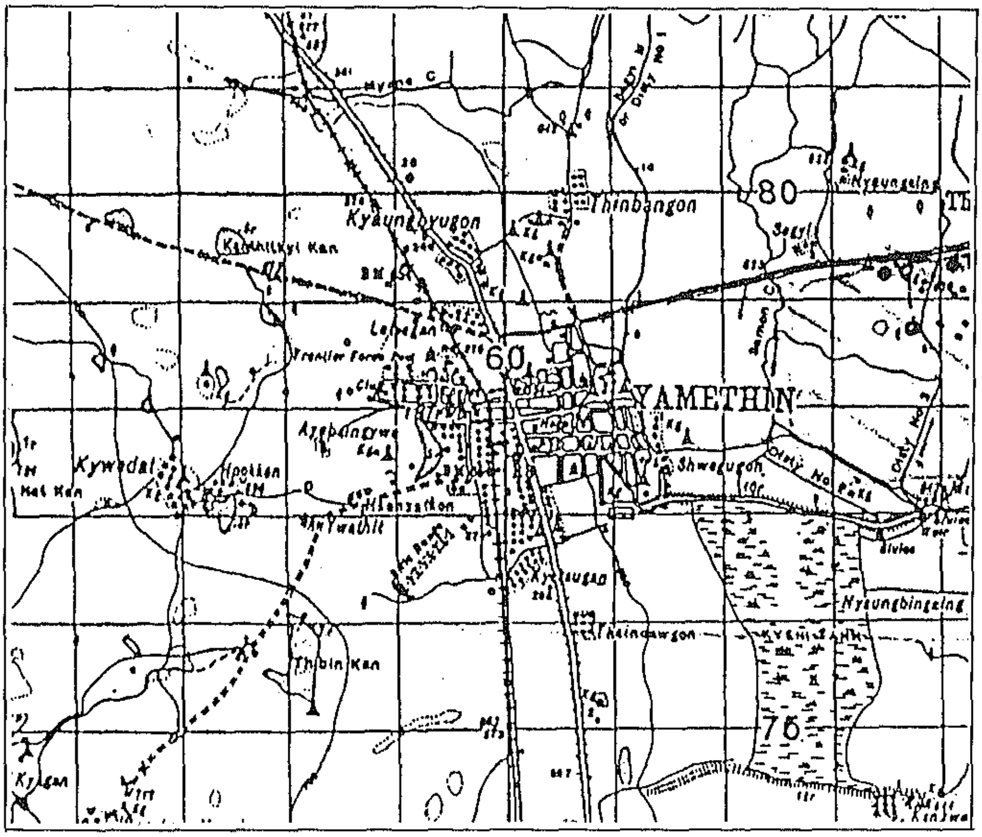
4.2 Yamethin



4.2.1 Outline of The Area

Yamethin is situated at about 100 km to the north of Pyinmana and at about 20 km to the south of Pyawbwe, on the Rangoon-Mandalay main road. It is a small city having an area of 7.7 km^2 and population of about 23000 persons. Both precipitation and air temperature in this area show the values typical of the dry hot zones. The annual precipitation for past 10 years is 610 to 1060 mm, and the air temperature is 42°C maximum in summer and 29°C on average in winter.

The main products are sesame, peanut, pepper and cotton, which are representative agricultural products of the dry hot zones. From the dam in the west, water is supplied into a pond, Kyeni tank, located in the southeastern part of the town, and rice is also grown. From many villages in the surrundings, these products are brought about, thus this town is being a transaction and commercial center.

4.2.2 Existing Water Supply Facilities

The water supply facilities of the town in the old days comprised the Kyeni tank (artificial pond) in the southeasten part, and by pumping-up from this tank, water was supplied through the panel type elevated tank to various places in the town. Even now, this system supplies water to some parts of the town.

The water supply facilities at the present comprise eight deep wells dug in Theingon village about 5 km to the east of the town. Water is pumped up by submersible pumps from these deep wells as the water source, and is once collected in the underground tank from which water is supplied through two main water pipes of 6 inch and 8 inch into two reinforced concrete elevated tanks in the town, from which water is supplied to the dwellers. (Refer to the conceptional water supply system diagramin in Fig. 4.2.1.1.) Water pipings are as shown in Fig. 4.2.1.2. The dwellers can take water from small public water supply tanks made of concrete installed at various places. Fire fighting tanks also are installed at the various places in the town.

These facilities were installed by the Ministry of Housing in 1964. At the present, five of eight deep wells are not working, only three are in operation. The present supply capacity per day is only 100000 gal/d (about 450 m^3/d). Therefore, the water area is divided into two, each of which is supplied every other day.

This water seems good for drinking having pH 8.5, total solids content 340 ppm, and hardness 92 ppm.

4.2.3 Purpose of the Survey

Regarding the existing water supply facilities as the whole, it is judged that by renovating the intake facility, the entire facility may be function sufficiently.

Therefore, this survey is intended to find out the causes of the failure of the wells, investigate the repair methods, and complete the intake facility to cope with the planned water supply quantity.

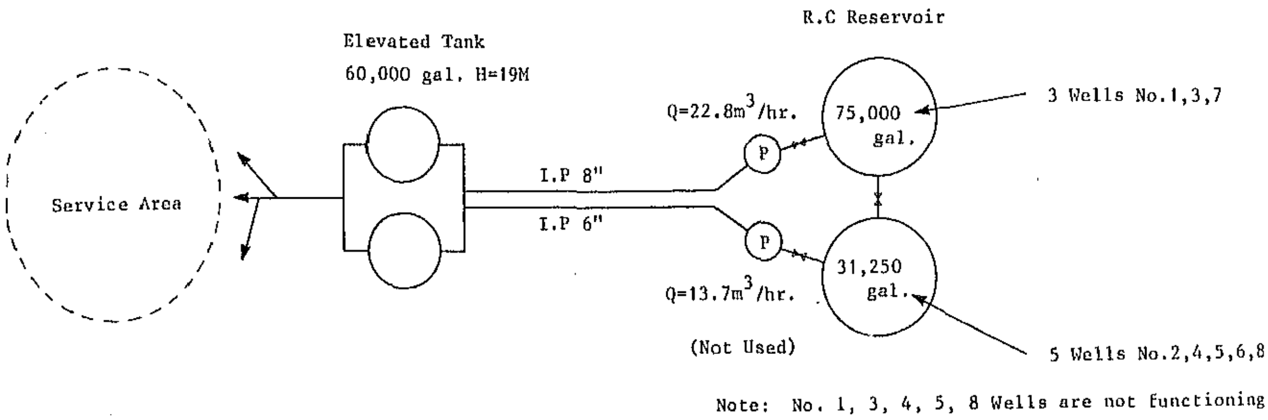


Fig. 4.2.1.1 Conceptional Diagramme of Existing Water Supply System

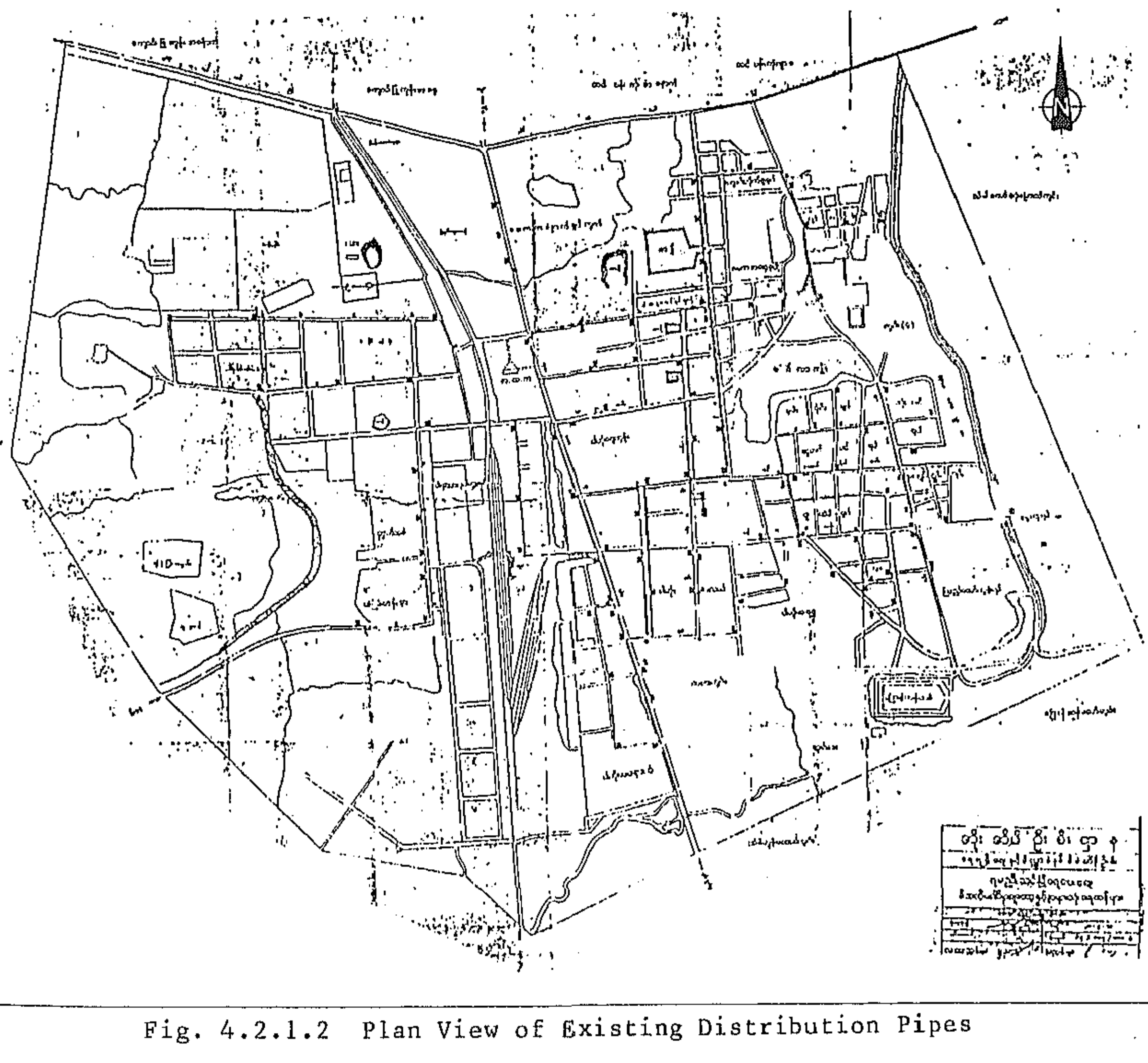


Fig. 4.2.1.2 Plan View of Existing Distribution Pipes

4.2.4 Water Resource Development Plan

1) Hydrogeology

(1) Topography and Geology

The neighborhood of Yamethin is a narrow basin contained between the Shan-Tenasserim high land consisting mainly of palaeozoic rocks and partially of granties at about 10 km on the east side and the Pegu Yoma uplift consisting of the Pegu formations of the oligocene and middle and lower miocene of the tertiary period at about 15 km on the west side. (Refer to Fig. 4.2.4.1 and Fig. 4.2.4.2.)

Inside the basin, the Irrawaddy formations formed in the upper miocene and pliocene of the tertiary period form a slow-sloping hilled plateau and are distributed in the west side of Yamethin. The diluvium layers (fan deposits) formed in the quaternary are distributed along the Shan-Tenasserin high lands. The alluvium layers are slenderly distributed along the railways and to the north of Yamethin, they spread gradually wide. On the alluvium low lands, small rivers such as Samor and Segyin flow to the north at slow slopes. To the southest of Yamethin, there is Kyent tank which has an area of about 2.4 km^2. These small rivers and lakes dry up in the dry season although water flows or is stored in the rainy season.

The alluvium low land has flat surfaces. The fan with fan deposits distributed and the hilled plateau with Irrawaddy formation distributed slowly slope toward the allevium low lands.

Theingon village has existing well groups and pump stations. It has fan topography and slowly slopes from east to west. Surrounding this Theingon village, the fan deposits corresponding to the diluvium layers are distributed in thick layers. Under them, it may be considered that the Irrawaddy formations are distributed.

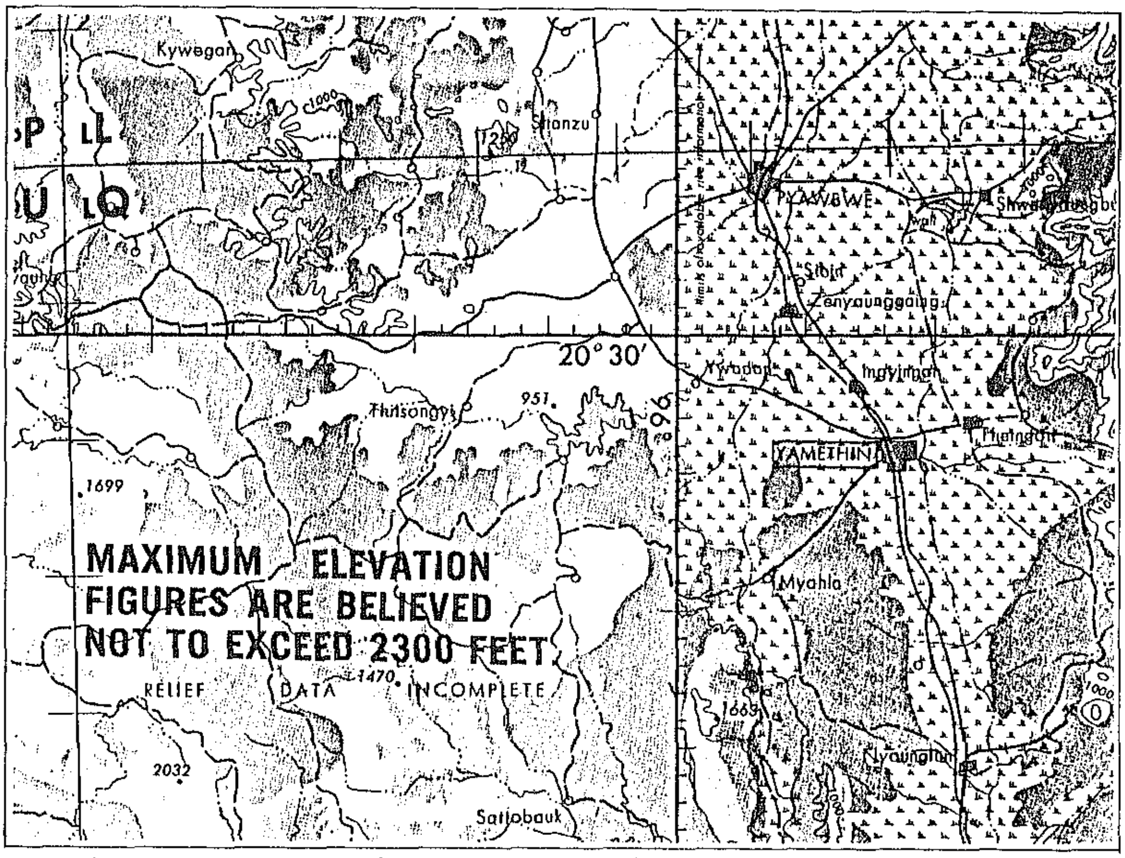


Fig. 4.2.4.1 Topographic Map of Yamethin Scale 1=500,000

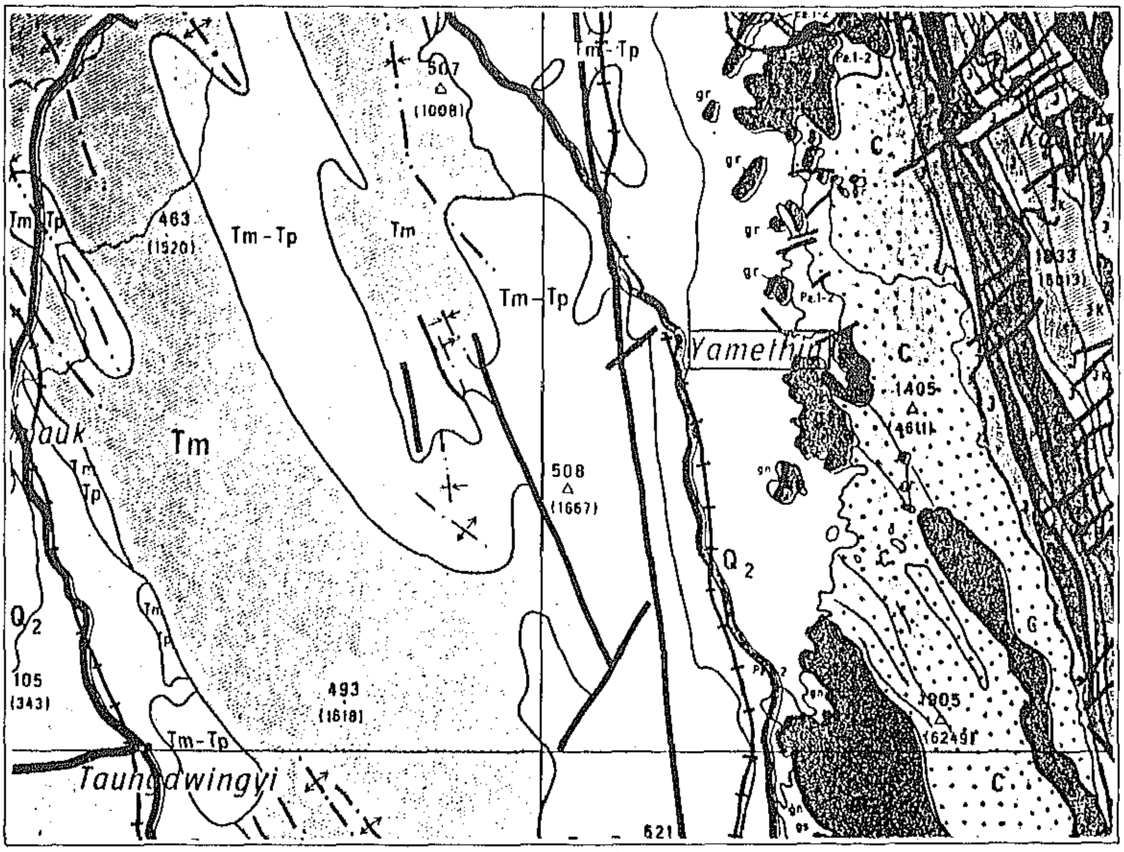


Fig. 4.2.4.2 Geological Map of Yamethin Scale 1:870,000

(2) Hydrogeology

The Theingon district slowly slopes to the west. The fan deposits consisting mainly of clay layers are distributed. The geological structure is simple. Fig. 4.2.4.3 shows a model geological profile of the area from Yamethin to the Shan high land.

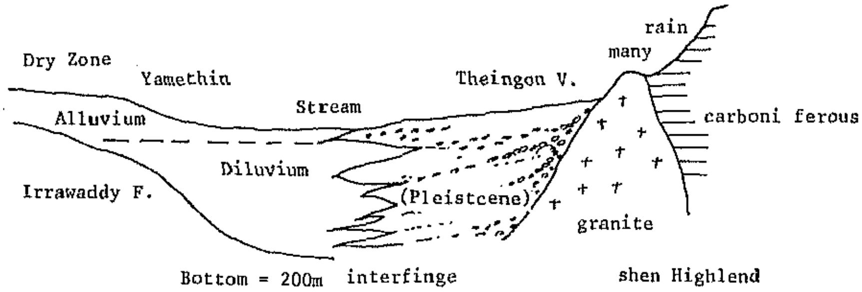
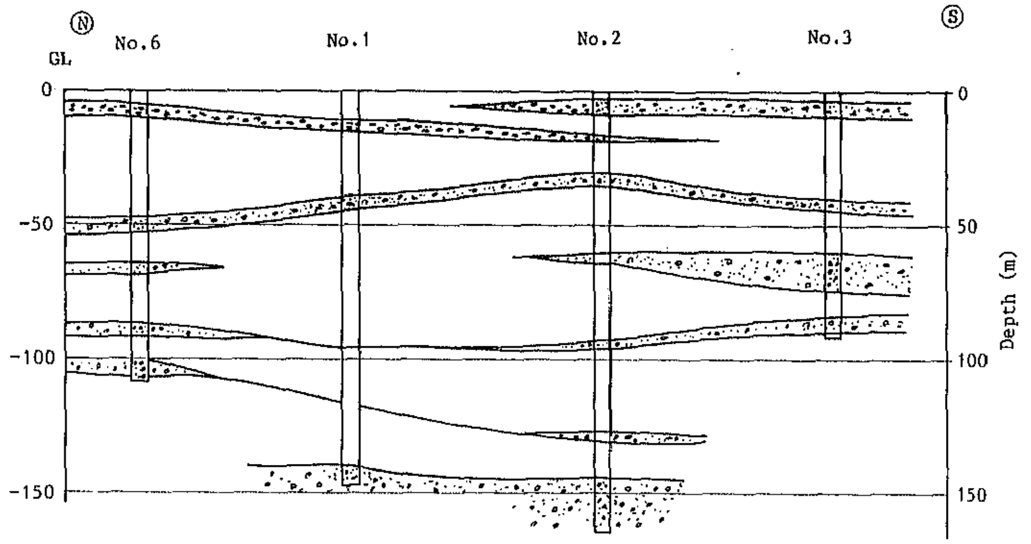


Fig. 4.2.4.3 Conceptional Profile of Yamethin to Shan Highland

Fig. 4.2.4.4 shows the geological structure at wells and pump stations in Theingon village. In this profile, clay layers and sand layers with clay mixed are predominant. Sand and gravel layers as the aquifers are distributed in good continuity. At about 140m or deeper from the ground surface, a gravel layer having at leats 20m thickness is distributed, and this layer forms the main aquifer in this area.

In this area, there are two wells of well diameter 150 mm dug in 1951, and eight wells of well diameter 200 mm (dig diameter 375 mm) dug in 1968, but only three of them are in operation at the present. Most of these wells are 90 to 100 m deep and some are 140 to 167m deep.

The screen length of these wells is not constant but varies with the location.



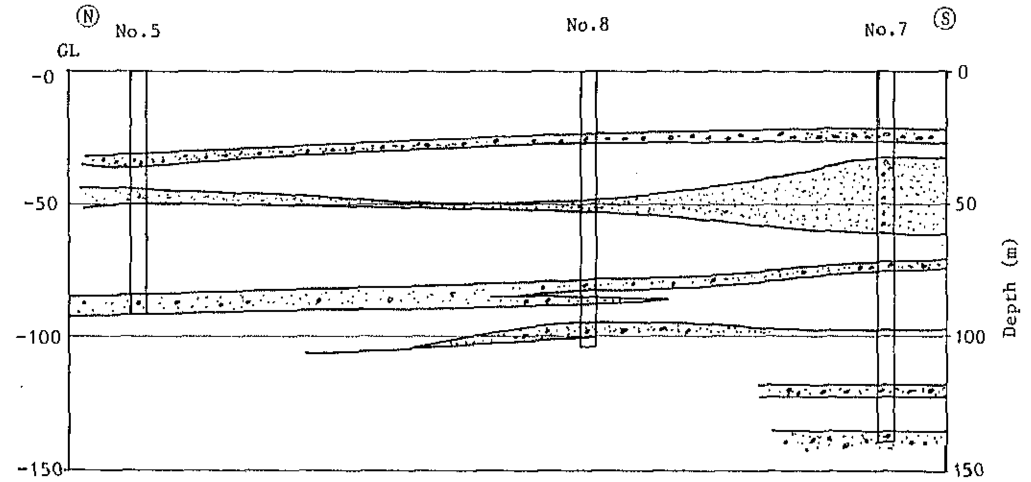


Fig. 4.2.4.4 N-S Section of Existing Tube-Wells Theingon

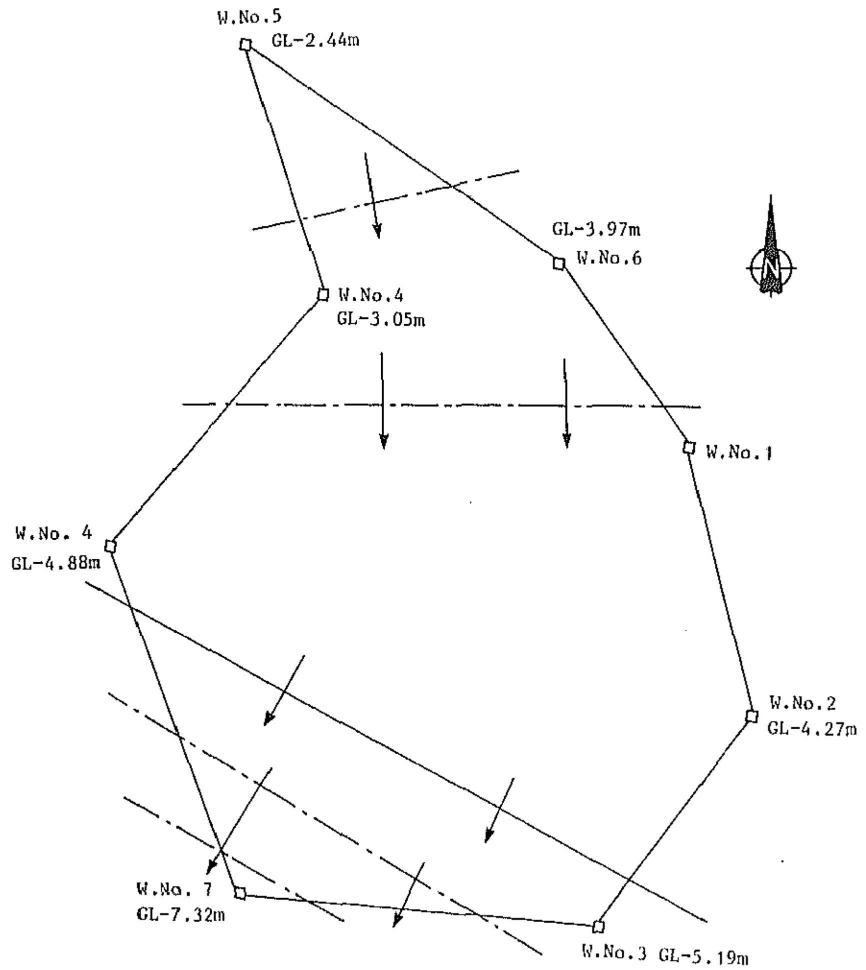


Fig. 4.2.4.5 Directions of Ground Water Flows in Theingon

The natural water level in this area is about 1.5 to 5m, being near the ground surface. The running water level is about 20 to 28m. The lowering of the water level is large for the pumping quantity, suggesting that the coefficient of permeability is small.

Just after digging, the pumping quantity was about 15.7m^3/hr for the well of 90 m depth and 31.5m^3/hr for the well of 140m depth, but it is about 11.2 to 13.5m^3/hr at the present. The probable causes are deterioration of wells and clogging of screens, etc.

Just after digging, the ground water level was high on the north side: GL - 2.4m on the north side and GL - 5.2 to 7.3m on the south side. It seems that the direction of flow was as shown in Fig. 4.2.4.5.

Fig. 4.2.4.6 shows variations of the ground water level at the Theingon well site. The monthly precipitation in Yamethin is shown also in this figure. From this figure, it can be said that the water level goes down in the dry season when the precipitation is small, and rises up as the precipitation increases. The difference between the maximum water level and the minimum water level in 1982 is about 6.6m. Therefore, the ground water at this well site depends largely on the precipitation. It rises up at the same time as starting recording, but it seems that the month of maximum precipitation and the month of the maximum water level show a delay of one to two months. It may be considered that the recharge source for the ground water is an influent water from the boundary between the Shan high land and the fan structure.

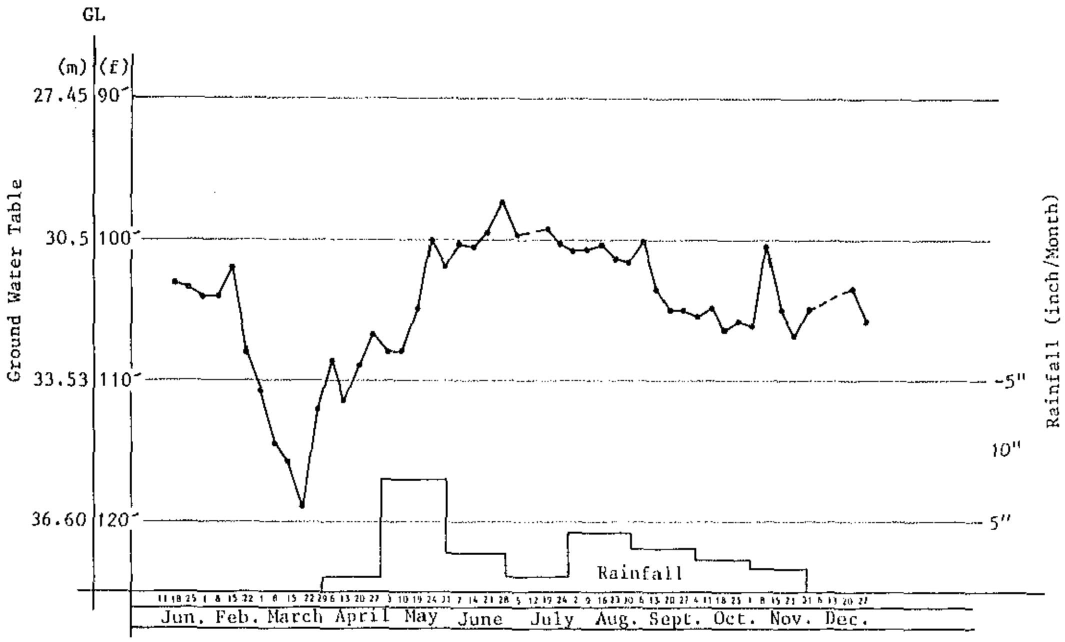


Fig. 4.2.4.6 Fluctuation Level in Well No. 3 and Monthly Rainfall of Yamethin. (1982) (Measurement by Irrigation Department)

2) Why Existing Wells cannot be Used

In Thaigon village, there are eight wells constructed in 1968 - 1969, but only three of them are in operation at the present. As shown in Fig. 4.2.4.5, the spacing between these wells is as small as 70 to 130m.

Each well is in the area of influence. For example, let us consider the area of influence of No. 6 and No. 7.

No. 6 Static water level upon construction GL-13' } → S = 63'
Running water level upon construction GL-76' (19.21m)

$$R_6 = 3000S\sqrt{k}$$
$$= 3000 \times 19.21 \times \sqrt{3.0 \times 10^{-5}}$$
$$= 315.6m$$

No. 7 Static water level upon construction GL-24' } → 62'
Running water level upon construction GL-86' (18.91m)

$$R_7 = 3000S\sqrt{k}$$
$$= 3000 \times 18.91 \times \sqrt{3.0 \times 10^{-5}}$$
$$= 310.7m$$

The horizontal distance between No. 7 and No. 8 is about 230m.

$$L = 230m < R_6 + R_7 = 315.6 + 310.7$$
$$= 626.3m$$

Thus, it may be considered that No. 6 and No. 7 are in the interference condition. The distance between No. 3 and No. 5, which are most away from each other, is only about 305m. Thus, all wells are in the area of influence where well interference takes place. Thus, it is considered that the running water level in each well was badly low.

Since the discharge rate in each well exceeds the limited quantity, the water balance around the well group is lost and the artesian head is decreased (static water level goes below). Table 4.2.4.1 shows the static water level upon construction and at the present.

Table 4.2.4.1 Variations of Static Water Level

Well No.	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
SWL upon construction	-	4.27	5.19	3.05	1.53	3.97	7.32	4.88
SWL at the present	-	23.18	27.20	42.17	28.13	40.10	23.18	29.71
Difference	-	18.91	22.01	39.12	26.60	36.13	15.86	24.83

Since the required pumping quantity was pumped up in spite of the lowering of the static water level, disturbances were caused around each well and thereby fine particles were moved. As a result, screens were clogged and sand accmulated in the well, the well function being deteriorated or stopped. The running water level was further lowered.

Moreover, voltage drop the like caused the motor to be overloaded and thereby the motor failed or the pumping quantity was lowered.

All these factors acted together so that most of pumps could not be used.

3) Aquifer

The aquifers in the Theingon district consist mainly of clay layers of fan deposits, and thin layers of sand and gravel in continuity are distributed. The clay layer is with sand and gravel mixed, and sand or gravel layer is with clay mixed in many cases. At about 140m or deeper under the ground surface, good adquifers consisting mainly of gravel layers are distributed.

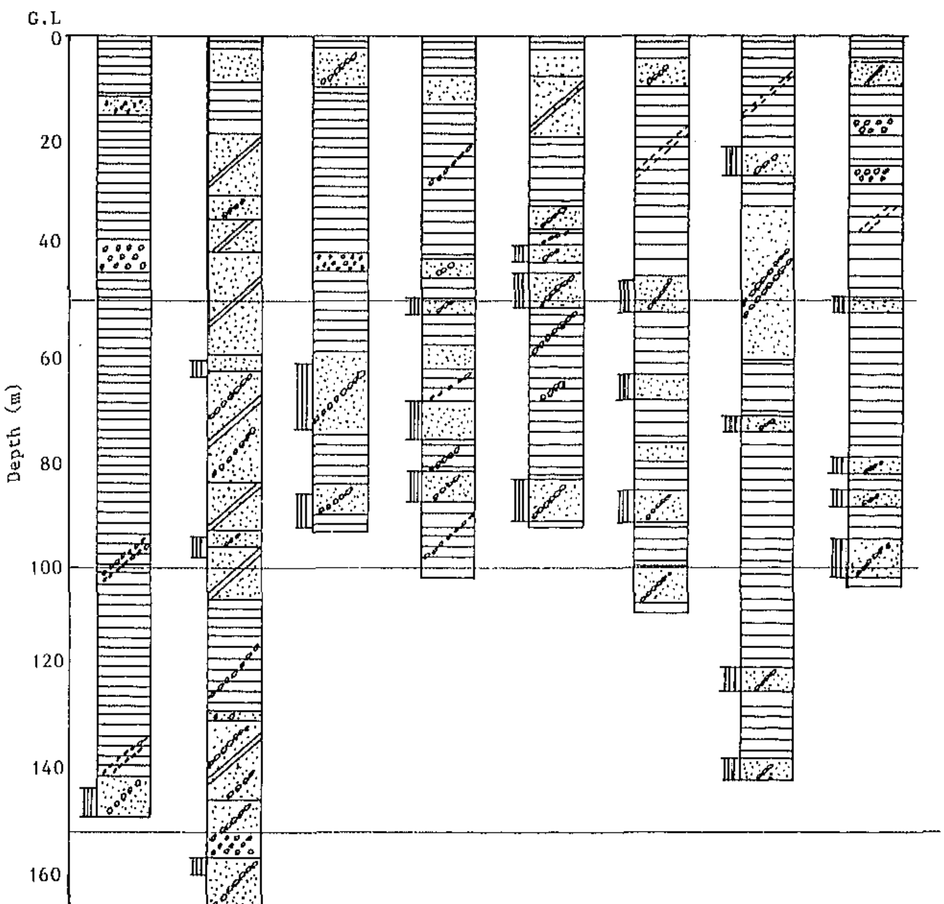


Fig. 4.2.4.7 Tube Well Logs in Theingon

The well log data for existing wells are shown in Fig. 4.2.4.7. As a whole, the clay layers are predominant, with thin layers of sand and gravel mixed. In the upper portion, good permeable beds are not distributed, but in the lower portion, good permeable beds are distributed. The screen is installed in the sand or gravel layers, and few permeable beds have adequate thickness.

Electric prospecting was carried out at three points along one measuring line in the south-north direction around the present well site, and 2 points along one sounding points in the east-west direction.

The results are shown at the resisitivity profile. From the results of analysis and the existing data, the following can be said:-

① Distribution of formations

i) Aquiclude (4.0 to 6.0 Ω-m)

Frequently absent in the south-north direction, but thick and continuous in the east-west direction. Especially, thick in on the west side.

ii) Permeable bed ∿ aquiclude (7 to 15 Ω-m)

Thick and continuous in the south-north direction, but in lens-like distribution in the east-west direction. Thick and fallen on the south side.

iii) Aquiclude ∿ impermeable bed (1.0 to 4.0 Ω-m)

Thick and continuous. The upper surface depth is about EL 160m except on the south side. The lower surface depth is about EL 50 to 60m except on the east side.

iv) Permeable bed (20 Ω-m min.)

Continuous. The upper surface depth is fallen on the west side and on the south side. Under the layer of 20 Ω-m, layers showing high resistvity are distributed. Impermeable beds are distributed on the east side.

According to the results of electric prospecting, it is considered that wells should be installed at EL 198m (650') or lower on the west side and on the south side.

② The results of electric prospecting nearly agree with well logs.

③ The main aquifers are permeable beds of EL 50m and deeper (GL - 150m). The upper surface depth is as deep as 150m.

As described above, the aquifers are sand and gravel layers mixed in clay layers in the upper portion, and relatively thick sand and gravel layers in the lower portion. The ground water in these aquifers is the artesian water. The water level in the initial stage is high.

Table 4.2.4.2 shows the static water level and running water level in wells obtained in the pumping test carried out on September 7, 1984.

Table 4.2.4.2 Static and Running Water Levels in Tube Wells in Theingon

Time	No. 2 Q=3,000	No. 3	No. 4	No. 5	No. 6 Q=3,000	No. 7 Q=3,000	
7:00	23.18	27.20	42.17	28.13	40.10	23.18	29.71
12:00	44.22	27.99	43.87	29.43	54.30	29.89	29.98
13:00	24.10	27.98	41.21	28.50	41.96	23.79	29.29
17:00	44.22	27.99	43.41	27.60	54.60	28.67	29.81

The reason for the lowering of water levels in this table is that the water level in the surroundings is lowered by pumping and the pumping quantity exceeds the ground water storage.

The fan deposits in this area are generally shifted from coarse particles to fine particles as the location is away from the Shan high land, and the sand and gravel layers mixed in the clay layers are produced in the diluvial epoch. Therefore, the fan deposits have complicated formations and show low coefficient of permeability.

Table 4.2.4.3 shows the coefficient of permeability obtained from available data.

Table 4.2.4.3 Coefficient of Permeability Thaingon

	Well No.	Aquifer m (cm)	Draw down H-h (cm)	Discharge $Q(m^3/sec)$	Diameter r (cm)	Permeability k (cm/sec)
Initial condition	No. 3	1,830	1,769	4,375	10.16	1.82×10^{-3}
	No. 7	1,600	1,830	8,750	10.16	4.03×10^{-3}
	No. 8	1,630	2,135	8,750	10.16	3.39×10^{-3}
	No. 2	1,372	2,104	3,750	10.16	1.76×10^{-3}
Present	No. 6	1,620	1,450	3,750	10.16	2.16×10^{-3}
	No. 7	1,630	671	3,750	10.16	4.63×10^{-3}

The coefficient of permeabilty was calculated in accordance with Thiem's formula described in Paragraph 3.1.2.3), on an assumption of the influence area (R) of 500m. The coefficient of permeabilty is approximately the same at the initial condition and at the present.

The average value of the coefficient of permeability at the well site is $k = 3.0 \times 10^{-3}$ cm/sec.

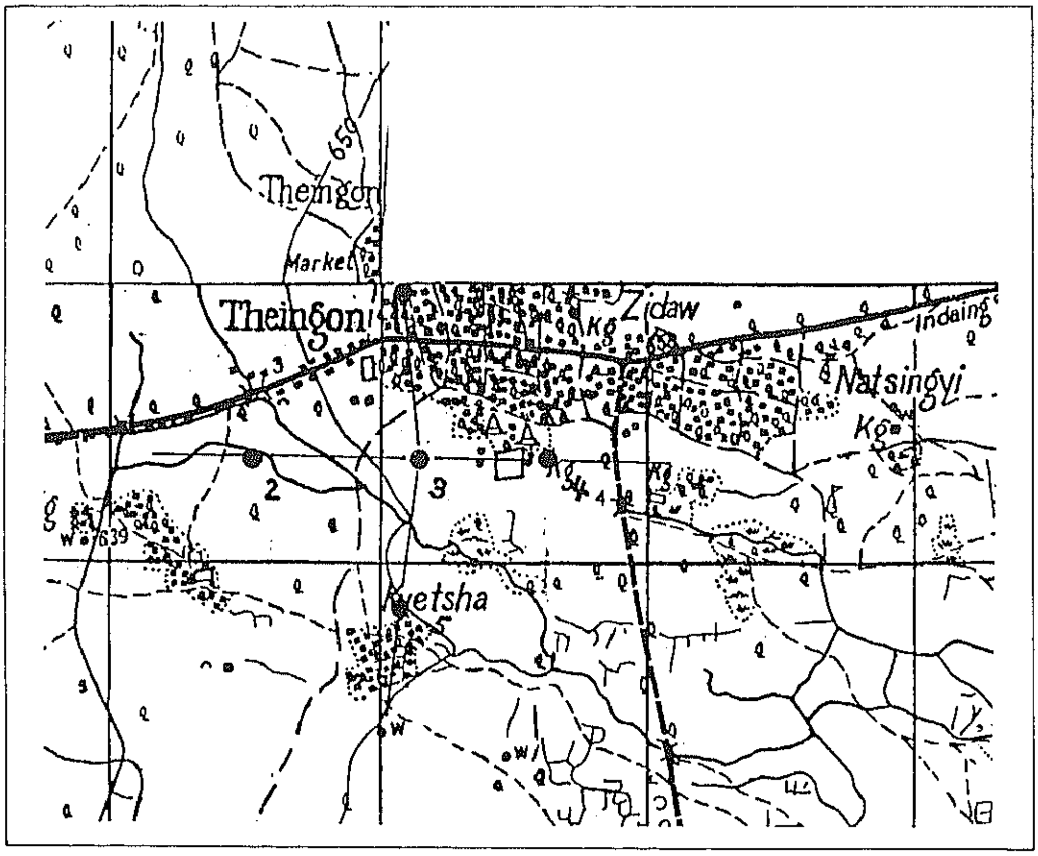


Fig. 4.2.4.8 Location of Electrical Survey Points

Scale 1:25,000

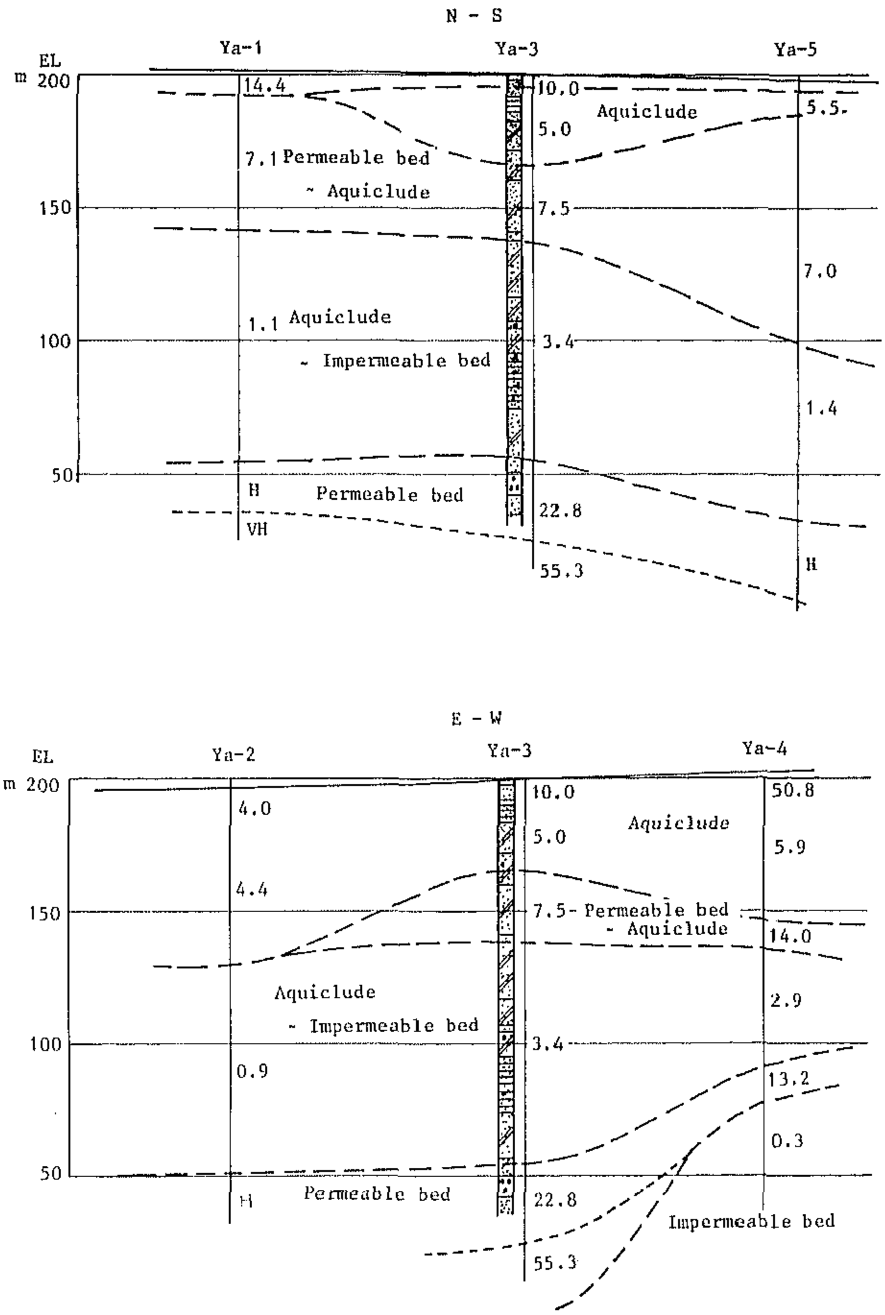


Fig. 4.2.4.9 Resistivity Profiles of Thingon

4) Ground Water Storage and Water Quality

(1) Ground Water Storage

The annual precipitation P and potential evapotranspiration E are as follows.

Precipitation $P = 34.19$ inch $= 868.6$ mm

Evapotranspiration $E = E_p \times 0.7$

$= 1,987 \times 0.7$

$= 1,390$ mm

(The value of evaportranspiration in Monywa is used)

Considering throughout the year, the ground water recharge G becomes as follows.

$G = P - E$

$= 868.6 - 1,390$

$\fallingdotseq -521$ mm

This means that the evapotranspiration exceeds the precipitation and therefore, no ground water recharge takes place. Considering the raing season only, the same may be said.

However, the ground water recharge in this area is supplied from the Shan high land, and the precipitation in the Shan high land is considered to be far above the precipitation in Yamethin. At this point, the precipitation in Pyinmana is used.

The precipitation in the rainy season in the Pyinmana area is 1,182 mm. If it is assumed that 75% of this value flows into the fan structure.

Effluent flow $P = 1,182 \times 0.75$

$= 886$ mm

Influent into the fan structure

$Q = P \times S = 0.88\text{m} \times 50\ \text{km}^2$

$= 4.3 \times 10^7 \text{m}^3$

If the infiltration ratio is 30%, then

$Q = 4.3 \times 10^7 \times 0.3$

$= 1.3 \times 10^7 \text{m}^3$

Thus, it is considered that the ground water rechange in this area is sufficient.

The ground water storage can be obtained from the volume and porosity of aquifers as follows.

$V = A \times S \times E$

where A: subject area 3.6 km^2

S: aquifer thickness 30m min.

E: porosity 15%

$$V = 3.6\ km^2 \times 30m \times 0.15$$
$$= 1.62 \times 10^7 m^3$$

This value ignores the ground water make-up flowout and shows the quantity stored in the present aquifer.

(2) Water Quality

Table 4.2.4.4 shows the results of the laboratory water test. As seen in this table, the ground water in the Theingon area satisfies the WHO standards and it presents no problem as the drinking water.

Table 4.2.4.4 Water Quality

		1984. 11.	1973. 9.26
1	Appearance	Clear	
2	Total solids	340.0 ppm	384.0 ppm
3	Total hardness	130.0 "	146.0 "
4	Permanent hardness	2.0 "	4.0 "
5	Calcium hardness	92.0 "	
6	Total iron	0.06 "	Nil
7	Chloride	6.0	4.0
8	pH	8.5	8.2
9	EC		

4) Discharge Rate per Well, spacing between Wells, and Well Depth

The discharge rate per well must be grapsed by conducting the pumping test. At this point, however, in accordance with Thiem's formula, the pumping quantity per well will be estimated. The lowering of water level S is found as 18.25m by the following calculations for the spacing between wells 600m (influence radius 300m).

$$S = R/3000\sqrt{k} = 300/3000\sqrt{3 \times 10^{-5}} = 18.25m$$

where R is 300m and k is 3×10^{-5} m/sec.

The ground water in this area is orterian water, and therefore, the discharge rate Q in given by

$$Q = \frac{2\pi Dk\ (H - h)}{2.3\ \log\ R/\gamma}$$

$$= \frac{2\pi\ \times 30 \times 3.0 \times 10^{-5} \times 18.25}{2.3\ \log\ 300/0.10}$$

$$= 0.0129\ m^3/sec = 836\ m^3/18\ hr$$

Therefore, it is considered that in this area at least 650 m^3/18 hr can be expected.

Regarding the well depth, considering the lower limit depth of storage of the aquifer of about 170m, the average depth of production wells will be taken as 176m (6m for sand reservoir)

4.2.5 Planning The Water Supply Systems

1) Project Area

When planning the water supply system for this town, the existing water conveyance facilties and water distribution facilties will be utilized as they are, on assumption of the rehabilitation of the intake facilities. Therefore, the area for this project will be that where the existing piping network is embedded.

2) Planned Water Supply Population and Planned Water Supply Rate

When planning the water supply system using the existing conveyance and distribution facilities as they are, it is necessary that the planned water supply population and the planned water supply rate should be below the capacities of the existing facilities. (Since both facilities have ample capacities, the planned water supply population and the planned water supply rate of this town will be based on the standards similar to those applied to other towns. Therefore, the planned water supply population will be taken as 25300 persons (1991) from the present population 22598 persons (1983) and the past average population growth rate 1.4%. The planned water supply rate will be taken as 2700 m^3/d from the planned water supply population and the planned daily maximum supply per capita 105 ℓ.

3) Facility Plan

As a result of the survey on the existing wells, it is judged that the cause for the trouble is that the planned pumping quantity is excessive as compared with the hydro-geological conditions of the existing well area, and the spacing between wells is too small. Therefore, since it is difficult to restore the function of the existing system by rehabilitation of the existing wells, new wells conforming to the hydrogeological conditions will be necessary to installed to be drilled.

The possible pumping quantity of planned wells is about 650 m^3/d per well as described above. On condition that the existing wells do not interfere with each other, only one well in operation at the present can be used, and this will be incorporated as part of the planned water supply rate. If the available pumping capacity with the existing wells is 200 m^3/d, the number of planned wells required (N) can be obtained in accordance with the following formula.

$$N = \frac{\text{planned water supply rate} - \text{possible pumping rate with existing wells}}{\text{available pumping rate with planned wells}}$$

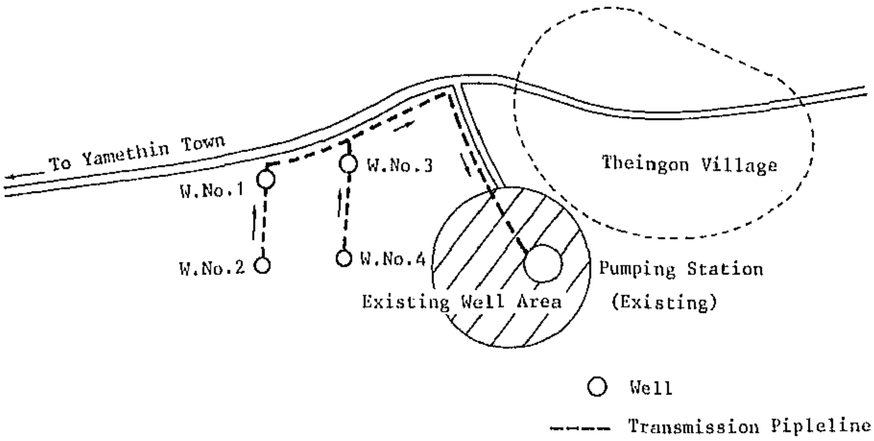
$$= \frac{2700\ m^3/d - 200\ m^3/d}{650\ m^3/d} = 3.8\ \text{(wells)}$$

From the above, 4 new wells will be installed. Fig. 4.2.5.1 shows the layout of the planned facilities.

4) Outline of The Facilities

Table 4.2.5.1 shows the specifications and quantities of various facilties.

For the construction of planned wells, refer to the reference drawings attached at the end.



Existing Population	22,598 ('83)
Pop. Increasing Rate	1.4 %
Design Population	25,300 ('91)
Water Demand	2,700 t/d
Discharg Rate per Well	600t/d-650t/d
Number of New Wells	4 nos.
Discharge from Existing Well	200 t/d

Fig. 4.2.5.1 Conceptional Diagrame of Proposed Faciliting

Table 5.2.5.1 List of Proposed Facilities

Facility	Item	Classification	No.	Remarks
Water intake facility	Production wells	Planned intake rate 600 to 650m^3/d φ200mm x H176m	4	Casing H = 160m Screen H = 16m
	Exploration wells	φ150mm x H220m	2	Casing H = 204m Screen H = 16m
	Observation wells	φ100mm x H176m	4	Casing H = 166m Screen H = 10m
	Intake pumps	φ65mm x 0.602m^3/min x 15kW	4	W-1 to W-4
	Pump rooms	Brick construction 4m x 4m Building area 16m^2	4 buildings	
Water transmission facility	Water transmission pipes	φ150mm to φ300mm T type ductile cast iron pipe class 3	2800m	
		Various reducers	1 set	
	Sluice valve	φ150mm to φ300	5	
	Air valve	φ20mm	4	
Electric facility	Substation equipment	3φ4W 150 kVA	1 set	
	Transmission line	OW 60□ CV 8□ x 4c	1.5km	
		Accessories	1 set	

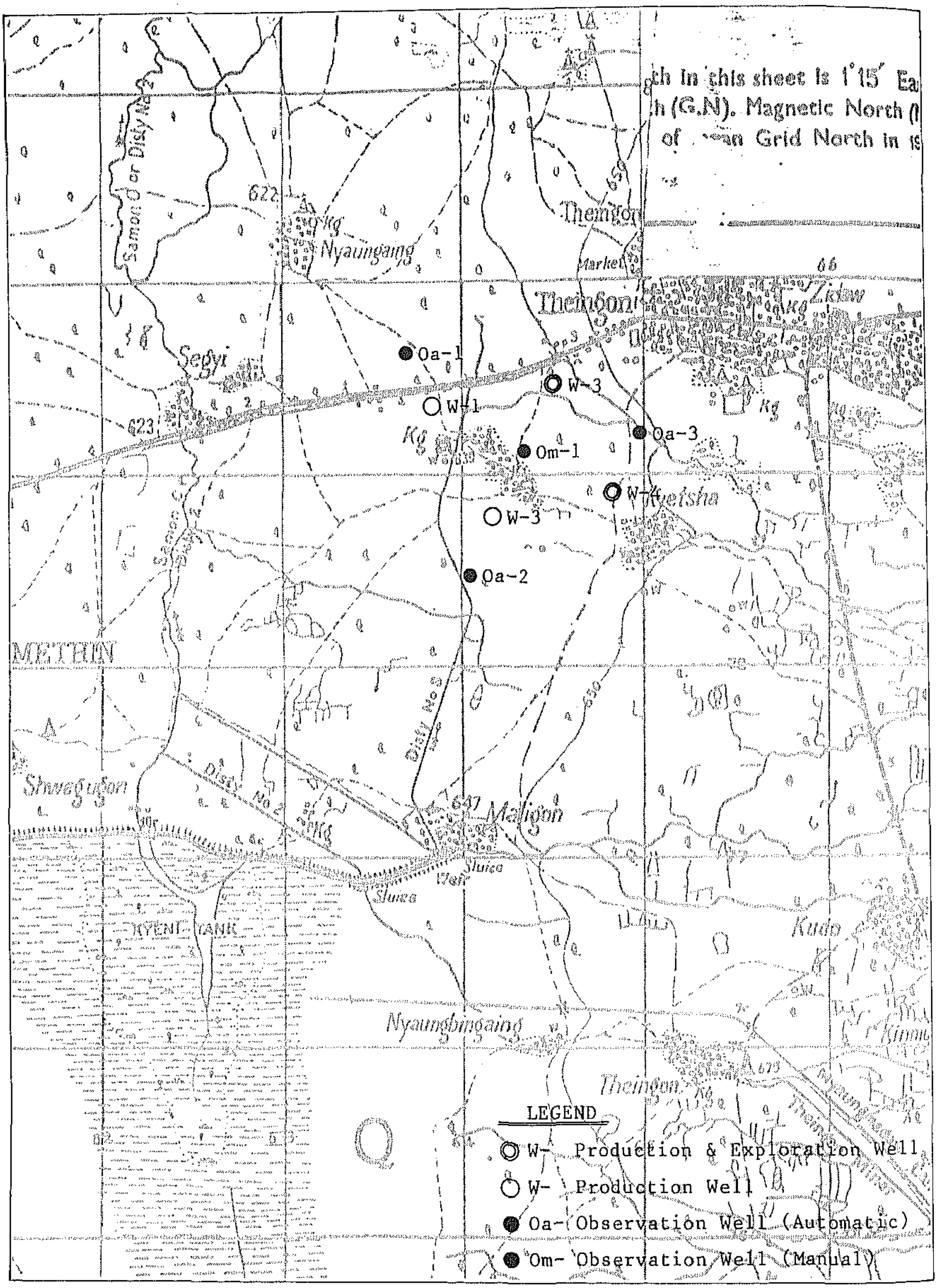
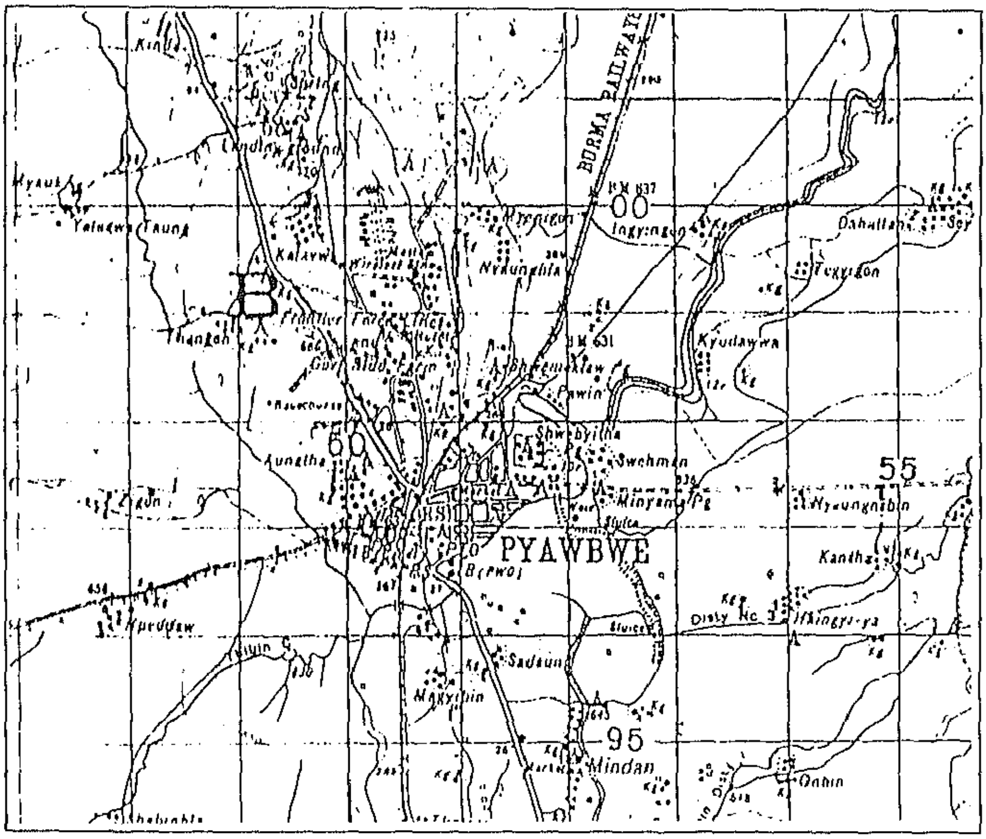
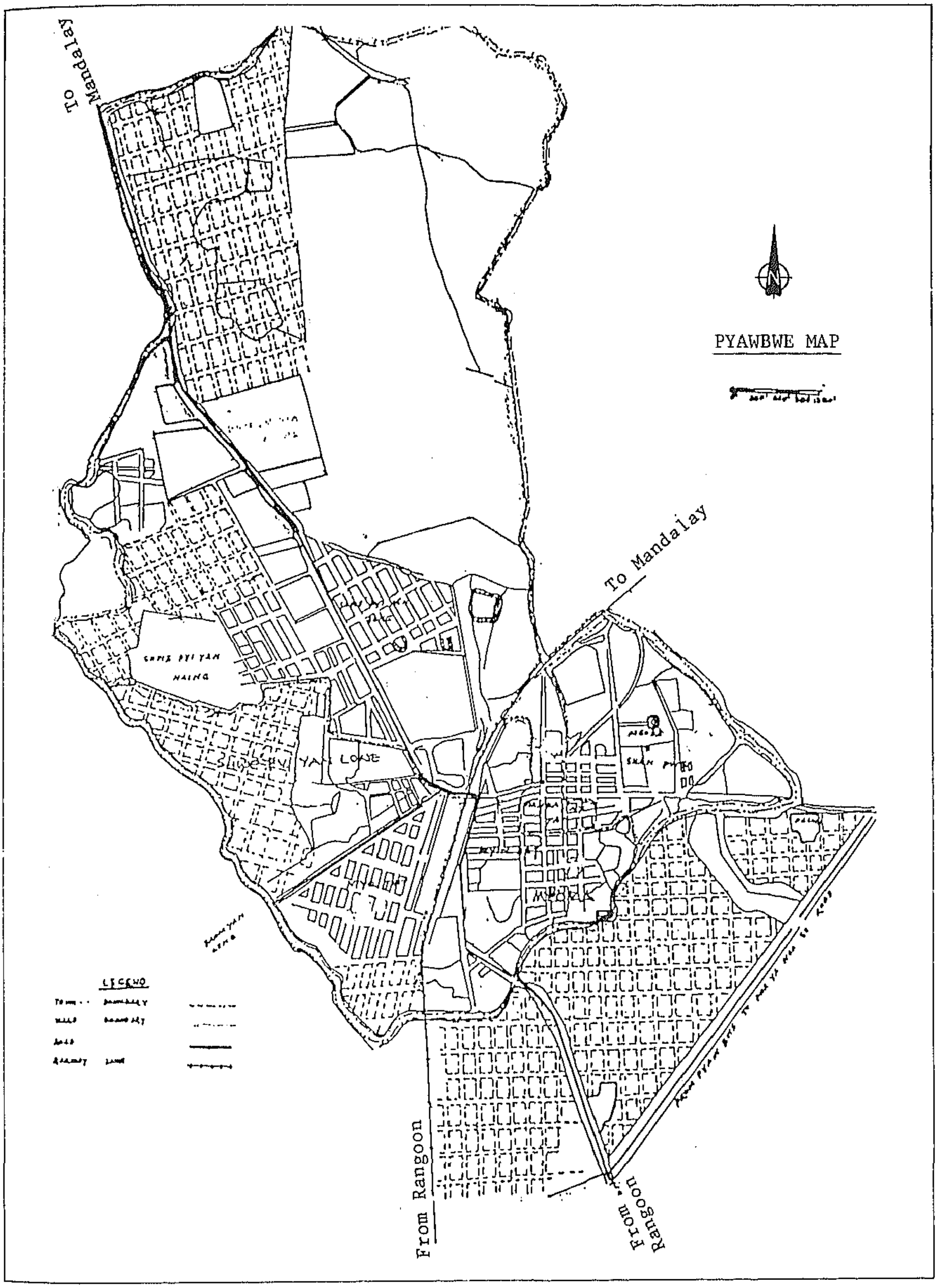


Fig. 4.2.5.2 Layout of Proposed Wells


BURMA RAILWAY
PYAWBWE
55
95
Mindan



To Mandalay
PYAWBWE MAP
To Mandalay
From Rangoon
From Rangoon
LEGEND

4.3.1 Outline of The Area

Pyawbwe we situated in the central part of Burma, and is located at about 450 km to the north of Rangoon. It has an area of 6.4 km^2 and population of 23834 persons.

This town was established as the town more than 60 years ago, and is on the Rangoon-Mandalay road as well as railways. It is connected through good roads with Magwe, too. In the town, there are several national factories, and in addition, private rice mills and cottage industry. Since industrial products, agricultural products, cattle, etc. are produced in the area, Pyawbwe has become en prosperous commercial center. Moreover, it is supplied with adequate electric power, and is provided with ample facilities for commerce, tranasportation, communication, etc., and therefore, many immigrants come to the town, and the town population is rapidly increasing. The annual growth rate of population is 2.2%.

The monthly average air temperature for past 10 years is 35°C maximum (April) and 20°C minimum (December to January). On the other hand, the annual average precipitation is about 850 mm, but the difference between years is as large as 500 mm to 1200 mm.

This town has had the water problem since its establishment, and dwellers are, even now, facing serious water shortage of drinking water and living water.

Up to now, the water resource development plans were set up several times, but for the monetary reason, none of them could be realized and there is no water supply system at the present.

Most of the dwellers depend on dug wells or tube wells, but well water in most cases is salty and is not sanitary. Especially in the dry season, the water quantity is badly decreased and the water quality is deteriorated, so that many people suffer from infectious diseases such as cholera, typhoid, smallpox, dengue fever, etc. Against fires, almost no measures can be taken.

In the dry season, almost wells in the town run dry and dwellers must obtain water from several shallow wells located about 3 km apart.

Fig. 5.3.1.1 shows population and areas by wards. Fig. 5.3.1.2 shows the ratio of areas by land use purposes.

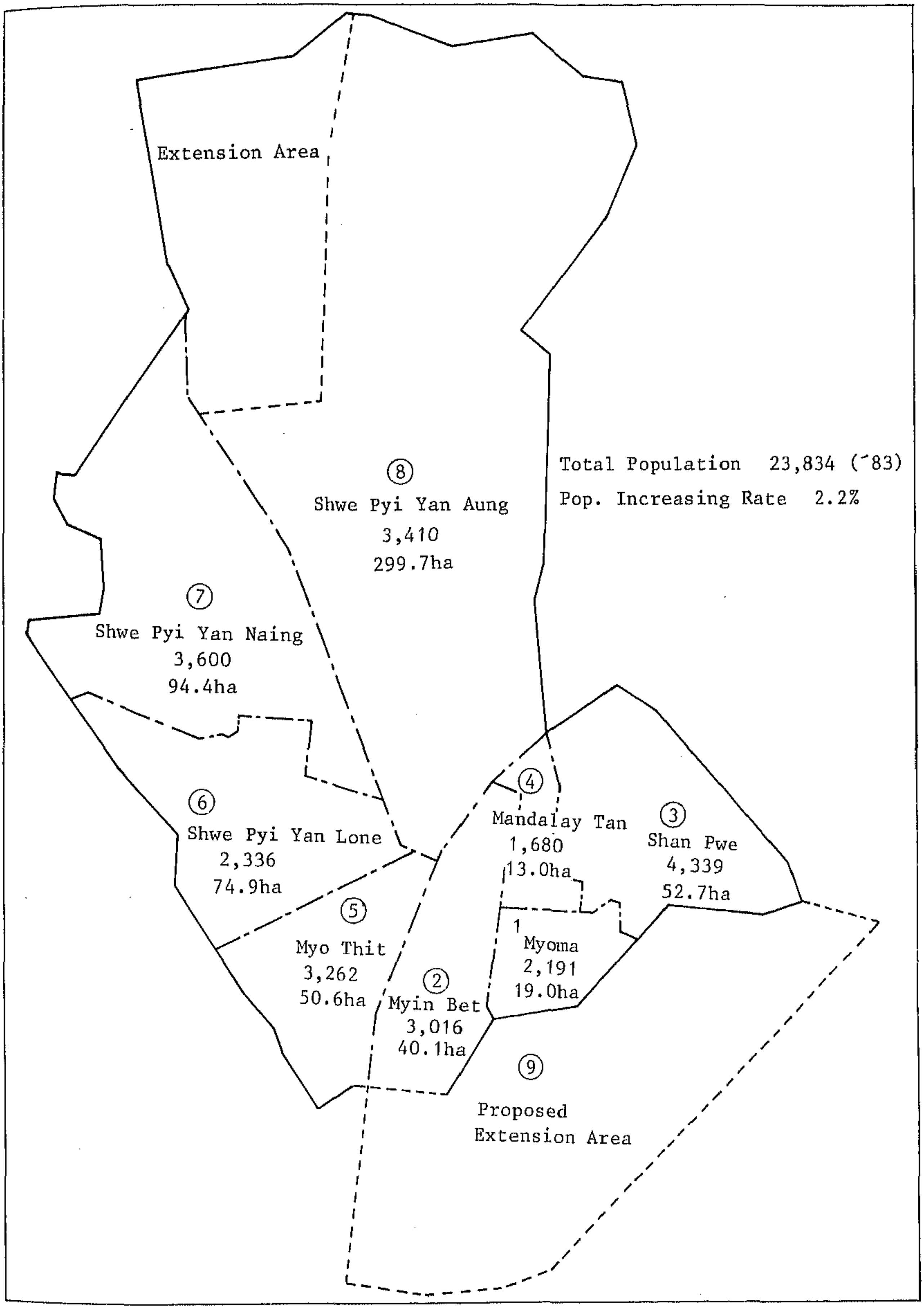
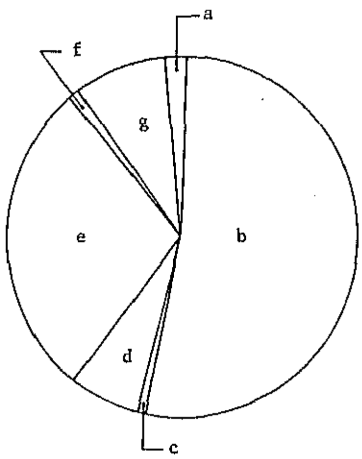


Fig. 4.3.1.1 Present Population and Area of Each Ward in 1983



a)	Agricultural Field.	2.0 %
b)	Residential Area	53.0 %
c)	Cemetery, Garden and Park	0.3 %
d)	Religious Center	6.6 %
e)	Commercial Places	28.9 %
f)	Industrial Areas	0.5 %
g)	Government Buildings (Offices, School, Hospital and Government Buildings)	8.7 %

Fig. 4.3.1.2 Ratio of Areas by Land Use Purposes of Pyawbwe

4.3.2 Water Resource Development Plan

1) Hydrogelogy

(1) Topography and Geology

The neighborhood of Pyawbwe is a part of a narrow basin contained bebween the Shan highlands consisting of palaeozoic rocks and graintes at about 15 km on the east side and the Pegu Yoma uplifts consisting of the Pegu formations of the oligocene and middle and lower mioscene of the tertiary period at about 10 km on the west side. (Fig. 4.3.2.1 and Fig. 4.3.2.2.)

On the west side of the basin, adjacent to the Pegu Yoma uplifts, the Irrawaddy formations formed in the upper miocene and pliocene of the tertiary period form hilled plateaus distributed at slow slopes. Moreover, the dilivium layers (fan deposits) formed in the quaternary period are distributed along the Shan highlands. In the other areaas, the alluvium layers are distributed, being narrow on the south side of Pyawbwe but becoming wider on the north side. However, on the north side of Pyawbwe, hills of the Irrawaddy formations extend at slow slopes toward Thazi. On the west side of the hills, at the part of transition from hills to alluvium low lands, faults of about 300 km extending from Mandalay to Toungoo run. (The neighborhood of the faults are expected for wells in the present plan.)

The alluvium low land divided into west and east parts around the central hills. On the west side, many small rivers flow down the hilled plateau at slow slopes to south or east toward the southern part of the Pyinmana area. On the other hand, small rivers from the Shan highlands flow across fans to west, and the Thitson river, Shweda river, etc. from Yamethin flow to north. These rivers have flowing water in the rainy season, but dry up in the dry season.

In the neighborhood of the Rangoon-Mandalay road in the southern part of the Pyawbwe area, the Irrawaddy formations following the hills appear in shallow places and the alluvium layers become thin.

The general geological order in the neighborhood of Pyawbwe is as follows.

Layer order	Age	Features
Alluvium	Alluvial epoch	Distributed in the surface layer.
Fan deposit	Diluvial epoch	Distributed along the Shan highlands
Diluvium	Diluvial epoch	Distributed in the plain and relatively thin
Irrawaddy formation	Upper miocene and pliocene	Distributed in hills and hilled plateaus. Partly, appearing in shallow places under the alluvium layers

The alluvium layers are distributed as sand and clay alternates, with thick distribution of sand layers in part. The diluvium layers consist mainly of clay, mixed with thin layers of sand and gravel. The Irrawaddy formations have the fold structure and consist mainly of clay, mixed with layers of sand and gravel.

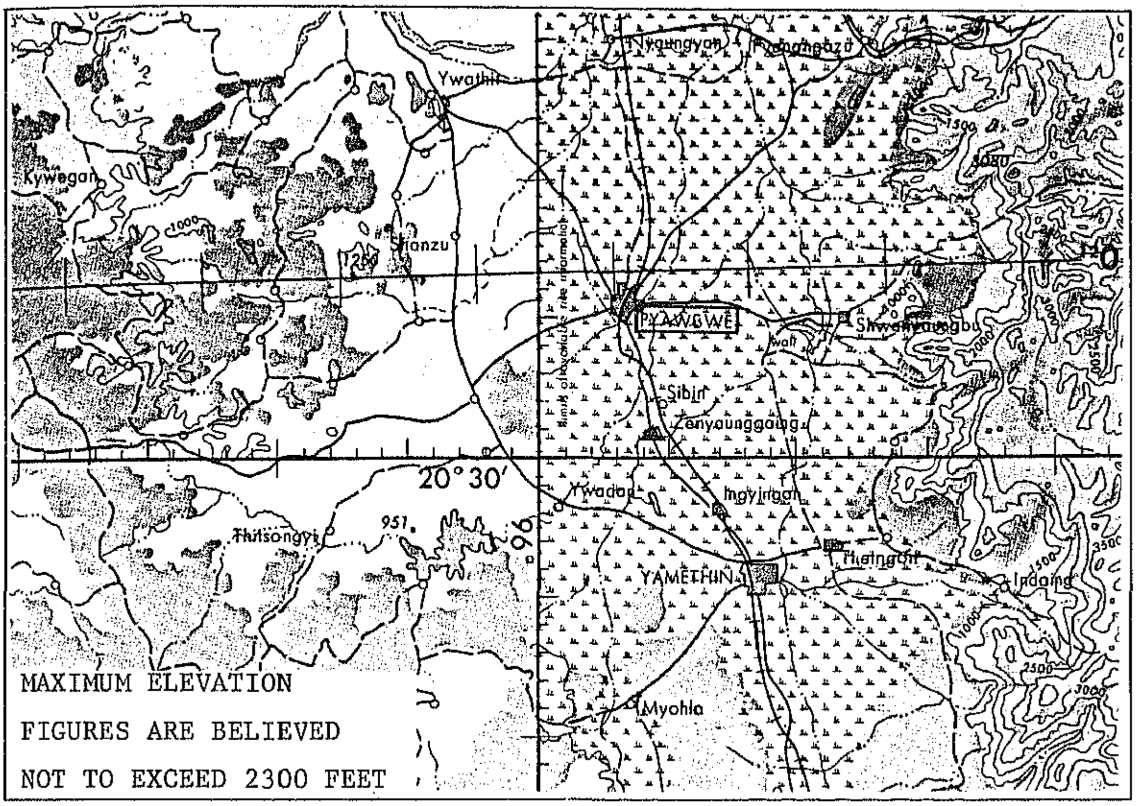


Fig. 4.3.2.1 Topographical map of Pyawbwe Scale 1:500,000

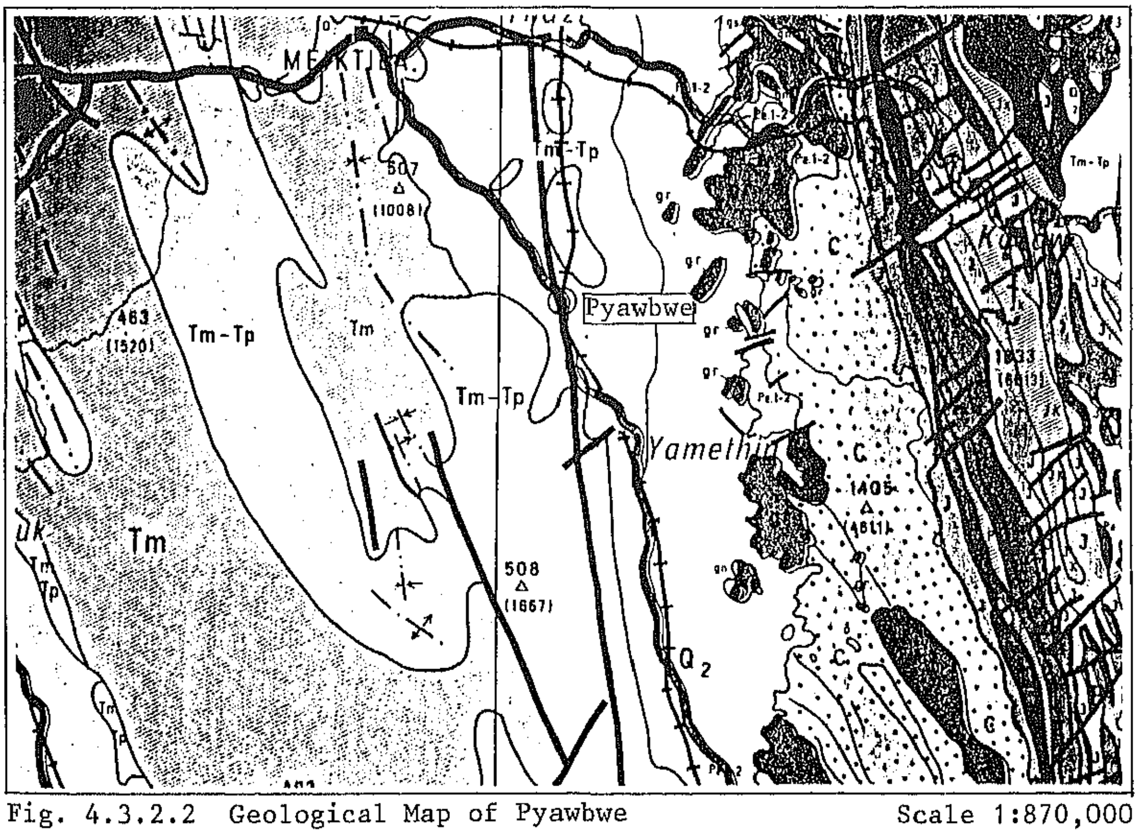


Fig. 4.3.2.2 Geological Map of Pyawbwe Scale 1:870,000

(2) Hydrogeology

In the Pyawbwe area, the geological structure is complicated in the hills and their neighborhood since there are folds and faults of the Irrawaddy formations extending in the south-north direction. However, the diluvium on both sides of hills slope slowly to the east and have relatively simple geological structures. The lower surfaces of the alluvium layers are rolling probably due to the extended Irrawaddy formations.

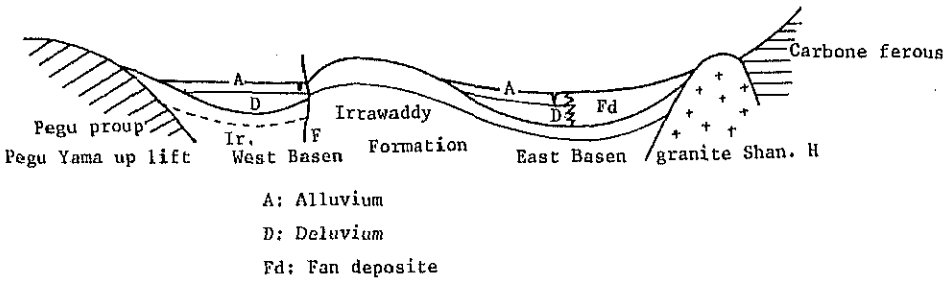


Fig. 4.3.2.3 Conceptional Profile of E to W

Fig. 4.3.2.3 shows a model profile in the east-west direction of Pyawbwe. This area is a semiarid area. It may be considered that the ground water recharge is undertaken by the water from the Shan high lands and Pegu Yoma uplifts.

In the basin on the west side and on the east side, the ground water is artesian water, and sometimes artisian flows are seen around the basin, because of the structure of diluvium or Irrawaddy formation.

On the south side of Pyawbwe, most parts except the ridges of the Irrawaddy formation are artesian zones.

Fig. 4.3.2.4 shows the distribution of the existing wells in the Pyawbwe area. These wells take water from sand and gravel layers in the Irrawaddy formations. On the north side of the railways, the well depth is about 18 to 30m except in some cases, and on the south side of the railways, it is 90 to 130m in most cases and 20 to 30m in some cases. For the ground water in shallow layers, shallow wells of 4 to 7m are seen.

The conditions of each aquifer are as follows.

① The aquifers in the surface layer portion distributed at 4 to 7m depth from the ground surface, and hand-dug wells are used, the water contains much salts and has high turbidity. The electric conductivity is 1,000 to 2,200 μS/cm, and pH 7 to 8.5. The water is in small quantity and the welkls dry up in the dry season.

② The aquifers in the hill portion have two ranges of depths, 20 to 30m and 90 to 130m. Tube wells are used. The water contains salts and has high turbidity. The electric conductivity widely varies with location in the range from 1,000 to 4,000 μS/cm but generally being 1,200 μS/cm indicative of considerably high dissolved salts.

③ The aquifers in the plain portion are sand and gravel layers mixed in the alluvium and diluvium layers. Wells are artesian wells. Generally speaking, the water quality is not good. The electric conductivity is usually higher than 1,000 μS/cm.

The ground water in this area follows the ground water surface along the topographical surfaces. In the alluvium low lands, it flows to south on the west side of Pyawbwe and to north or east on the east side.

2) Aquifer

The aquifers in the Pyawbwe are sand and gravel layers of alluvium and diluvium, and sand and gravel layers of the Irrawaddy formations. Any of these layers is mixed in the clay layers, and the thickness varies with the location. Few existing well logs are available, and the well log data for hospital wells are as follows.

0.0 to 6.1m :	clay	6.1 to 9.1m :	fine sand
9.1 to 12.2m:	clay	12.2 to 24.4m:	fine sand
24.4 to 36.6m:	coarse sand with gravel		

These wells are located in the hills corresponding to the Irrawaddy formations.

In the alluvium low sands, the aquifers are 3 to 5m thick in the clay layers. The depth varies badly with the location, but generally 30 to 40m.

In the Pyawbwe area, electric prospecting was carried out at 28 points as shown in Fig. 4.3.2.5.

The results are shown by the resistivity profile in Fig. 4.3.2.6, and the low resistivity values for the impermeable beds are also shown. The low resisitivity profiles are showing the contour of impermiable bed depths as shown in Fig. 4.3.2.7.

The analytical results indicate the following conclusions:-

① The resistivity in the Pyawbwe area is low as a whole. The high resisitivity as the permeable beds is shown only in the surface layer. Except the surface layer, the layer corresponding to aquiclude beds shown 1.0 to 10 Ω-m forms the second layer. The third layer form the impermeable bed of 0.1 Ω-m or below, and this impermeable bed is distributed down to the deep portions.

② The layer corresponding to aquiclude bed is distributed in the form eroding the impermeable bed.

③ The condition of the altitude of the upper surface of the impermeable bed showing the low resistivity (profiles shown in Fig. 4.4.3.7) depend on the condition of the hills and embedded hills consisting of the Irrawaddy formations.
The depressions on the east side seem due to erosion, but the depressions on the west side seems to depend on the condition of the fault extending from Thazi.

④ In the neighborhood of points Pya-4 and -5 and in the neighborhood of Pya-14, -18 and -21, where the electric prospecting has been done, of and Pya-24, -25, -26 and -27, it is found that the aquiclude layer is extending in these areas. It is good therefore to plan wells in these areas.

It may be considered that the ground water in this area is stored in the layer corresponding to the aquiclude layer. The ground water is also stored in the sand and gravel layers mixed in the impermeable beds. The former is in the form of free groundwater, and the latter is in the form of artesian water.

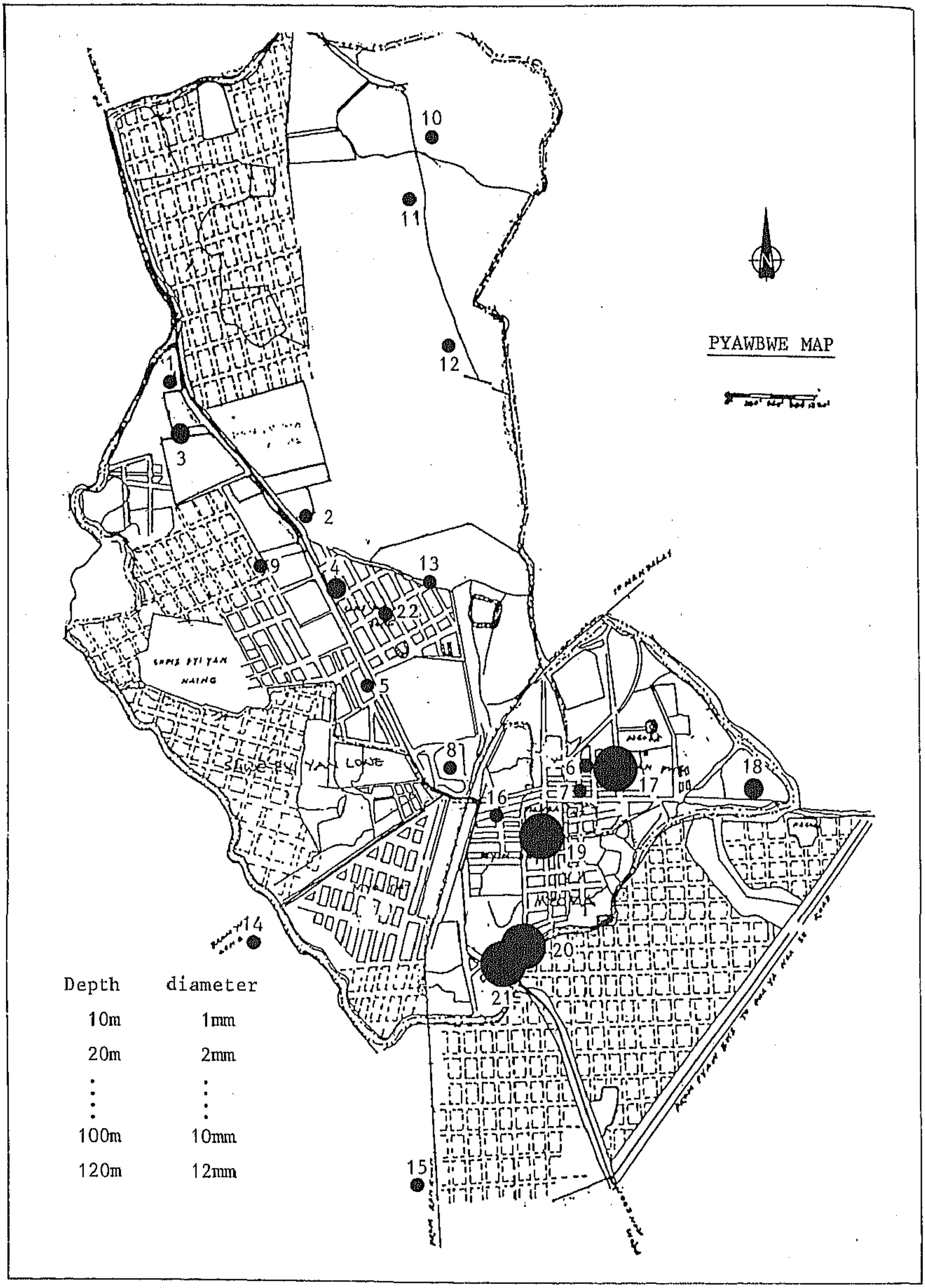


Fig. 4.3.2.4 Location and Depth of Existing Tube Wells.

In the Pyawbwe area, much fine particles are mixed in the layer where the screen is installed, the permeability seems to be lower.

According to one existing well log for the Irrawaddy formations, the permeability can be calculated as follows:-

$$Q = \frac{2.3\ \theta\ \log R/r}{2\pi m\ (H - h)} = \frac{2.3 \times 4525 \times \log 50{,}000/1016}{2\pi \times 1{,}220 \times 305}$$

$$= 1.68 \times 10^{-2}\ \text{cm/sec}$$

This value may be considered as the general value for the Irrawaddy formations.

Since no existing well log for the alluvium and diluvium is available, it is dificult to calcualte the coefficient of permeability. However, on assumption of fine sand aquifer, it can be estimated to be about 2×10^{-3} cm/sec.

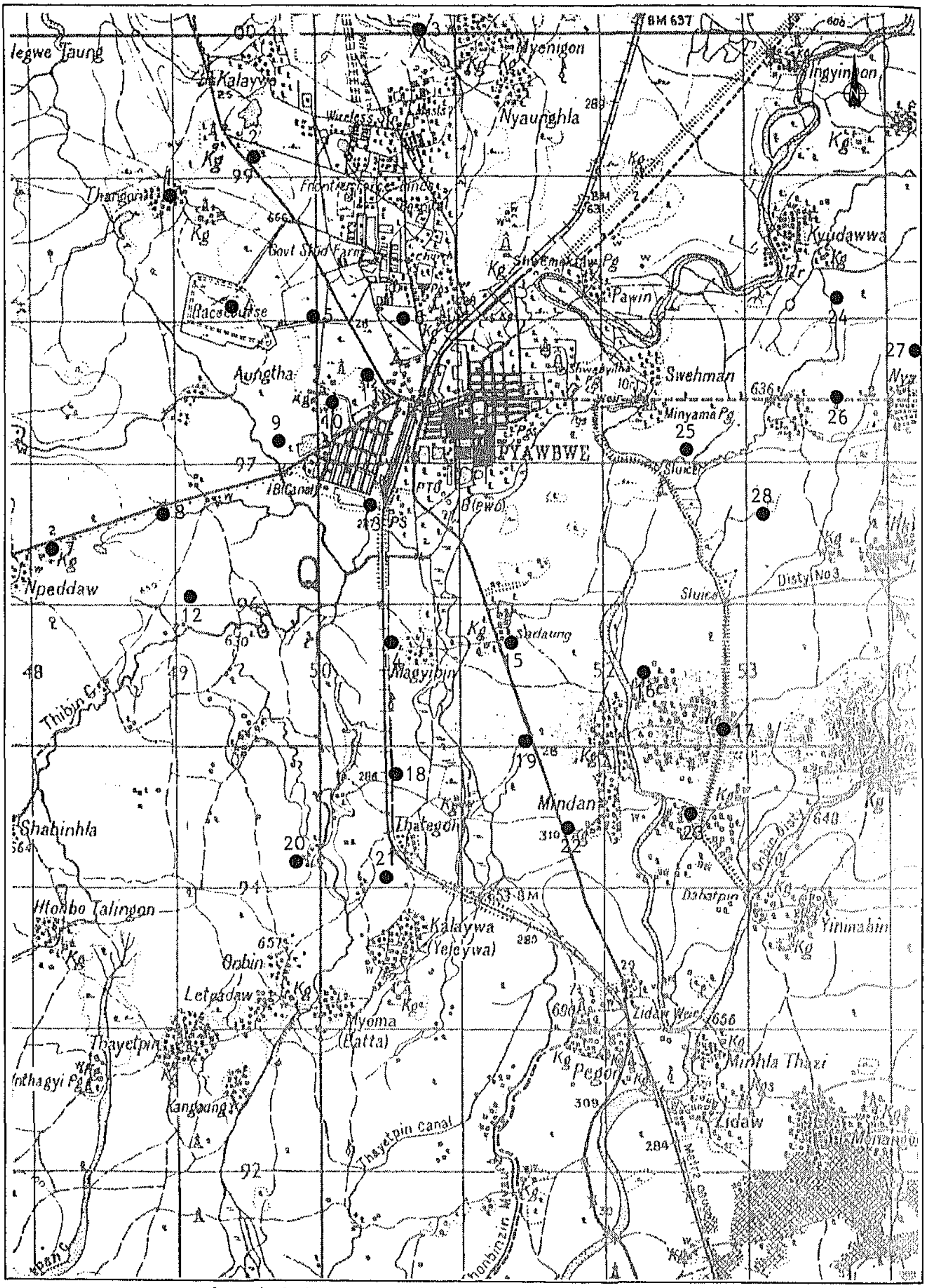


Fig. 4.3.2.5 Location of Electrical Survey Points

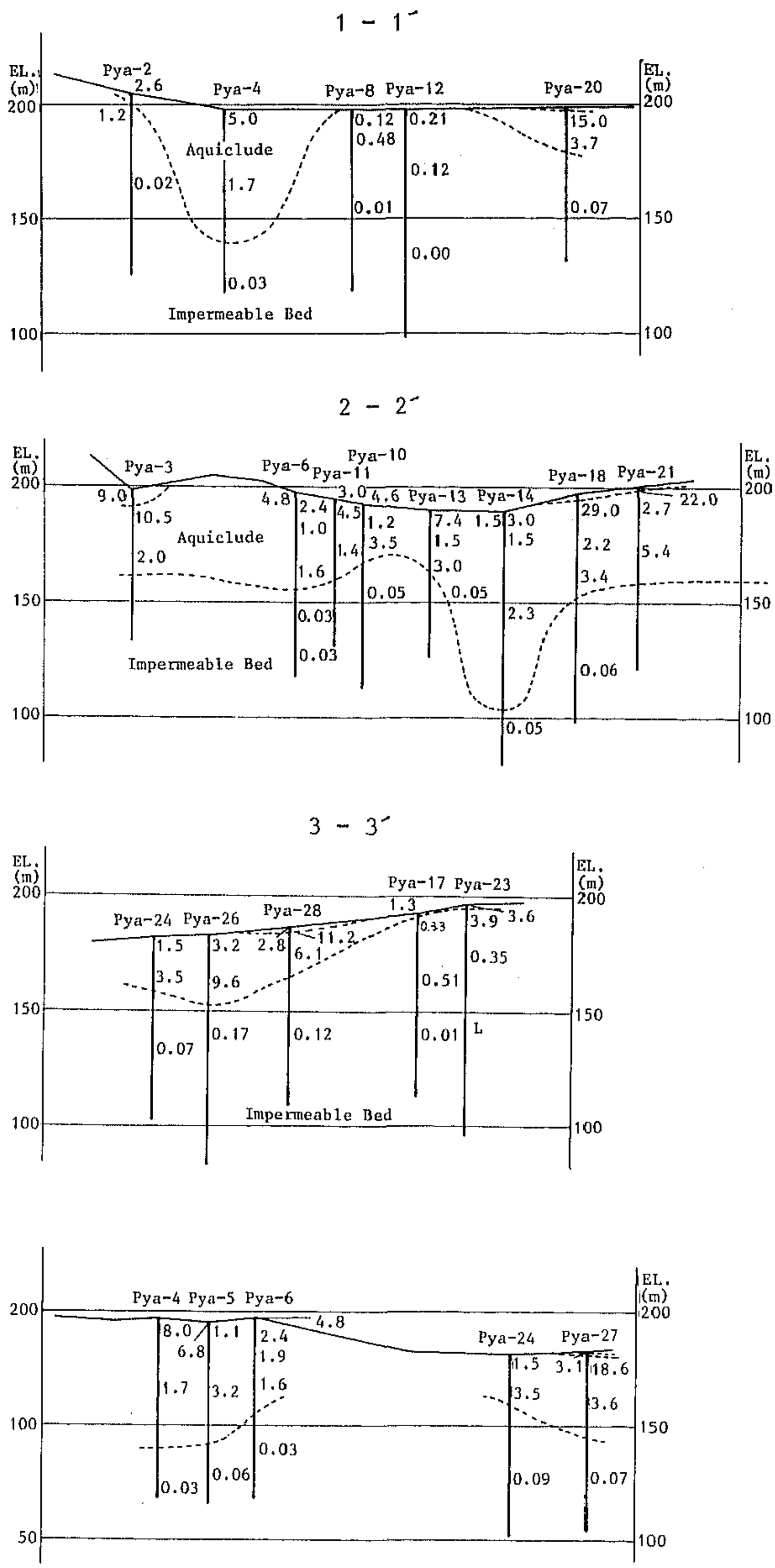


Fig. 4.3.2.6 Resistivity Profiles of Pyawbwe (1)

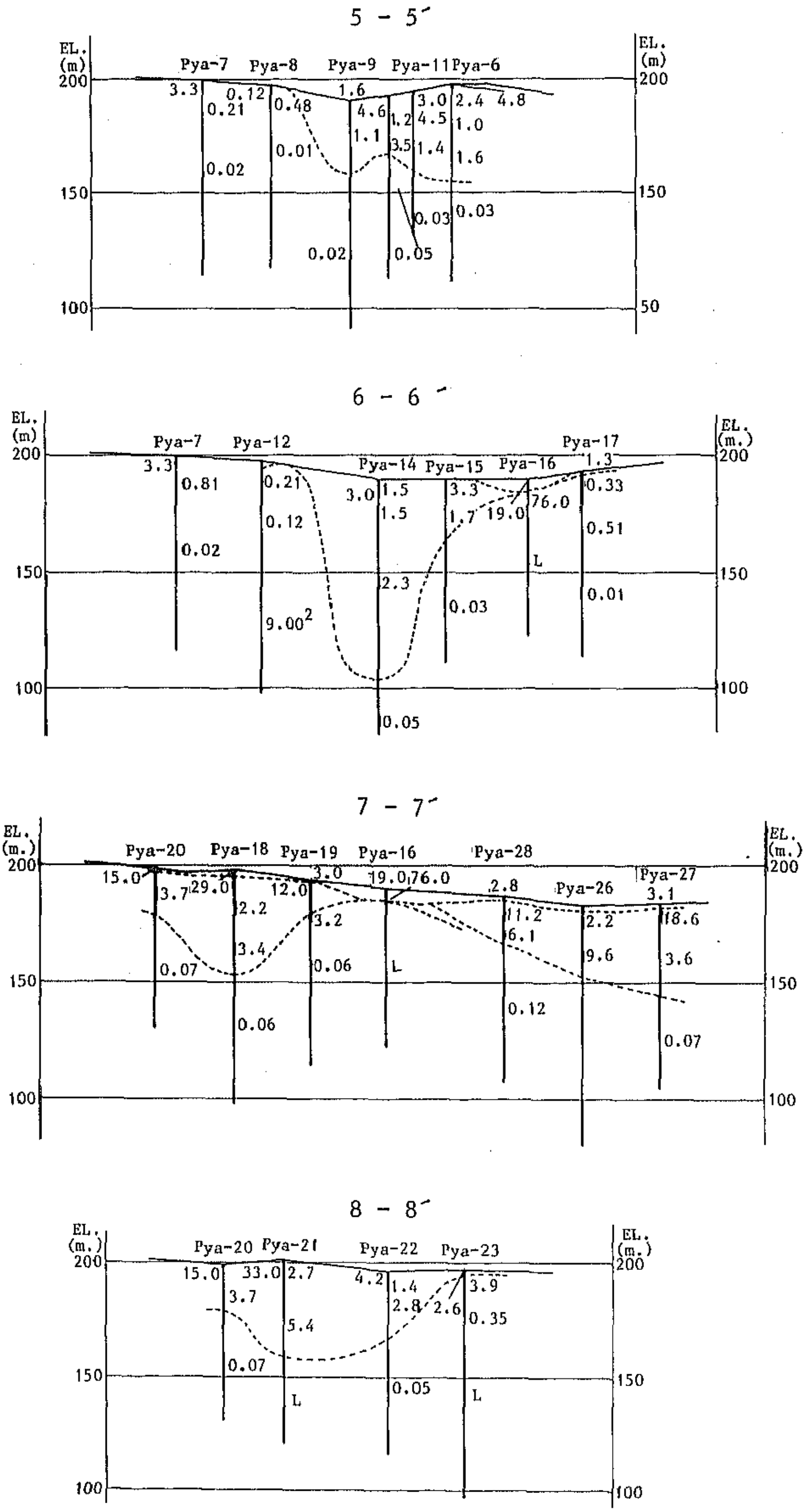


Fig. 4.3.2.6 Resistivity Profiles of Pyawbwe (2)

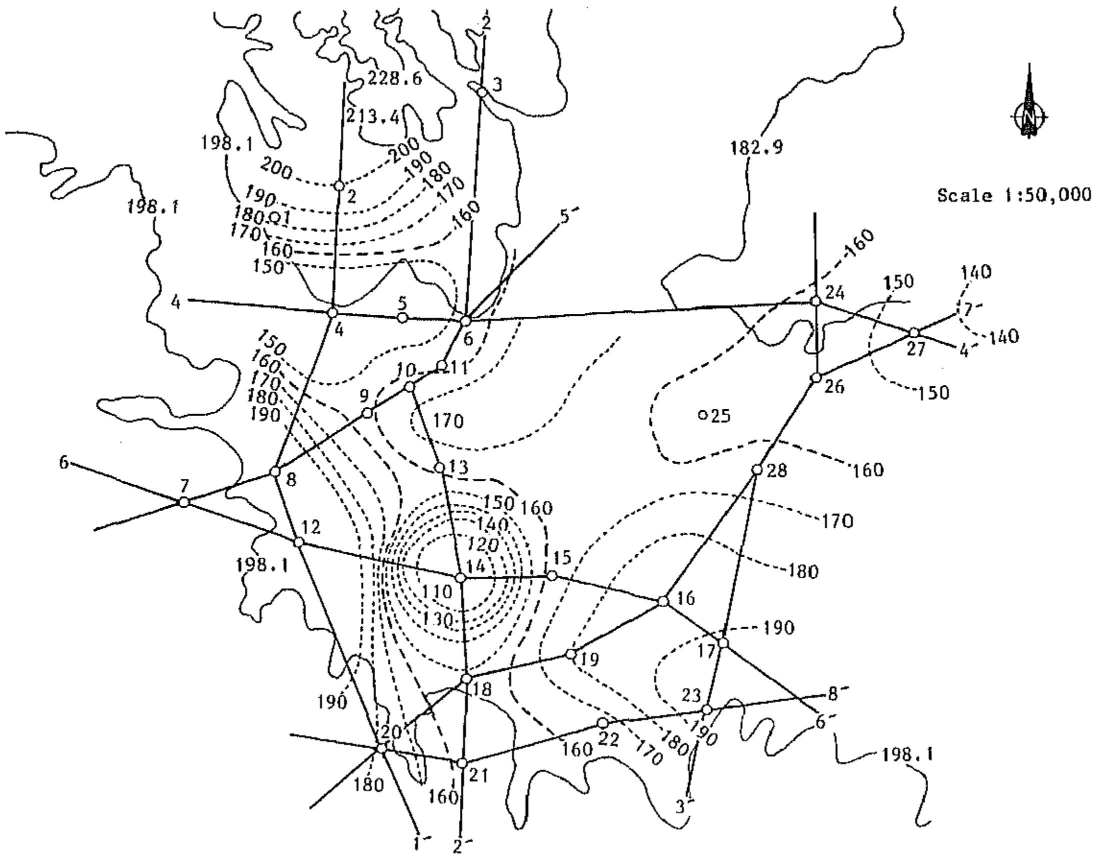


Fig. 4.3.2.7 Resistivity Contour of Impermeable Bed in Pyawbwe

3) Ground Water Storage and Water Quality

(1) Ground Water Storage

The groundwater storage in the Pyawbwe area is in the form of free and artesian water. At this point, the ground water supply and storage will be calculated on the basis of the free groundwater.

The annual precipitation P and potential evapotranspiration E are as follows:-

Precipitation P = 33.41 inch = 848.6 mm

Evapotranspiration E = Ep x 0.7

= 2,040.9 x 0.7

= 1,429 mm

(The value of evapotranspiration in Mandalary is used)

Considering throughout the year, the ground water recharge G becomes as follows:-

$$G = P - E$$
$$= 848.6 = 1,429$$
$$\fallingdotseq -580 \text{ mm}$$

This means that the evapotranspiration exceeds the precipitation and therefore, no groundwater recharge has taken place.

However, the groundwater recharge in this area is suppliec by river water flowing out from the Pegu Yoma and hilled plateaus. The precipitation in the rainy season in the Pyawbwe area is 761 mm. If it is assumed that 60% of this value flows into the allevium low lands, then

Effluent flow $P = 761 \times 0.6$
$= 456$ mm

Influent into the alluvium low land

$$Q = P \times S = 0.45 \text{ m} \times 2.5 \text{ km}^2$$
$$= 1.12 \times 10^7 \text{ m}^3$$

If the infiltration ratio is 40%, then

$$Q = 1.12 \times 10^7 \times 0.4$$
$$= 4.48 \times 10^6 \text{ m}^3$$

Thus, annually, water is made up in the value of 4.5×10^6 m^3. However, if the annual precipitation varies (decreases), the water make-up is not sufficient and the water level may be lowered.

The groundwater storage can be obtained from the volume and porosity of aquifers as follows:-

$$V = A \times S \times E$$

where A: subject area 8.5 km^2

S: aquifer thickness 1.0m

E: porosity 10%

$$V = 8.5 \text{ km}^2 \times 20\text{m} \times 0.10$$
$$= 1.7 \times 10^7 \text{ m}^3$$

This value ignores the groundwater make-up and flow out and shown the quantity stored in the present aquifer.

(2) Water Quality

Table 4.3.2.1 shows the results of the laboratory water test.

Table 4.3.2.1 Water Quality

Item \ Location	Magyibin V.	Tanaung Sin Waing V
1 Appearance	Clear	Clear
2 Total Solids	850	1,410
3 Total hardness	100	40
4 Permanent hardness	2	2
5 Calcium hardness	40	30
6 Total iron	0.05	0.05
7 Chloride	22	116
8 pH	6.2	7.8
9 EC	1,100	2,200

The Tanaung Sin Waing village in the outside of the subject area shows very large total solids content and the water is not suitable for drinking. The Magyibin village also shows slightly higher total solids and chloride contents, but since these values satisfy WHO standards, the water seems suited for drinking.

4) Discharge Rate per Well, Spacing between Wells, and Well Depth

The discharge rate per well must be grasped by conducting the pumping test. At this point, however, in accordance with Thiem's formula, the discharge rate per well will be estimated. The lowering of water level S is found as 22.36m by the following calculations for the spacing between wells 600m (influence radius 300m).

$$S = R/3000 \sqrt{k} = 300/3000 \sqrt{2x10^{-5}} = 22.36mm$$

where R is 200m and k is 2×10^{-5} m/sec.

For free ground water:

$$Q = \frac{\pi . k \ (H^2 - h^2)}{2.3 \log R/r}$$

$$= \frac{\pi \times 2 \times 10^{-5} \times (400^2 - 17.7^2)}{2.3 \log 3000/0.076}$$

$$= 9.77 \times 10^{-3} \ m^3/sec = 633 \ m^3/18 \ hr$$

For artesian ground water:

$$Q = \frac{2\pi Dk \ (H - h)}{2.3 \log R/r}$$

$$= \frac{2\pi \times 20 \times 2 \times 10^{-5} \times 22.36}{2.3 \log 300/0.076}$$

$$= 6.8 \times 10^{-3} \ m^3/sec = 440 \ m^3/18 \ hr$$

In the case of free ground water, 633 m^3/18 hr is obtained, and in the case of artesian ground water, 440 m^3/18 hr can be expected. However, the lowering of the water level of 22.3m is too large for the well depth and permeability. It is desirable to keep it at about 10m. In such case, Q = 3.5 x 10^{-3} m^3/sec = 226 m^3/18 hr, hence 200 m^3/18 hr can be expected.

(2) Spacing between Wells

Considering the ground formations, conditions of aquifers, and the discharge rate per well and the lowering of the water level in accordance with the existing data, etc., the minimum spacing bewteen wells will be taken as 500m.

(3) Well Depth

Regarding the well depth, considering the lower limit depth of storage of the aquifer of about 40m, the average depth of production wells will be taken as 46m (6m for sand reservoir).

4.3.3 Planning The Water Supply System

1) Project Area

The dwelling area in this town consists of wards 1 through 7 and part of wards 8. TDC is planning to construct a new extesion area in each of two parts, northern and southern, of the town.

The new extension area in the northern part is now under construction and dwelling has started although only to a small extent.

The new extention area in the southern part is located in the construction of the road from Rangoon to Shan State. It is scheduled that the construction of this road should be started 4 to 5 years after, but there are many uncertain factors, and accordingly, the construction of the new extension are in the southern part is not certain. (Fefer to Fig. 4.3.3.1.)

Therefore, for the present plan, the new extension area in the southern part will be omitted, that is, this plan will cover wards 1 through 7, part of ward 8, and the new extension area in the northern part only. (Refer to Fig. 5.3.3.1.)

2) Planned water supply population

The planned water supply population is taken as 28400 persons (1991) considering the present population 23834 persons (1983) and the past average population growth rate of 2.2%.

3) Planned Water Supply Amount

The planned water supply amount is takne as 3000 m^3/d considering the planned water supply population and the planned daily maximum supply per capita 105 ℓ.

4) Division into Water Supply Blocks

The present dwelling area is divided by the Rangoon-Mandalay railway into two parts, east and west. The parts on the east side are wards No. 1 through No. 4 and the parts on the west side are wards No. 5 through No. 8. The extension area is planned in a remote place to the north of these dwelling wards. Therefore, in this project, the planned water supply area will be divided into three blocks A, B and C, each of which has been given an independent system (as shown in Fig. 4.3.3.3).

The planned water supply population, water supply area, popultion density and planned water supply amount by blocks are as shown in the following table.

Table 4.3.3.1 Planning Conditions by Blocks

	Planned water supply population (person)	Water supply area (ha)	Population density (person/ha)	Planned water supply amount (m^3/d)
A	11,500	109	106	1,200
B	14,900	217	69	1,560
C	2,000	89	23	210
Total	28,400	415	Ave. 68	2,980

5) Facility Planning

① Number of wells required

The available discharge rate per well of this area is about 200 m^3/day as described above. Therefore, the number of wells required by blocks is as follows:-

Block A 1200 $m^3/d \div 200 = 6.0 \rightarrow 6$

Block B 1560 $\div 200 = 7.8 \rightarrow 8$

Block C 210 $\div 200 = 2.1 \rightarrow 1$

Thus, the total number of wells will be 15.

② Water supply system

Pyawbwe is situated on the hills called Pyawbwe hill, which is slowly slopes as a whole. In this plan, however, since the geographical map (contour map) showing the slope of the area hasa not been available, it is assumed that the water supply area is practically level.

To the water supply system for each block, the basic system shown in the following table has been applied in accordance with the relation between the expected well site and water supply area. Block C which is sloping slowly is convexed at the central part and it is judged that if the ground reservoir is installed there, water distribution by gravity may be possible. Thus it was decided that the elevated tank should not be installed.

Table 4.3.3.2 Basic System for Each Block

Block	Basic system	Remarks
A	2	
B	2	
C	3	Production well 1

Fig. 4.3.3.4 shows the facility layout for each block based on the above basic system.

6) Outline of Facilities

Table 4.3.3.3 shows specifications and quantities for facilities.

Fig. 4.3.3.4 and Fig. 4.3.3.5 show water transmission pipeline and distribution pipeline networks, respectively. For the construction of the planned wells and elevated tanks, refer to the drawings given at the end of this chapger.

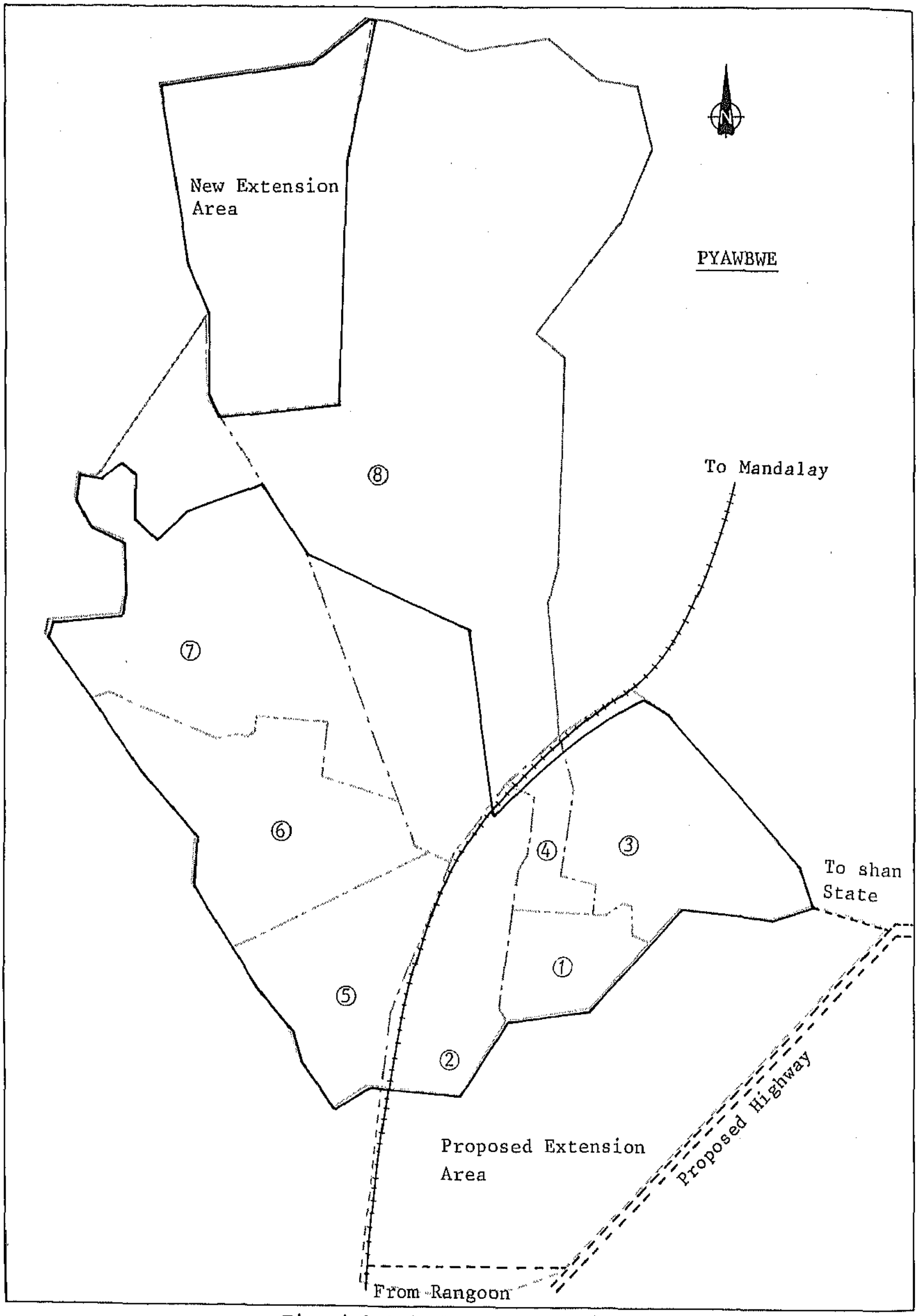


Fig. 4.3.3.1 Proposed Service Area

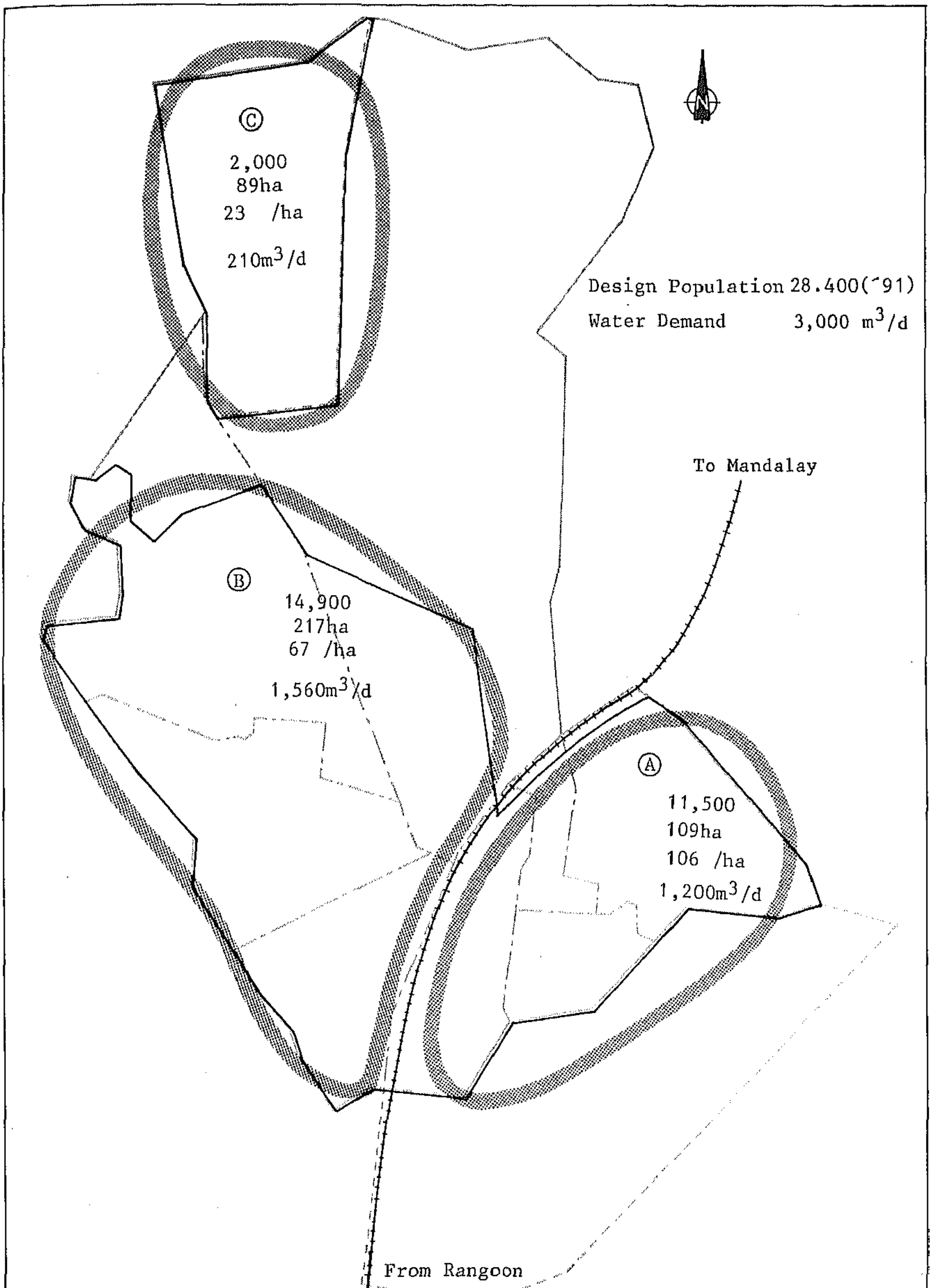


Fig. 4.3.3.2 Distribution of Design Population

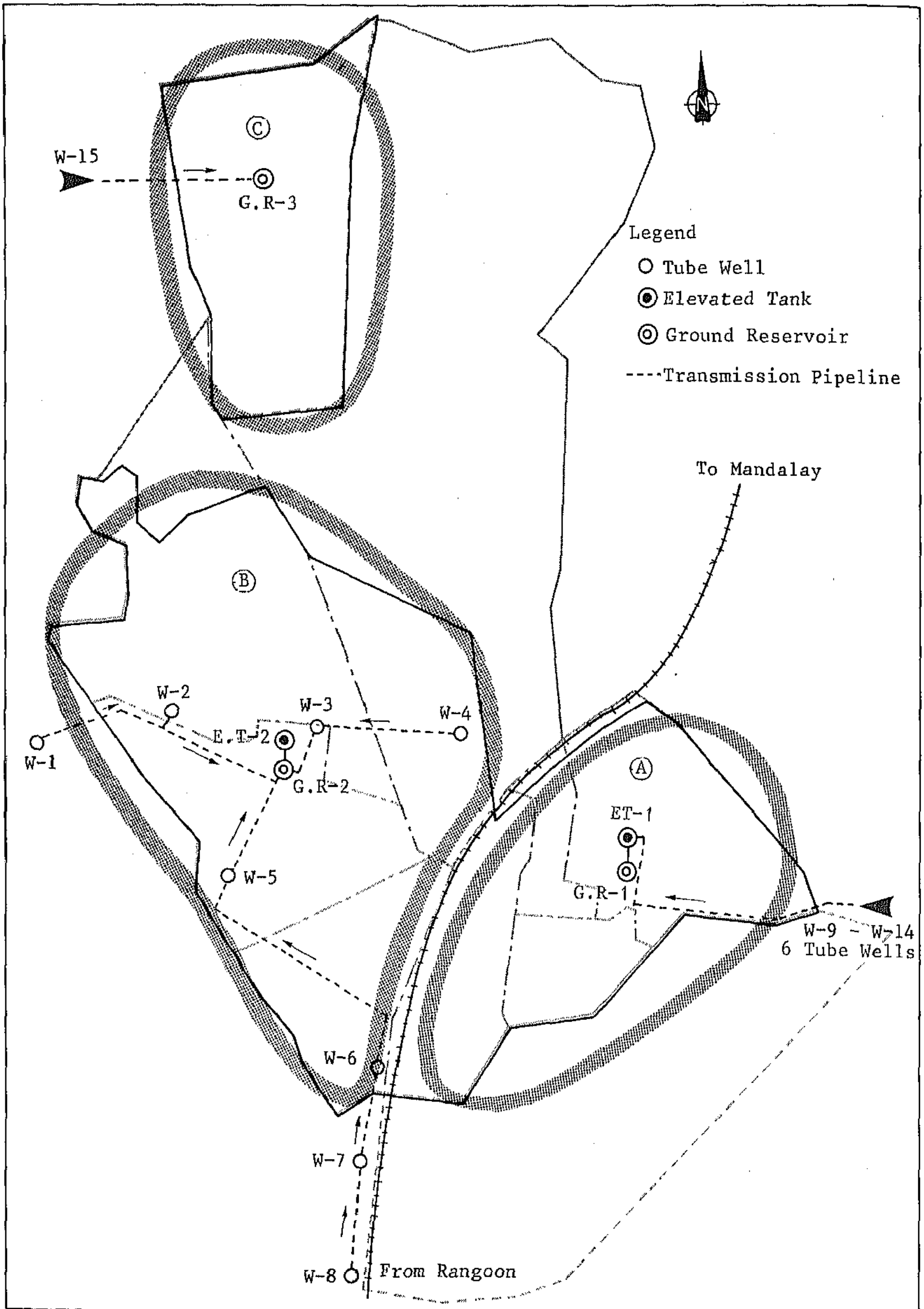


Fig. 4.3.3.3 Layout Plan of Proposed Facilities

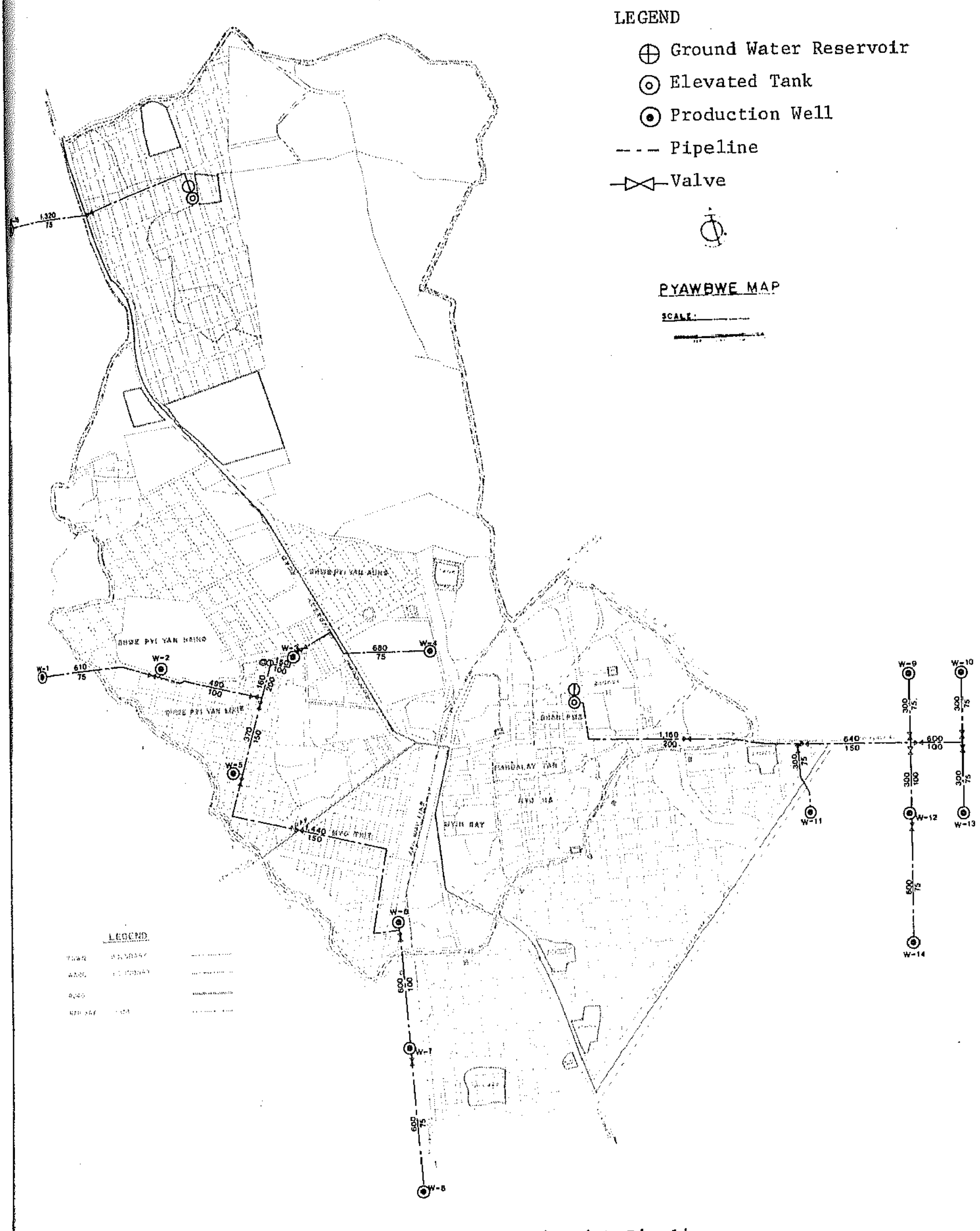


Fig. 4.3.3.4 Network of Distribution Pipeline

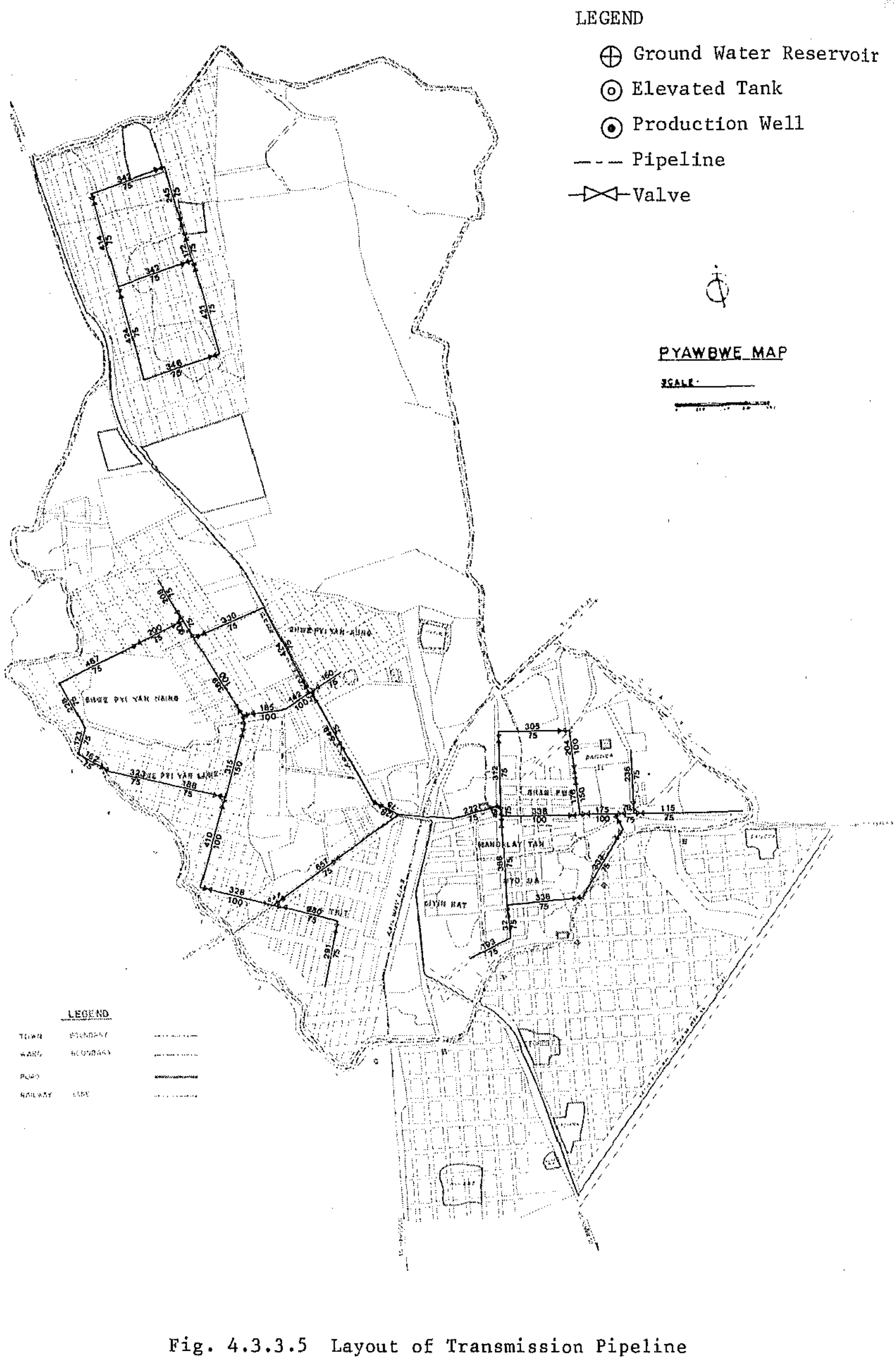


Fig. 4.3.3.5 Layout of Transmission Pipeline

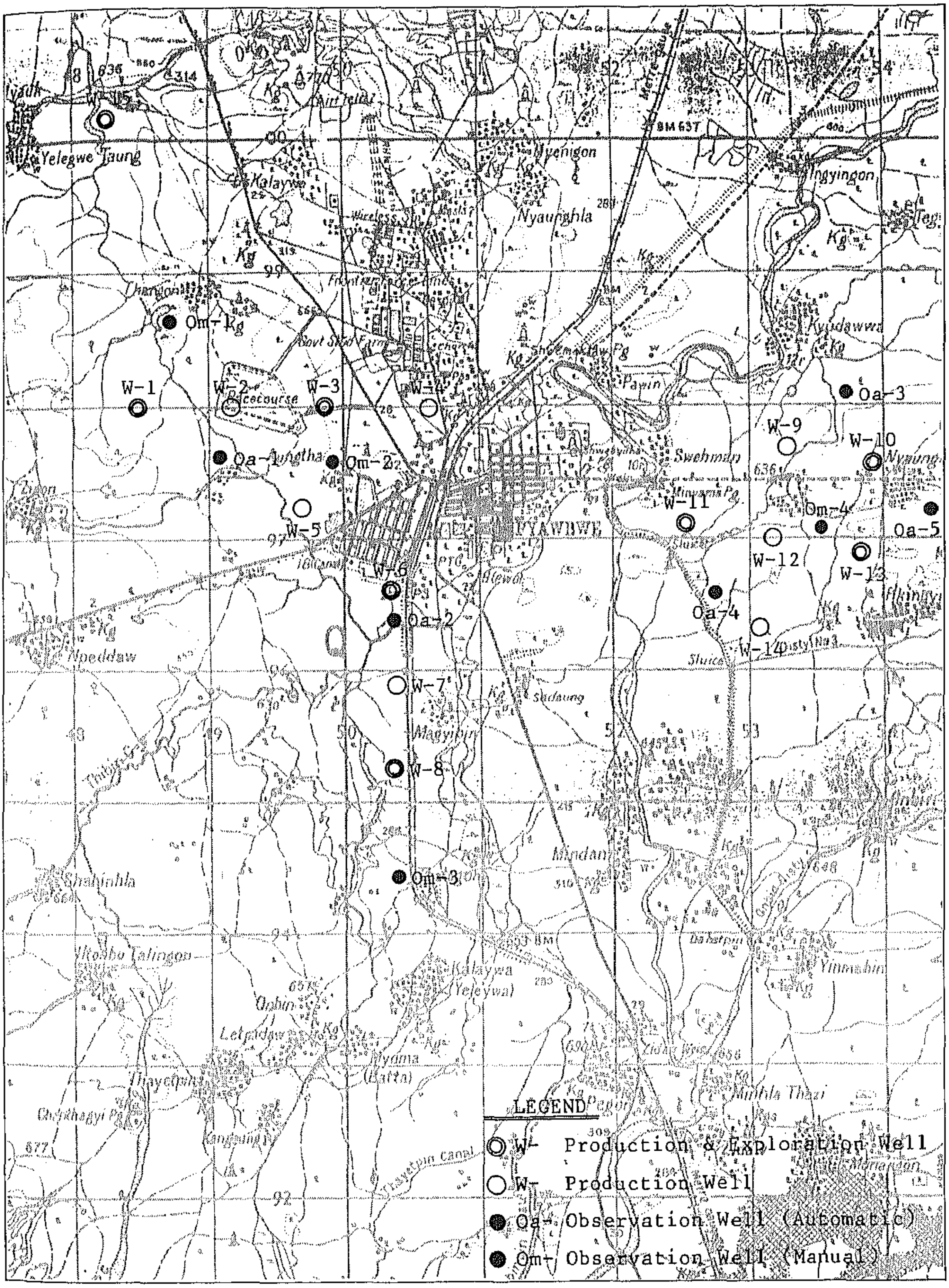
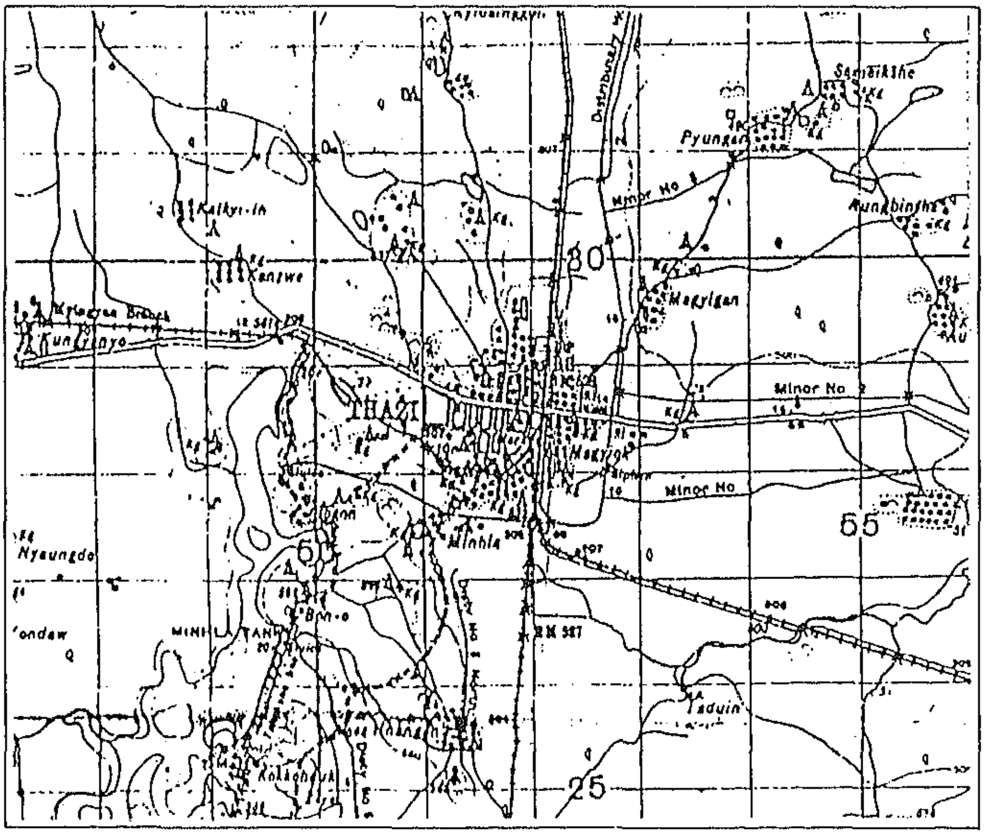


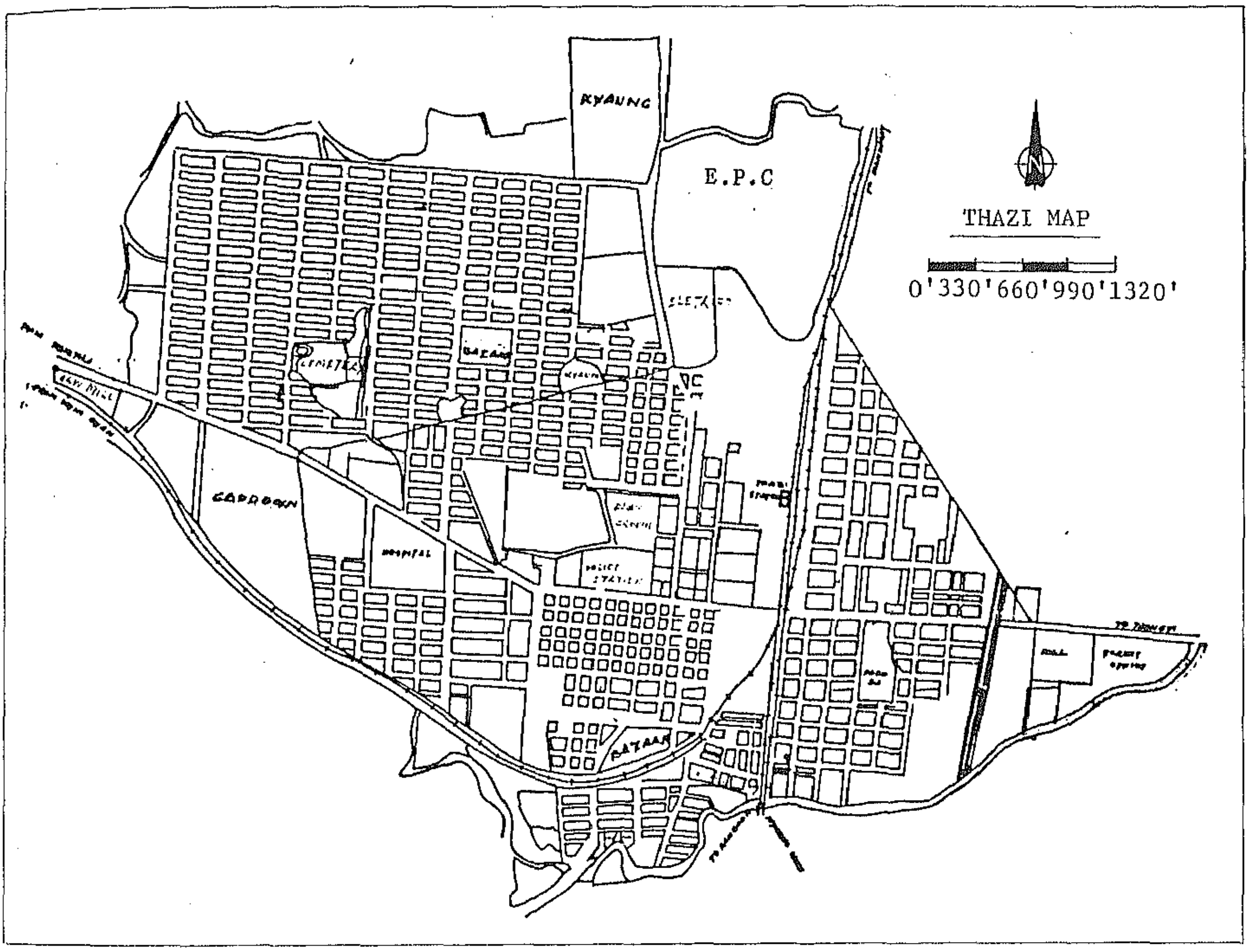
Fig. 4.3.3.6 Layout of Proposed Wells

Table 4.3.3.3 List of Proposed Facilities Pyawbwe

Facility	Item	Classification	No.	Remarks
Water intake facility	Production wells	Planned intake rate 200 to 250m^3/d ϕ150mm x H46m	15	Casing H = 36m Screen H = 10m
	Exploration wells	ϕ150mm x H55m	8	Casing H = 45m Screen H = 10m
	Observation wells	ϕ100mm x H46m	9	Casing H = 36m Screen H = 10m
	Intake pumps	ϕ150mmx0.194m^3/min x 7.5kW	1	W-15
		ϕ50mmx0.185m^3/min x 5.5kW	8	W-1 to W-8
		ϕ50mmx0.194m^3/min x 5.5kW	6	W-9 to W-14
	Pump rooms	Brick construction 4m x 4m Building area 16m^2	15 buildings	
Water transmission facility	Water transmission pipes	ϕ75m to ϕ200mm T type ductile cast iron pipe Class 3	17.140m	
		Various reducers	1 set	
	Sluice valve	ϕ75 to ϕ200	18	
	Air valve	ϕ20mm	23	
Water distribution facility	Storage tank	Capacity 20m^3 Underground RC construction	1	GR
	Junction well	Capacity 100m^3 Underground RC construction	1	JW
		Capacity 130m^3 Underground RC construction	1	JW
	Overhead tank	Capacity 32.6m^3 FRP panel Steel base stand H = 15.0m	1	ET-2
		Capacity 25.2m^3 FRP panel Steel base stand H = 15.0m	1	ET-1
	Booster pump	ϕ125mm x 1,488m^3/min x 11kW ϕ100mm x 1,164m^3/min x 7.5kW	1 1	ET-2 ET-1
	Distribution pipes	ϕ75mm to ϕ150mm T type ductile cast iron pipe class 3	13,190m	
		Various reducers	1 set	
	Sluice values	ϕ75mm to ϕ150m	46	
	Air valves	ϕ20mm	28	
Electric facility	Substation equipment	3ϕ4W 11 kV/0.4 ϕ75 kVA, 50 kVA	2 sets	
	Transmission	OW 14□ to 80□ CV 5.5□ x 4c	47.0 km	
		Accessories	1 set	

4.4 Thazi




KYAUNG
E.P.C
THAZI MAP
0'330'660'990'1320'
BAZAAR

4.4.1 Outline of The Area

Thazi is located at about 470 km to the north of Rangoon and has an altitude of 210 m. This town is on the Rangoon-Mandalay railway and on the Meiktila-Taugy gyi main road. It is an junction between towns and an important center of commerce.

Thazi has an area of about 2.4 km^2, and population is concentrated on 60% of the area. The town is divided into 7 wards, and has a population of 18500 in 1983, and the annual growth rate is 1.91%.

Thazi is situated in the eastern part of the arid area of Burma, and is known as one of the highest temperature areas in Burma. Normally, the rainy season begins in May and ends in October. The annual average precipitatiaon in this area is about 760 mm and the range is generally between 480 mm and 990 mm.

The air temperature is 5°C minimum and 42°C maximum. The average temperature is lowest in January between 5° and 31°C, highest in May between 17° and 42°C.

The annual average humidity in this area is 55%, and the monthly average humidity is lowest in March, being 40% and highest in August being 74%.

About 100 years ago, main railway line was opened, and Thazi become prosperous as a town for supplying water for the steam locomotives. At the present, it is a relay point between the main electric power transmission and distribution. The electric power is transmitted to Mandalay in the north and Pyawbwe, Yamethin and Pyinmana in the south. Scheduled service interruption for power saving is also adjusted at this place.

The main railway line runs approximately through the center of the town. The railway going to Meiktila run from the station located at the center of the town along a semi-circle in the southern part of the town to west. The main road penetrates through the town in the route of Meiktila-Thazi-Hlaingdet (about 10 km east)-Taunggyi.

Situated in the southwestern part of the town is the Minhla lake. The water of this lake comes from the overflow of Meiktila lake in the west and the Chaung Ma Dam in the southwest.

Fig. 4.4.1.1 shows population and areas by wards. Fig. 4.4.1.2 shows the ratio of areas by land use purposes.

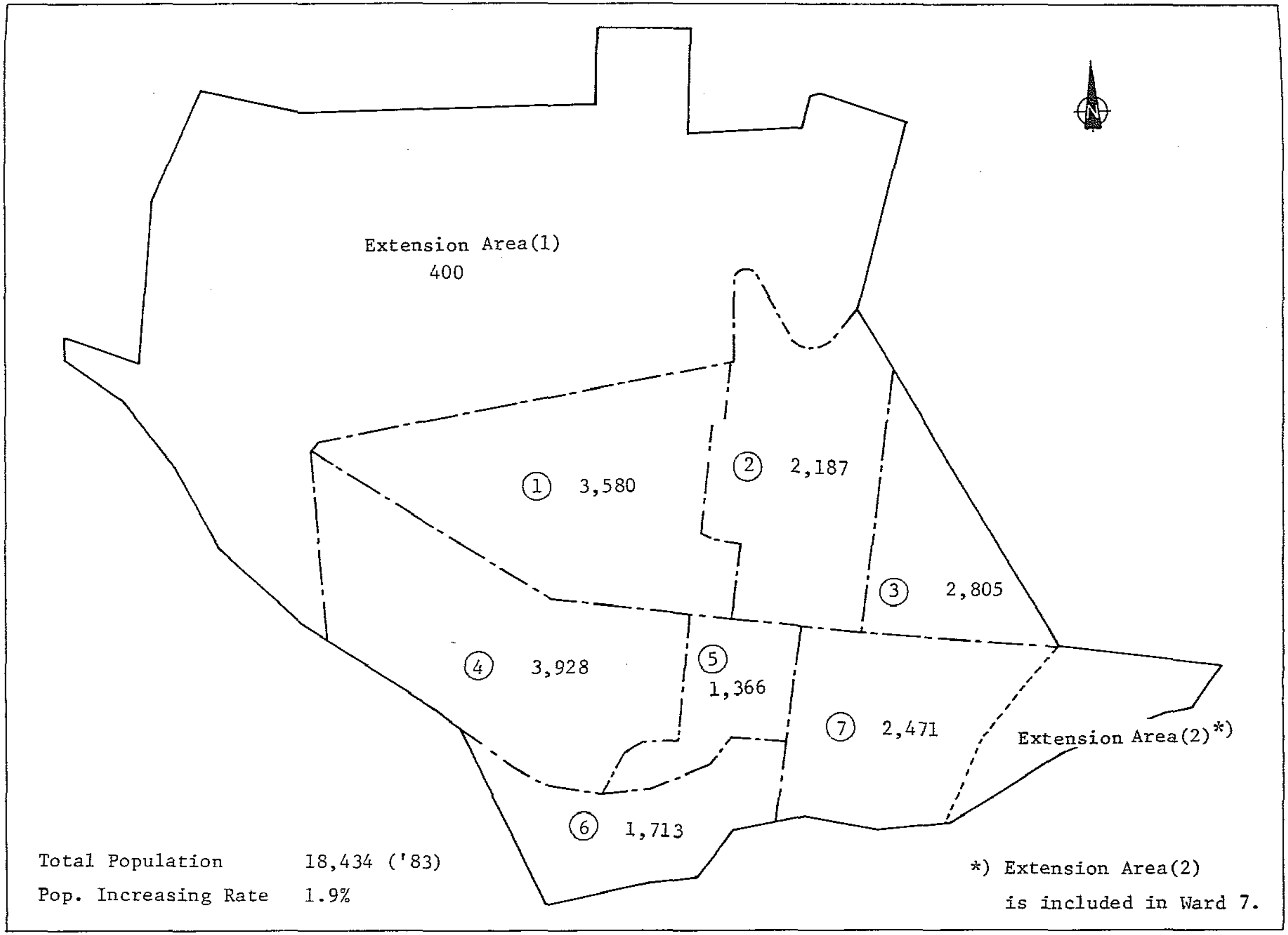
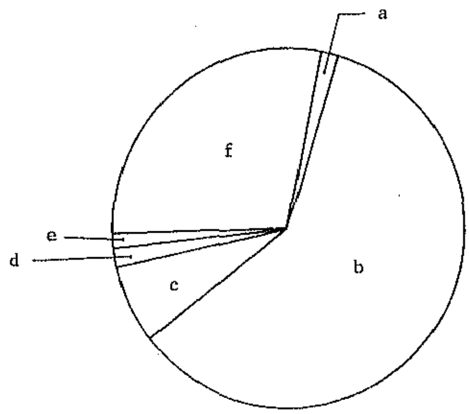


Fig. 4.4.1.1 Present Population of Each Ward



a)	Agricultural field, etc.	1.36 %
b)	Residential Area	59.93 %
c)	Cemetery, Garden and Park	7.14 %
d)	Commercial Places	1.69 %
e)	Industrial Areas	1.19 %
f)	Government Buildings (Offices, School, Hospital and Government Buildings)	28.69 %

Fig. 4.4.1.2 Ratio of Areas by Land Use Purposes of Thazi

4.4.2 Water Resource Development Plan

1) Hydrogeology

(1) Topography and Geology

The neighborhood of Thazi is a part of the narrow basin contained between the Shan highland consisting mainly of granites penetrating into the mesozoic and cenozoic and partially of the palaeozoic at about 20 km on the east side and the Pegu Yoma uplift consisting of the Pegu formations of the oligocene and middle and lower miocene of the tertiary period at about 20 km on the west side. (Refer to Fig. 4.4.2.1 and Fig. 4.4.2.2.)

Inside the basin, the Irrawaddy formations formed in the upper miocene and pliocene of the tertiary period form hills and are distributed in the south-north direction along the Pegu Yoma uplift and at the boundary between the alluvium and diluvium. The diluvium forms a plateau and is distributed on both sides of the Rangoon-Mandalay railway. The fan consisting of fan deposits belonging to the diluvium is distributed slenderly along the Shan highland. Between the plateau and the fan, an alluvium low-land is seen. The alluvium low-land has the Samon river and its branched rivers developed like a network, but because of its slow slope, dries up in the dry season although water flows in the rainy season.

The alluvium low land has flat surfaces. The fan distributed on the east side slowly slopes to the west side, and the diluvium plateau distributed on the west side slowly slopes to the east side, while the slope is rather steep in the hills in which the Irrawaddy formations are distributed.

In the neighborhood of Thazi, the Irrawaddy formations strike in the N20-40E direction and dips at 30° to 50° to the NE direction. They consist mainly of clay in some parts and of sand in the other. It is considered that the diluvium layers are generally horizontal, but in the north, take the syncline structure. Moreover, it is said that, at the boundary between the Irrawaddy formations and the diluvium layers, there are faults extending from Mandalay. Under the alluvium, the diluvium layers are contained and are considered to intersect with the fan deposits.

The general layer order is as follows.

Layer order	Age	Features
Alluvium	Alluvial epoch	Distributed in the surface layer.
Fan deposits	Diluvial epoch	Distributed along Shan highland.
Diluvium	Diluvial epoch	Distributed widely in flat lands and relatively thick.
Irrawaddy formation	Upper miocene and pliocene	Distributed in depths of hills and alluvium and diluvium layers.

The alluvium layers are distributed as sand and clay alternates, with thick distribution of sand layers in part. The diluvium layers and Irawaddy formations consist mainly of clay, mixed with thin layers of sand and gravel. The Irrawaddy formations have dips due to folds and faults.

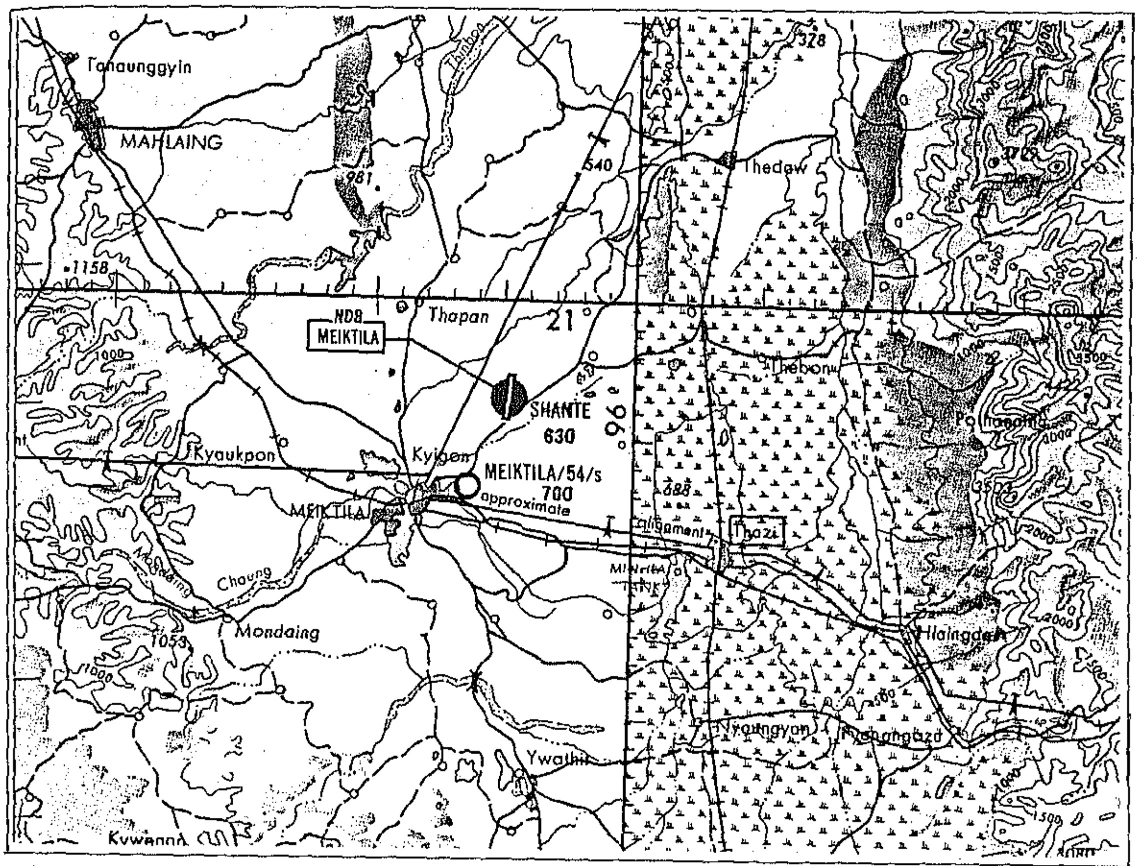


Fig. 4.4.2.1 Topographical Map of Thazi Scale 1:500,000

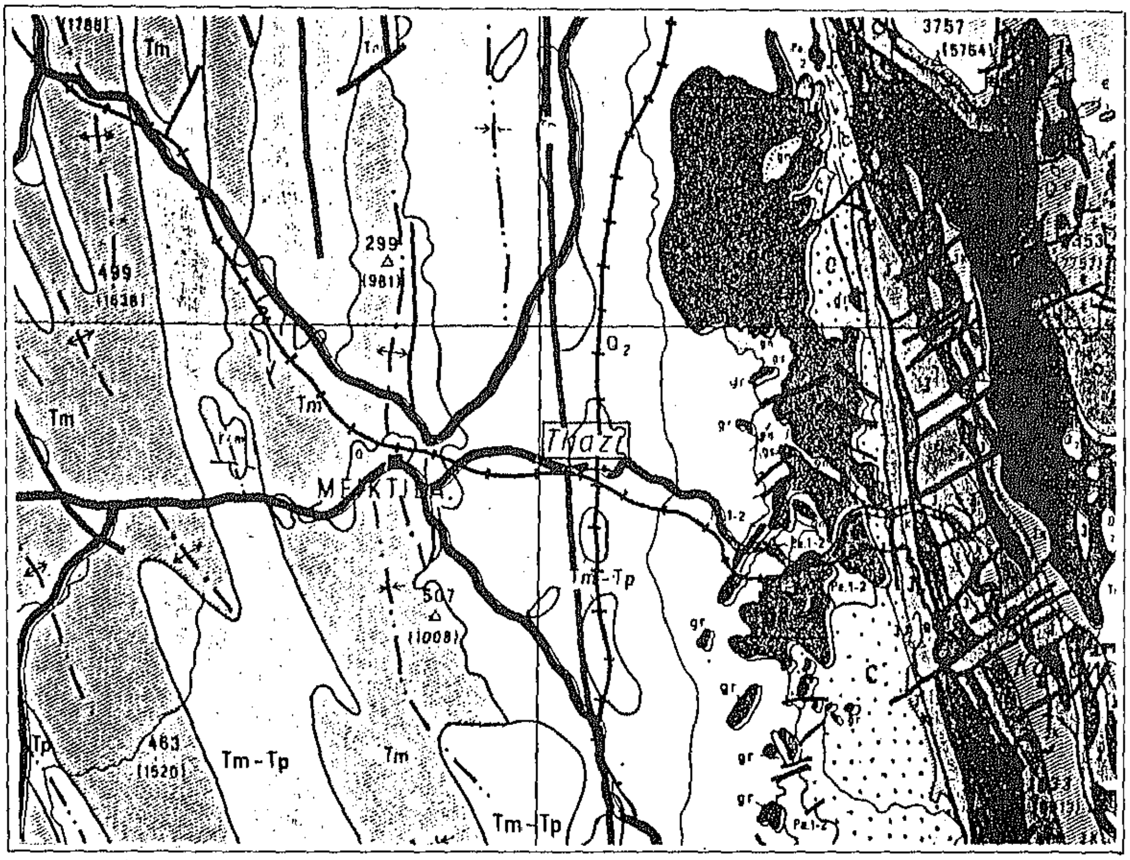


Fig. 4.4.2.2 Geological Map of Thazi Scale 1:870,000

(2) Hydrogeology

In the Thazi area, the geological structure is complicated in the hills and their neighborhood since there are folds and faults extending in the south-north direction. However, the diluvium and alluvium layers distributed on both sides of hills slope slowly to the east and have relatively simple geological structures. The lower surfaces of these layers seem to be not constant because of the rolling Irrawaddy formations.

Fig. 4.4.2.3 shows a model profile in the east-west direction of Thazi. This area is a semiarid. The precipitation exceeds the evapotranspiration, and therefore, it may be considered that the ground water recharge is undertaken by river water flow out in the Shan highlands and Pegu Yoma uplifts.

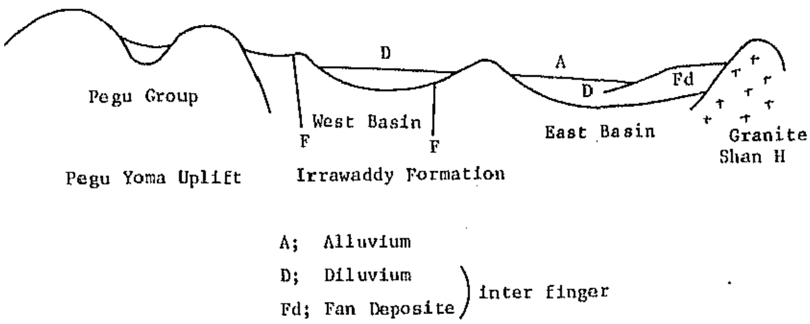


Fig. 4.4.2.3 Conceptional Profile of Pegu Yoma to Shan Hiland

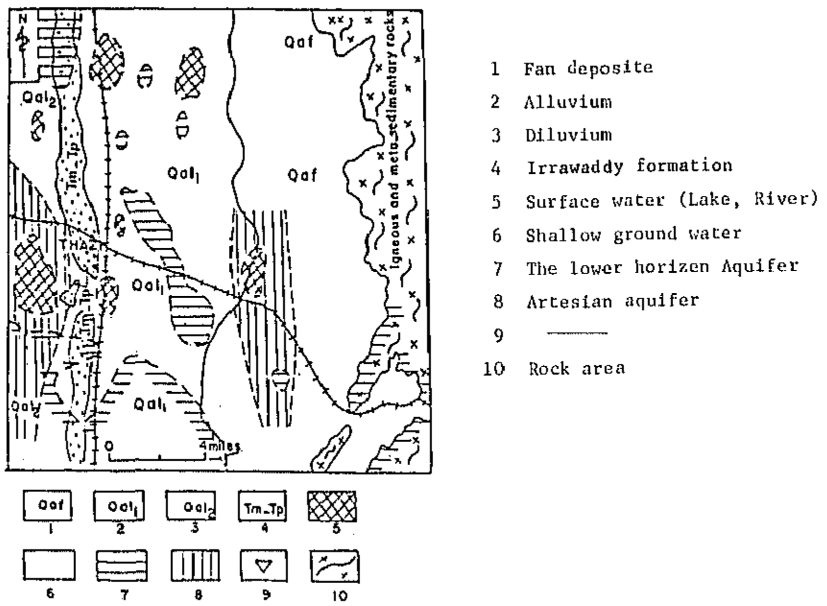


Fig. 4.4.2.4 Sketch Map Shwoing the Hydrogeology

As shown in Fig. 4.4.2.4, it seems that the ground water distribution in the Thazi area greatly varies with the location. The ground water stored in the diluvium layers and Irrawaddy formations is artesian water and sometimes artesian flows are seen.

The existing wells in the Thazi area are concentrated in the hill portion where the Irrawaddy formations are distributed. Fig. 4.4.2 5 and Fig. 4.4.2.6 show the sectional view nearly perpendicular to the strikes approximately at the center of the hills. Each layer dips at a nearly constant angle from west to east, and the strainers are installed in the gravel layers.

The conditions of each aquifer are as follows.

① In the Thazi area, there are two aquifers, one is for the shallow layer ground water in the surface layer portion, and the other is for the deep layer ground water in the Irrawaddy formations.

② The shallow layer ground water in the surface layer portion is stored also in the hill portion, but generally, tends to be stored in the alluvium low lands. Hand-dug wells have been installed for the ground water to be stored in the alluvium low lands, and fresh water can be obtained.

③ The deep layer ground water in the Irrawaddy formations is divided into three layers, upper, middle and lower. The upper layer is at about 40 to 60m and has EC of 640 to 4,600 μS/cm and pH of 8.3 to 9.0. The middle layer is at 70 to 80m and its water quality varies with the location. The lower layer is at 95 to 110m and generally contains salts the concentration of which seems to be high.

The ground water level in this area flows along the topographical surface, but the artesian water is governed by the strikes and dips of the strata and flow from west to east.

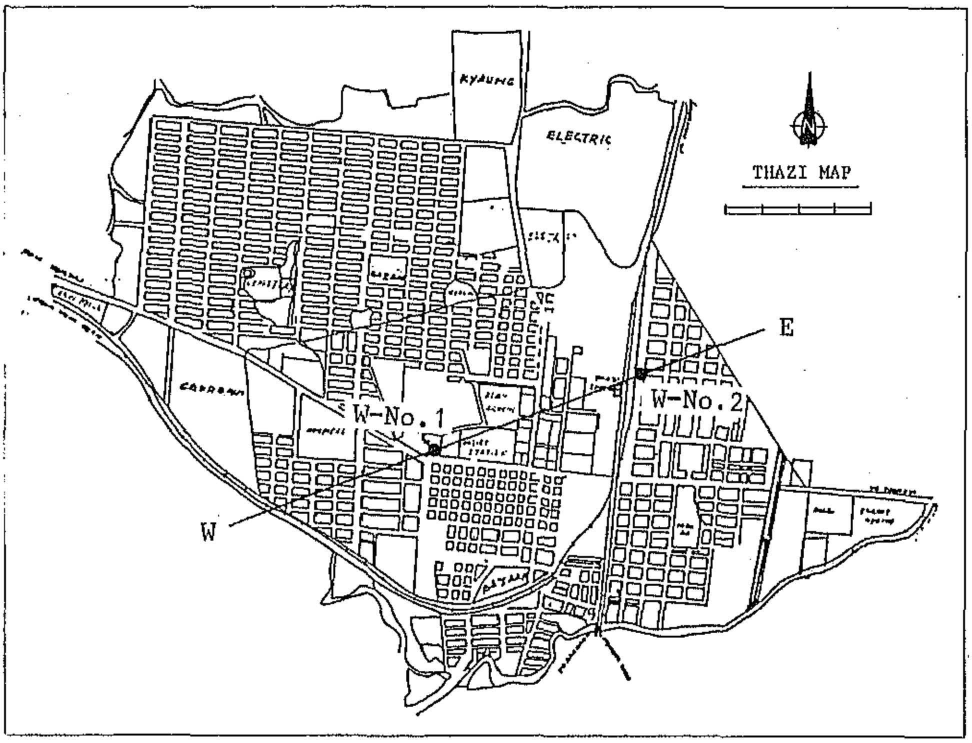


Fig. 4.4.2.5 Location of Tube Well Log Points

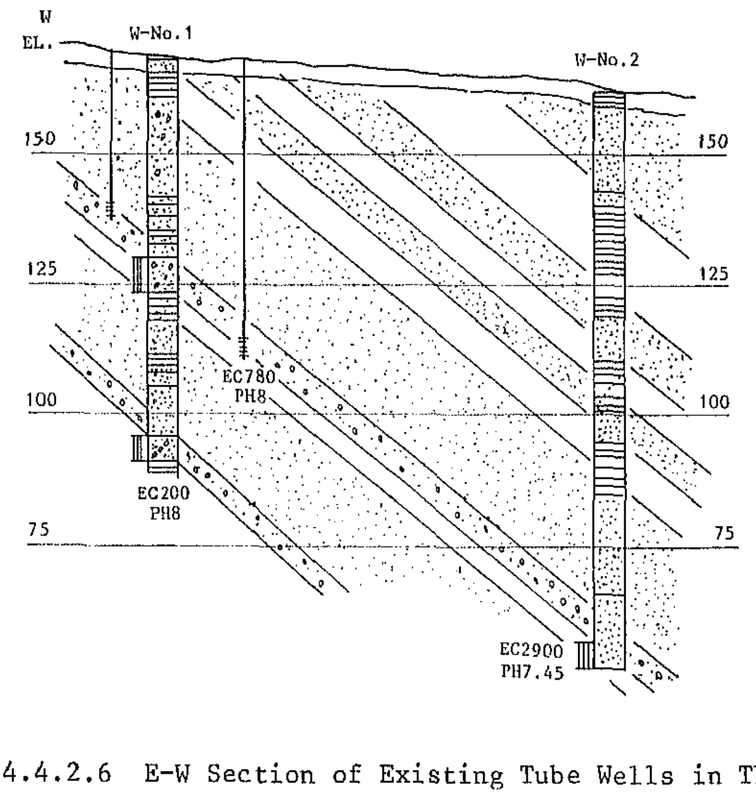


Fig. 4.4.2.6 E-W Section of Existing Tube Wells in Thazi

2) Aquifer

The aquifers in the Thazi area consists of sand and gravel layers of the Irrawaddy formations, and at the present, the water quality is poor and sufficient quantities of water cannot be obtained. As described above, the aquifers are for the shallow layer ground wter in the surface layer portion and for the deep layer ground water in the Irrawaddy formations.

The aquifers for the shallow layer ground water are contained frequently in the alluvium layers and consist mainly of sand layers. The well log data for tube wells for the deep layer ground water indicate that the aquifers are sand, gravel and clay alternates, and because of dips from west to east, the tube well depth varies with the location.

For these reasons, in the Thazi area, taking the ground water from the Irrawaddy formations is not suitable, and it may be considered that the ground water should be taken from the alluvium layers.

In the Thazi area, electric prospecting was carried out at 7 points in the alluvium low lands in the southern part of this area as shown in Fig. 4.4.2.7.

The results are shown by the resistivity profile in Fig. 5.4.2.8.

① The resistivity in the Thazi area is low as a whole. The surface layer only shows the high resistivity as the permeable bed. Except the surface layer, the layer corresponding to permeable bed - aquiclude layers showing 1.0 to 10 Ω-m forms the second layer. The third layer of 0.1 Ω-m is formed by the impermeable bed and is distributed in the deep portions.

② The layer corresponding to permeable bed - aquiclude layers is distributed in thickness of 20 to 25m in the alluvium layer.

It may be considered that the ground water in this area is stored in the layer corresponding to the permeable bed - aquiclude layers. The ground water is alsao stored in the sand and gravel layers mixed in the impermeable beds, but its water quality may be poor.

Therefore, the ground water in this area should be taken from the layer corresponding to the permeable bed - aquiclude layers distributed in the alluvium low lands, and this layer consists of sand and clay alternates.

Since no data are available for the alluvium layers in the southern part of the Thazi area, it is impossible to grasp the permeability. Considering fine sand, the value of k of about 5×10^{-3} cm/sec will be adopted.

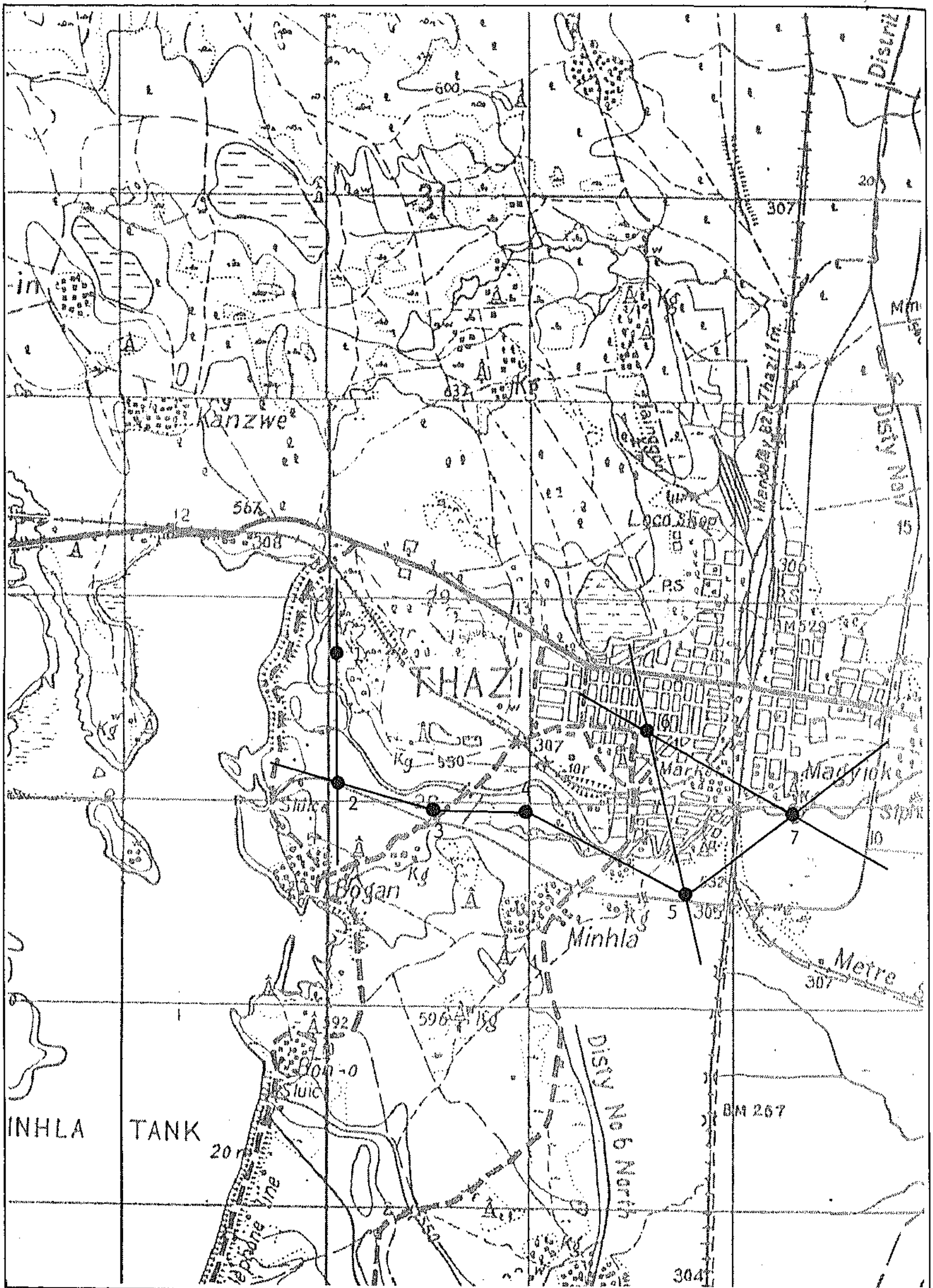


Fig. 4.4.2.7 Location of Electrical Survey Points

Scale 1:25,000

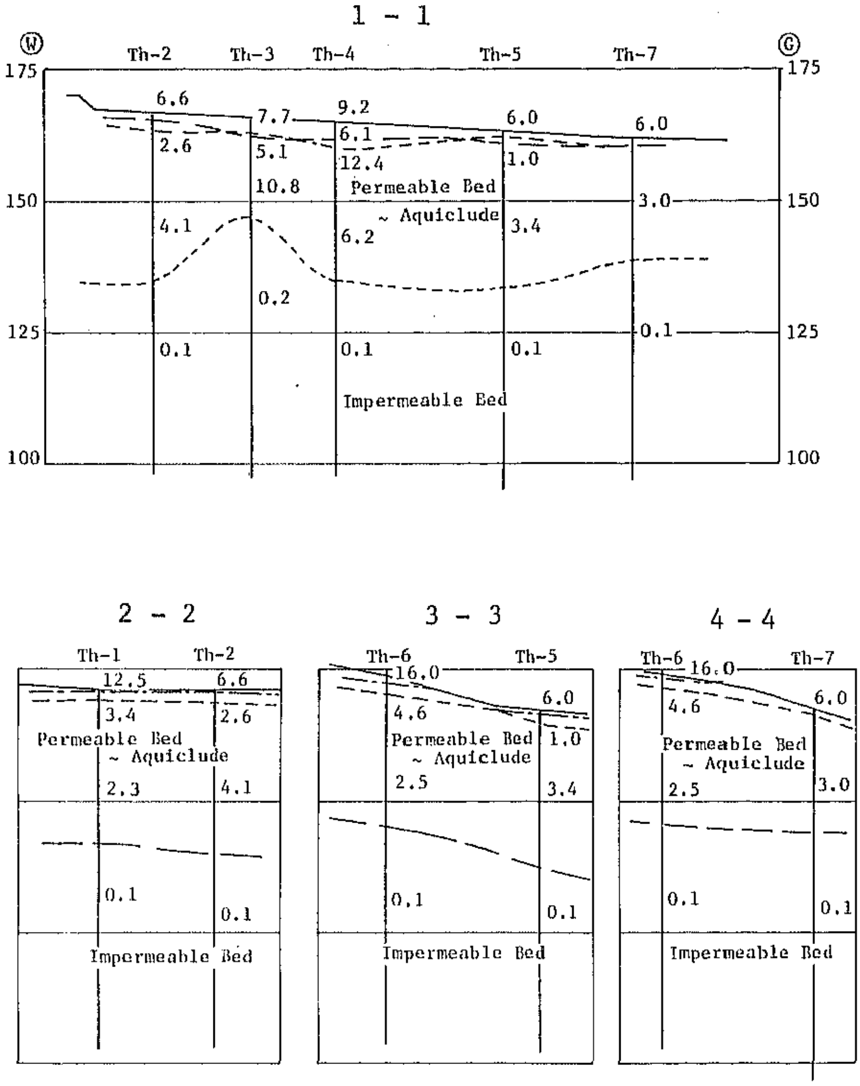


Fig. 4.4.2.8 Resistivity Profiles of Thazi

3) Ground Water Storage and Water Quality

(1) Ground Water Storage

In the Thazi area, the evapotranspiration exceeds the precipitation throughout the year or in the rainy season, and if the Thazi area only is considered, no storage of ground water will take place.

However, on the upstream side of the alluvium layers from which the ground water is to be taken in the sourthern part of the Thazi area, there is Minhla tank, and it is considered that the alluvium layers are recharged with ground water through infiltration from the bank of this tank and from the water channels. At this point, the ground water recharge from the bank will be examined.

The infiltration from the bank is calculated under the following conditions.

$$Q = \frac{k\ (h_1^2 - h_2^2)}{2\ell} \times L$$

where h_1: distance from water surface in the reservoir tank to permeable bed (m)

h_2: distance from water surface in the reservoir tank to impermeable bed (m)

k : coefficient of permeability of bank part and base ground (m/day)

ℓ : width of bank base (m)

L : length of bank (m)

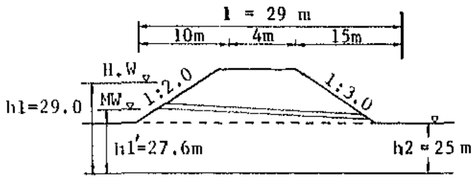


Fig. 4.4.2.9 Closs-Section of the Bank

Let the condition be:

$h_1 = 25 + 4 = 29\text{m}$

$h_2 = 25\text{m}$

$l = 29\text{m}$

$L = 1{,}000\text{m}$

$k = 5 \times 10^{-3}$ cm/sec = 4.3 m/day

Then,

$$Q = \frac{43 \times (29^2 - 25^2)}{2 \times 29} \times 1,000$$

$$= 16,000 \text{ m}^3/\text{day}$$

If the water level goes down and h_1 reaches the intake port in the dry season:

Let $h_1 = 26.5$ m

$\ell = 29$

then,

$$Q = \frac{43 \times (27^2 - 25^2)}{2 \times 29} \times 1,000$$

$$= 7,700 \text{ m}^3/\text{day}$$

The indicates that the water recharge exceeds the pumping quantity. However, if the water level in the Minhla tank is extremely low, the water recharge will be short of the discharge rate.

On the other hand, the ground water storage will be obtained from the volume and porosity of the aquifer. The area to be calculated will be the alluvium layer extending from the bank of the Minhla tank to the railway.

$V = A \times S \times E$

where A: area to be calculated

$= 1.1 \times 10^6 m^2$

S: thickness of the aquifer

$= 10m$

E: porosity

$= 10\%$

Then, the ground water storage in the alluvium layer in the southern part of the Thazi area is as follows.

$$V = 1.1 \times 10^6 \times 10 \times 0.10$$

$$= 1.1 \times 10^6 \text{ m}^3$$

The value ignores the ground water make-up and flowout and shows the storage in the aquifer at the present.

(2) Water Quality

Field tests and laboratory test were conducted on the well rate taken from Irrawaddy formations in the hill part. Except for some parts, the water samples from Irrawaddy formations have EC of 1,200 to 3,000 μS/cm in many cases. At some wells, it reached 4,000 to 6,000 maximum, suggesting that dissolve salt concentrations are very high. pH is 8.2 to 8.5 weakly alkaline.

On the other hand, the laboratory examination was made at one point in the area and at Kyetmauk village of about 5 km west of Thai. The results are shown in Table 5.4.2.1.

Table 4.4.2.1 Results of Water Test

Item \ Location		Kyetmauk Village	U Mg Mg Soe
1	Appearance	Clear	Clear
2	Total solids	1,470.0	500.0
3	Total hardness	25	74.0
4	Permanent hardness	2	4.0
5	Calcium hardness	20	26.0
6	Total iron	0.05	0.12
7	Chloride	48	24.0
8	pH	8.5	8.1
9	EC	2,200	780
10	Temperature	29	

The water of Kyetmauk village shows total solids content of 1,470 mg/ℓ and EC 2,200 μS/cm, which exceed WHO standards, and can not be used for drinking. The well at U Mg Mg Soe's compound in this area is one having the lowest electric conductivity and shows total solids content of 500 mg/ℓ and EC 780 μS/cm, which satisfy WHO standards.

4) Discharge Rate per Well, Spacing between Wells, and Well Depth

(1) Discharge rate

The discharge rate per well must be grasped by conducting the pumping test. At this point, however, in accordance with Thiem's formula, the discharge rate per well will be estimated. The lowering of water level S is found as 22.4m by the following calculations for the spacing between wells 600m (influence radius 300m).

$$S = R/3000\sqrt{k}$$

where R is 300m and k is 5.0×10^{-5} m/sec.

The ground water at the subject area is free ground water, and therefore,

$$Q = \frac{\pi k\ (H^2 - k^2)}{2.3 \log R/r}$$

$$= \frac{\pi \times 5.0 \times 10^{-5} \times (25.0^2 - 10.9^2)}{2.3 \log 300/0.1}$$

$$= 0.00994\ m^3/sec = 644\ m^3/18\ hr$$

Therefore, it is considered that Q of 644 m^3/18 hr can be expected. However, it is also conceivable that in the dry season that water level goes down below this case, the discharge rate per day will be taken as 500 m^3/18 hr.

(2) Spacing between Wells

Considering the ground formations, conditions of aquifers, and the discharge rate per well and the lowering of the water level in accordance with the existing data, etc., the minimum spacing between adjacent wells will be taken as 600m.

(3) Well Depth

Regarding well depth, considering the depth of storage of the aquifer of about 30m as the lower limit, the average depth of production wells will be taken as 36m (6m for sand-pit).

4.4.3 Planning The Water Supply System

1) Project Area

The existing dwelling area has a very high population density 120 persons/ha to 150 person/ha, already becoming saturated. In order to cope with this condition, TDC is planning to construct a new town of about 50 ha to the westnorth of the town. The expected place for this new town is a pasture land at the present and even the construction of the streets is not yet started, although several families have already started to dwell. In planning the water supply system, the existing dwelling area and the new town are covered as the project area. Refer to fig. 4.4.3.1.

2) Planned Water Supply Population

The population as of 1983 is 18434 persons. The past annual population is increase 1.9%. Therefore, the planned water supply population y is

$y = 18434\ (1 + 0.019)^8$

$= 21430$ persons

Thus, the planned water supply population is taken as 21400 persons.

3) Planned Water Supply Amount

Planned water supply amount

= planned water supply population

x planned daily maximum supply per capita

= 21400 person x 150 ℓ pcd

= 2247000 ℓ/day

= 2250 m^3/d

4) Division into Water Supply Blocks

The project area is shown in Fig. 4.4.3.1. Considering the condition of population distribution, the project area is divided into three water supply blocks A, B and C. (Refer to Fig. 4.4.3.1.) Regarding the allocation of planned population, it is supposed that most of the future increase should dwell in the new town since the existing dwelling area is in the saturated condition. The planned specifications for each block are as shown below.

Table 4.4.3.1 Planned Specification for Each Block

	Planned water supply population (person)	Water supply area (ha)	Population density (person/ha)	Planned water supply amount (m^3/d)
A	4,400	86	51.2	460
B	9,500	78	122.0	1,000
C	7,500	51	147.0	790
Total	21,400	215	Ave 99.5	2,250

5) Facility Planning

As described above, the water source is the water channel area in the southern part of the town. At a relatively high position in the central part of the town, the junction well and elevated tank are installed and from them, water is supplied. To the water supply system, the basic system is applied.

The planned discharge rate per well in this area is 500 m^3/day. The planned maximum water supply per day is 2250 m^3/day. Therefore, the number of planned wells N is $2250 \div 500 = 4.5 \rightarrow 5$.

The layout of facilities is shown in Fig. 4.4.3.2.

6) Outline of Facilities

Table 4.4.3.1 shows specification and quantities for facilities.

Fig. 4.4.3.3 and Fig. 4.1.3.4 show water transmission pipeline and distribution pipeline networks, respectively. For the construction of planned wells and elevated tanks, refer to the reference drawings given at the end of this chapter.

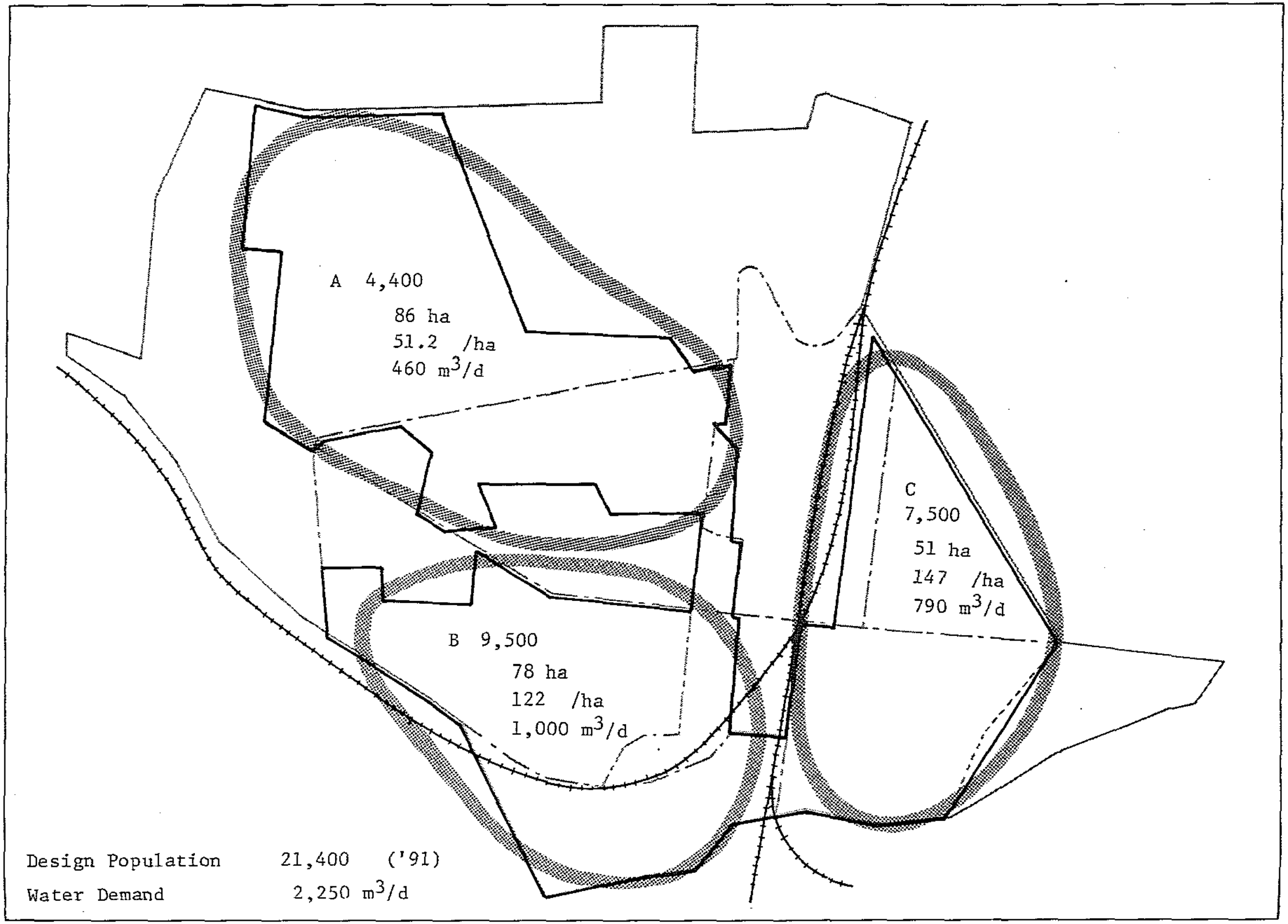


Fig. 4.4.3.1 Distribution of Design Population

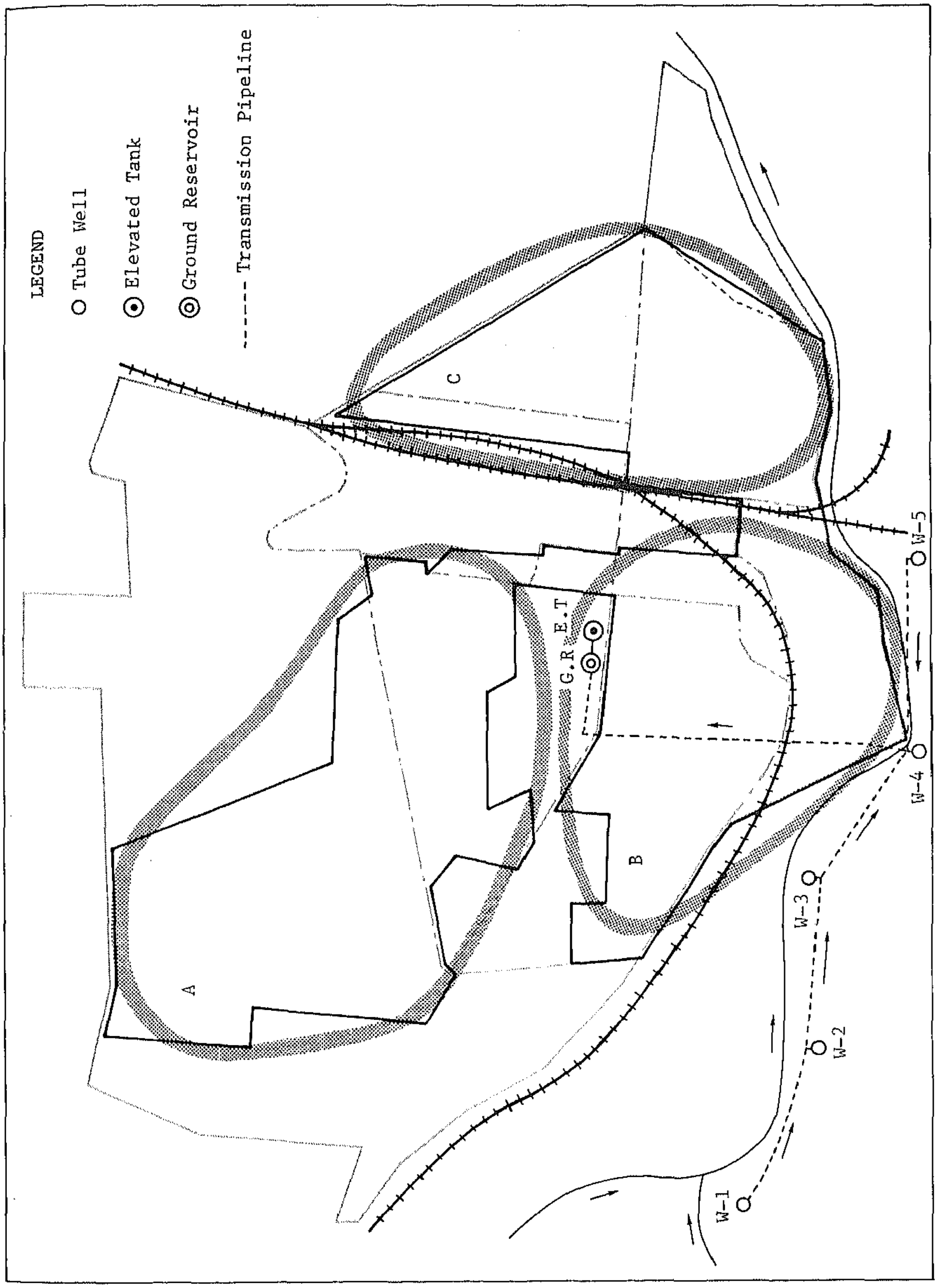


Fig. 4.4.3.2 Layout Plan of Proposed Facilities

Table 4.4.3.2 List of Proposed Facilities

Facility	Item	Classification	No.	Remarks
Water intake facility	Production wells	Planned intake rate 500m^3/d ϕ200mm x H36m	5	Casing H = 20m Screen H = 16m
	Exploration wells	ϕ150mm x H40m	2	Casing H = 24m Screen H = 16m
	Observation wells	ϕ100mm x H36m	4	Casing H = 26m Screen H = 10m
	Intake pumps	ϕ65mm x 0.463m^3/min x 11kW	5	W-1 to W-5
	Pump rooms	Brick construction 4m x 4m Building area 16m^2	5 buildings	
Water transmission facility	Water transmission pipes	ϕ100mm to ϕ250mm T-type ductile cast iron pipe class 3	3,040m	
		Various reducers	1 set	
	Sluice valve	ϕ160mm to ϕ250mm	5	
	Air valve	ϕ20mm	4	
Water distribution facility	Junction well	Capacity 190m^3 Underground RC construction	1	JW
	Elevated tank	Capacity 46.8m^3 FRP panel Height 15.0m Steel base stand	1	ET
	Booster pump	ϕ150mm x 0.648m^3/min x 11kW	1	
	Distribution pipe	ϕ75mm to ϕ200mm T type ductile cast iron pipe class 3	8,720m	
		Various reducers	1 set	
	Sluice valves	ϕ75mm to ϕ200mm	27	
	Air valves	ϕ20mm	20	
Electric facility	Substation equipment	3ϕ4W 11kV/0.4 100 kVA	1 set	
	Transmission	OW 50□ CV 8□ x 4c	9.4 km	
		Accessories	1 set	

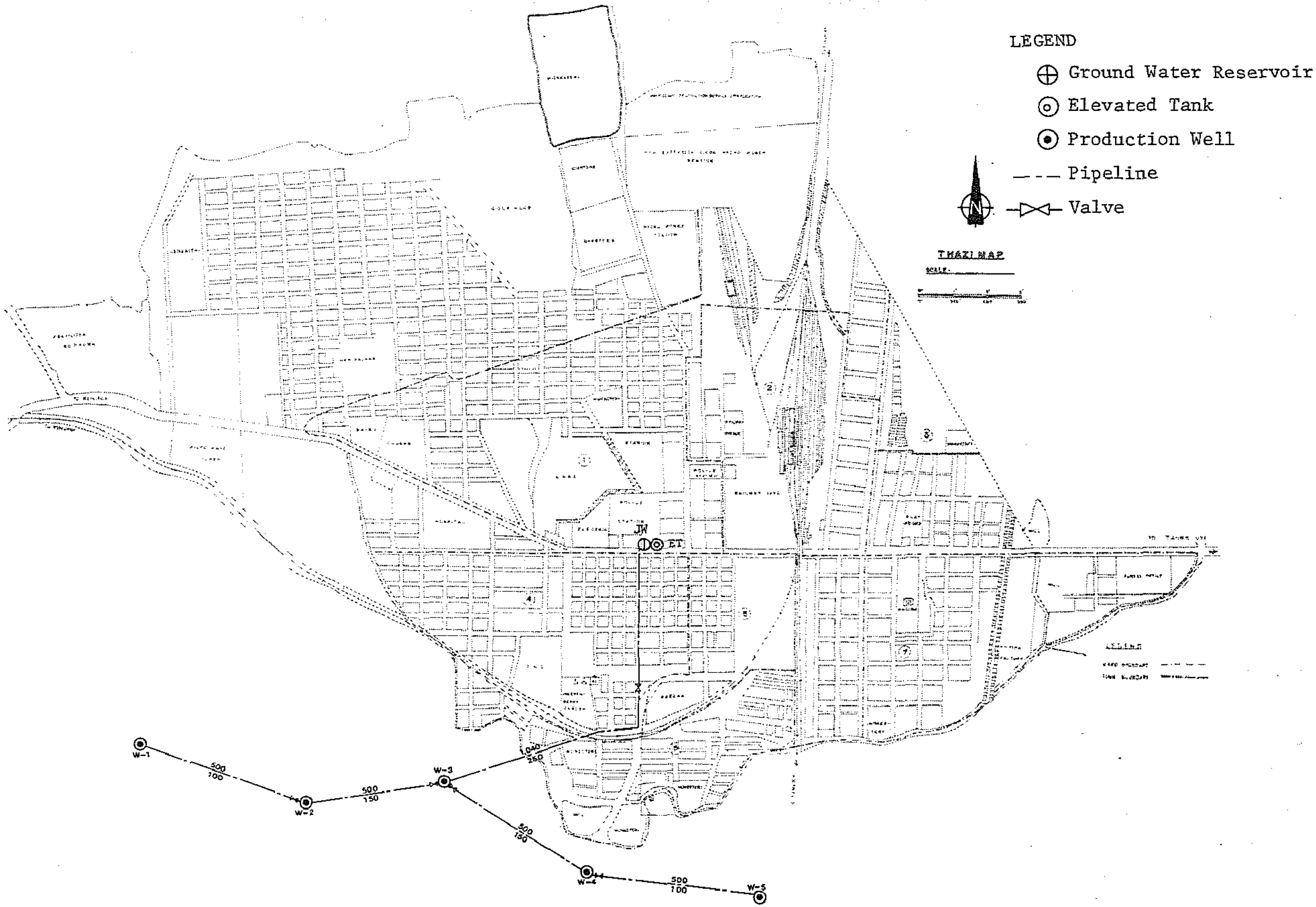


Fig. 4.4.3.4 Layout of Transmission Pipeline

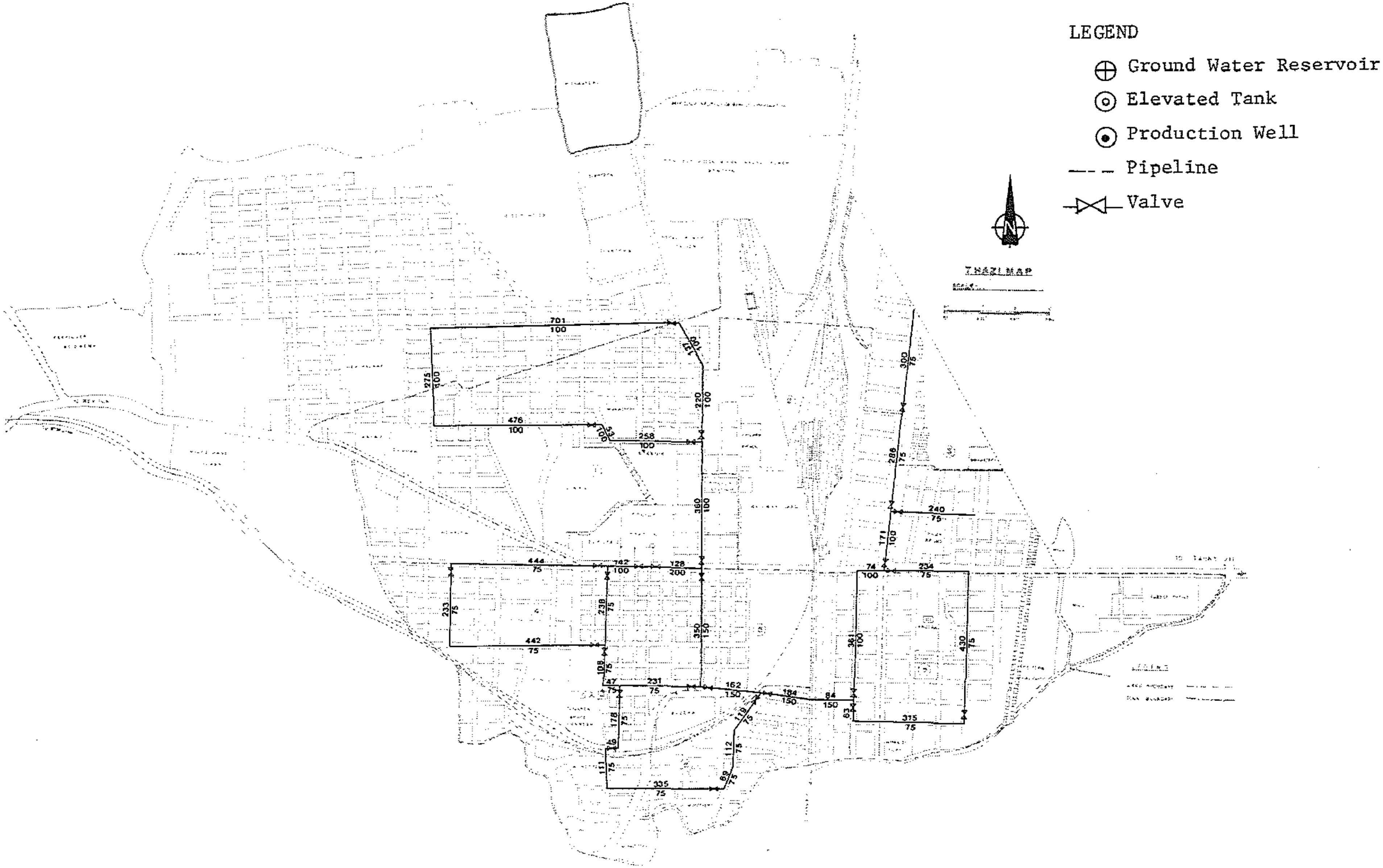


Fig. 4.4.3.5 Network of Distribution Pipeline

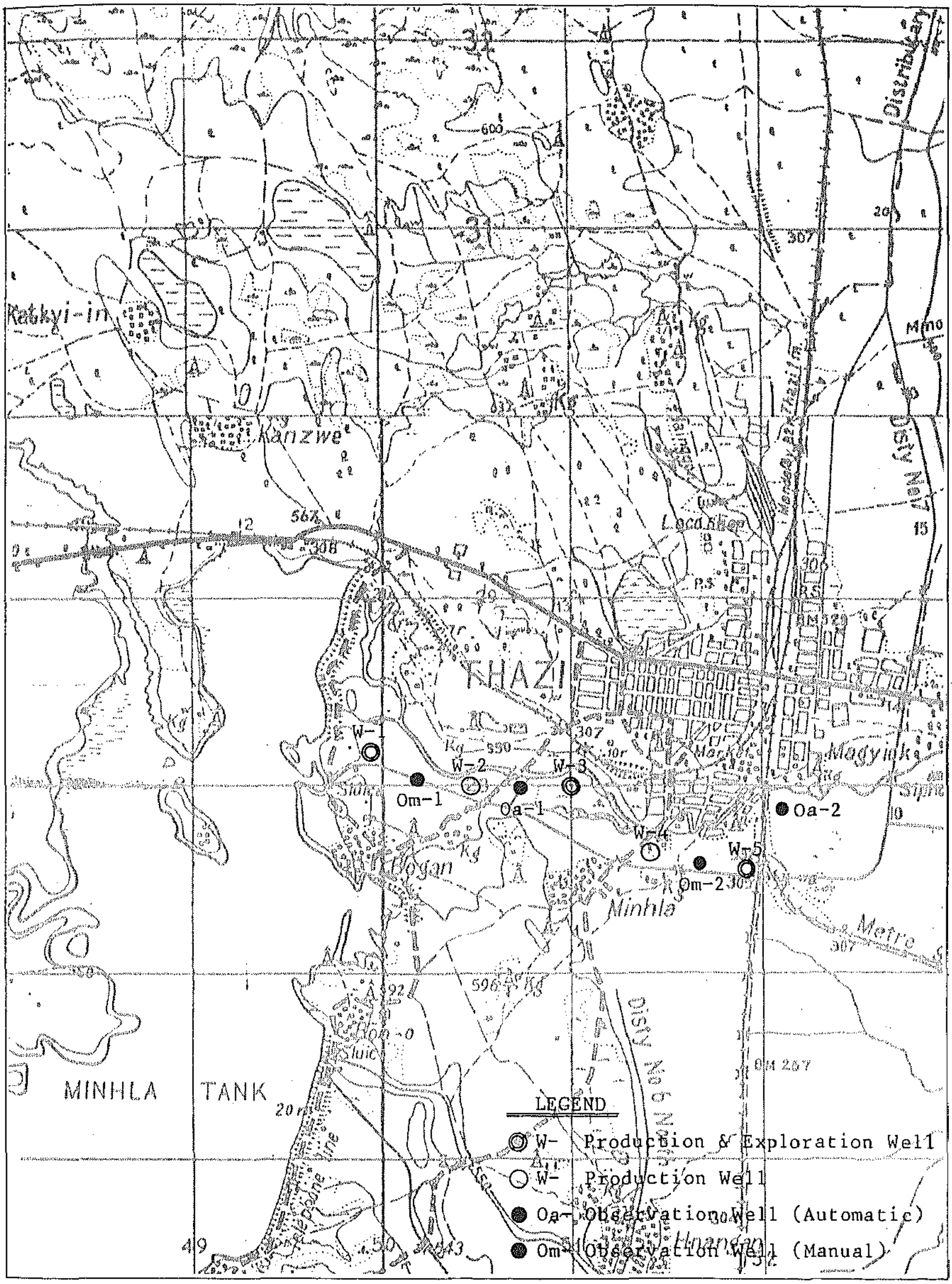
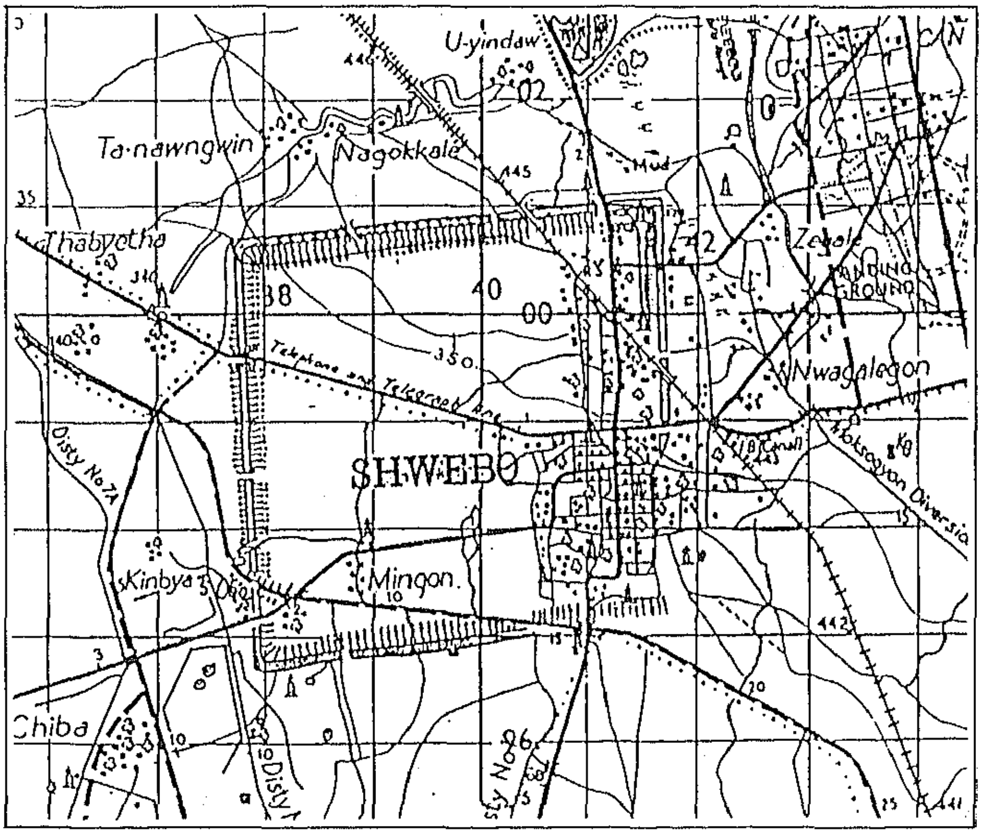
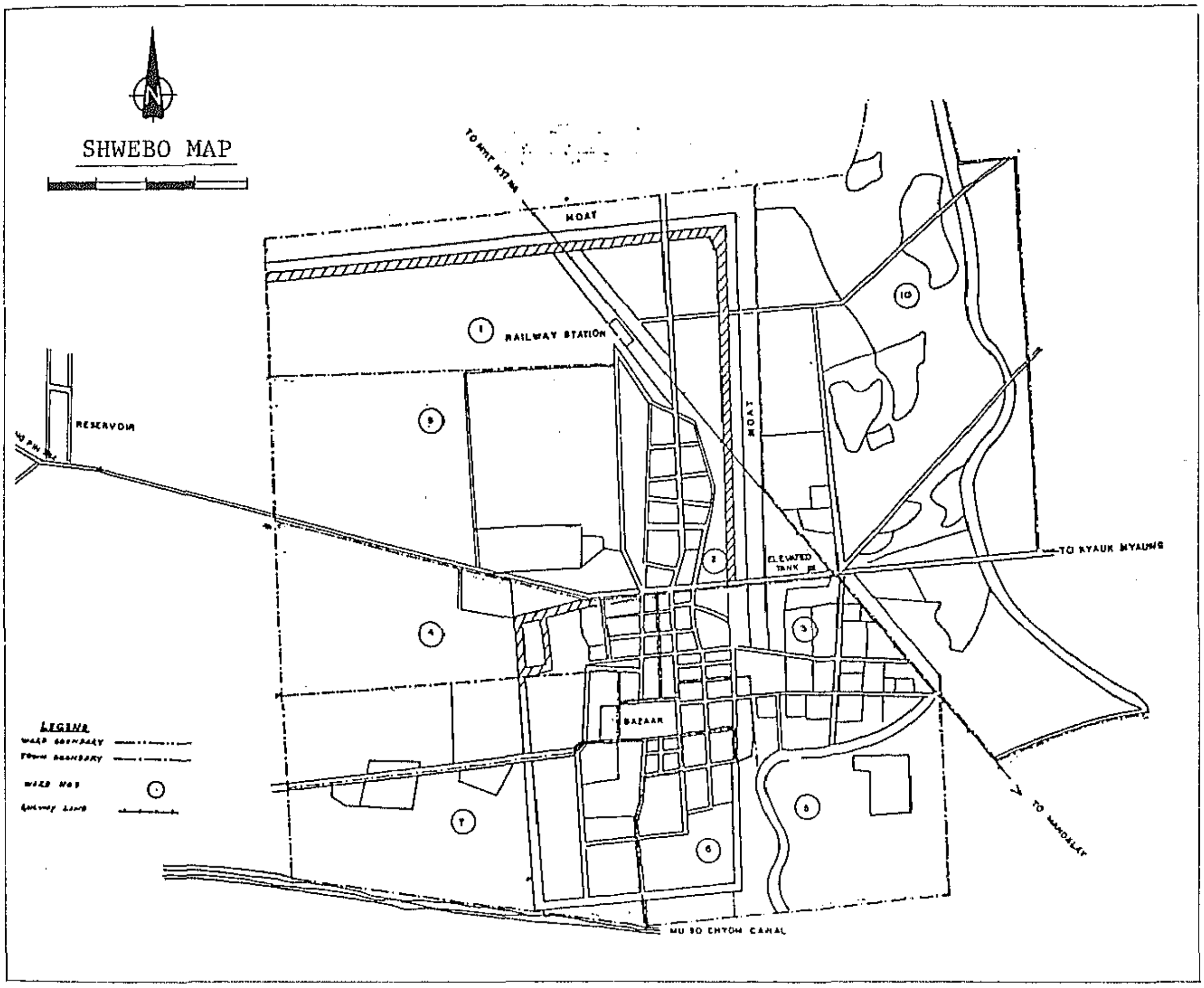


Fig. 4.4.3.6 Layout of Proposed Wells

4.5 Shwebo


U-yindaw
Ta-nawngwin
Nagokkale
Thabyetha
Zegale
Nwagalegon
SHWEBO
Disty No.7A
Kinbya
Mingon
Chiba


SHWEBO MAP
MOAT
RAILWAY STATION
RESERVOIR
ELEVATED TANK
TO KYAUK MYAUNG
BAZAAR
TO MANDALAY
LEGEND

4.5.1 Outline of the Area

Shwebo is situated at about 100 km to the northwest of Mondalay and at about 30 km from the Irrawaddy river towrd the west. It is a flat town at an altitude of about 110m.

The town area is about 6.1 km^2 and the population as of 1983 is 48,920. The annual average population growth rate for the past 10 years is 2.1%.

Shwebo is located in the northern part of the arid area of Burma. The annual average precipitation is about 860 mm, and the monthly average air temperature for the past 10 years is 34.2°C and exceeds 40°C in summer.

Agricultural products such as sasame, bean, peanut, etc. are produced. There are irrigation facilities and rice is grown actively. The karbo Diversion weir was constructed in the Mu river at about 20 km to the west of the town, and from this, irrigation water is conveyed through a canal. In addition, the Koebin Chaung dam was completed in 1984 at about 11 km to the north of the town for both purposes of irrigation and drinking water supply. Outlines of the Karbo Diversion weir and the Koebin Chaung dam are shown in Table 4.5.1.1 and Table 4.5.1.2, respectively.

At the present, the town has no wter supply system, and the dwellers make use of 18 common wells in the town and the canals from the Karbo Diversion weir. However, the water from the wells, except for 2 or 3, has high salt content and cannot be used for drinking water. Therefore, most of the dwellers use the water from the canals. In the rainy season, this water has high turbidity and requires clarification by sedimentation. In some areas, the rain water is stored and used as drinking water.

In the dry season, the water supply to the canal is stopped. Therefore water shortage is a serious problem during the dry season.

In order to solve this problem, TDC secured the right to use part of the water from the Koebin Chaung dam owned by the Ministry of Agriculture & Forest. The intake tower has an intake provided for securing the drinking water. However, this cannot be utilized at present, due to lack of transmission line and shortage of budget.

In this survey, investigation was made for the propriety of the above water supply facilities. It was found that the water quality has a problem and the water conveyance pipes are too long and not economical. In the present plan, therefore, the water supply facilties will be adopted on the assumption of ground water development.

Fig. 4.5.1.1 shows the ratio of areas by land use purposes.

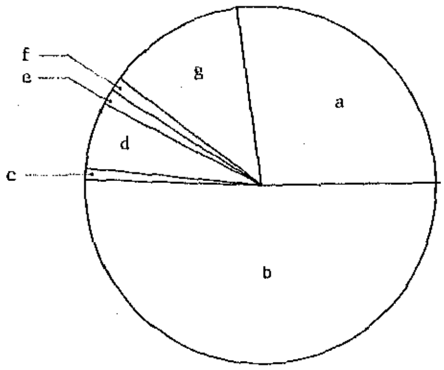
Table 4.5.1.1 Outline of Carbo Diversion Dam

Item	Unit	Shwebo canal	Ye U canal	Remarks
Length	Miles	28.6	44.6	
Base width	ft.	100.0	80.0	
Max. Ft.	ft.	8.7	7.0	
Water volume	Cu.ft./sec	2,800	1,750	
Water feed area	Acre	229,815	128,900	
Canal (A)	No.	2	2	Main
Canal (B)	Miles	41.7	19.1	Branch
Minor branch	No.	21	24	
Water course	No.	76	40	
Total length	Miles	409	260	

*) From the karbo diversion dam, there is Ye.U canal on the right side and shwebo canal on the left side.

Table 4.5.1.2 Outline of Koebin Chaung Dam

Item		Remarks
Catchment area	44 square miles	
Height of dam	35 ft.	
Length of dam	4,244 ft.	
Maximum water level	425 ft.	
Reservoir area	973 acres	
Storage capacity	9,764 acres	
Spillaway	100 ft.	
Size of intake pipe	24"ϕ	
Capacity of intake pipe	65 Cu-sec.	for irrigation
Capacity of intake pipe	5 Cu-sec.	for town water



a)	Agricultural Field,etc	27.20 %
b)	Residential Area	50.86 %
c)	Cemetery, Garden and Park	0.80 %
d)	Religious Center	6.11 %
e)	Commercial Places	1.44 %
f)	Industrial Areas	0.94 %
g)	Government Buildings (Offices, School, Hospital and Government Buildings)	12.65 %

Fig. 4.5.1.1 Ratio of Areas by Land Use Purposes of Shwebo

4.5.2 Water Resource Development Plan

1) Hydrogeology

(1) Topography and Geology

In the neighborhood of Shwebo, the Shan highlands consisting mainly of igneous rocks such as volcanic rocks and granities. The Irrawaddy river runs at about 20 to 30 km on the eastern side of the town, and at the western end of the highlands. At about 30 km on the western side, mountains consisting of the Pegu formations of the oligocene and middle and lower miocene of the tertiary period with the highest altitude of 28m run nearly south to north. Shwebo is a part of the basin contained between these highlands and mountains. (Refer to Fig. 4.5.2.1 and Fig. 4.5.2.2.)

Around the basin, the Irrawaddy formations formed in the upper miocene and pliocene of the tertiary period, forming slow-sloping plateaus. In the neighborhood of the center of the basin, the Mu river flows to the south. A flat land continues from the Mu river to Shwebo, and the strata formed in the diluvium and alluvium of the quaternary period are distributed.

The plateaus distributed on the east side of the Shwebo area are eroded and rolling at slow slopes. The Koebin Chaung dam was constructed necently by blocking a depressed area, collecting water from the small rivers which flow to the south-west. The rivers and water channels around this area run dry in the dry season.

In the Shwebo area, the alluvium layers are distributed as thin layers in the surface layer, and the diluvium layers and the Irrawaddy formulations are distributed in the lower portions.

The general geological layer order in the neighborhood of Shwebo is as follows.

Layer order	Age	Features
Alluvium	Alluvial epoch	Distributed in the surface layer, and thin.
Diluvium	Diluvial epoch	Distributed under the alluvium, and thin.
Irrawaddy formations	Upper miocene and pliocene	Distributed in hills and plateaus, and also distributed as thin layers under the alluvium and diluvial layers.

The alluvium and diluvium layers consist of sand and clay alternates. The Irrawaddy formations show the folding structure in some parts and consist mainly of clay, with sand and layers mixed.

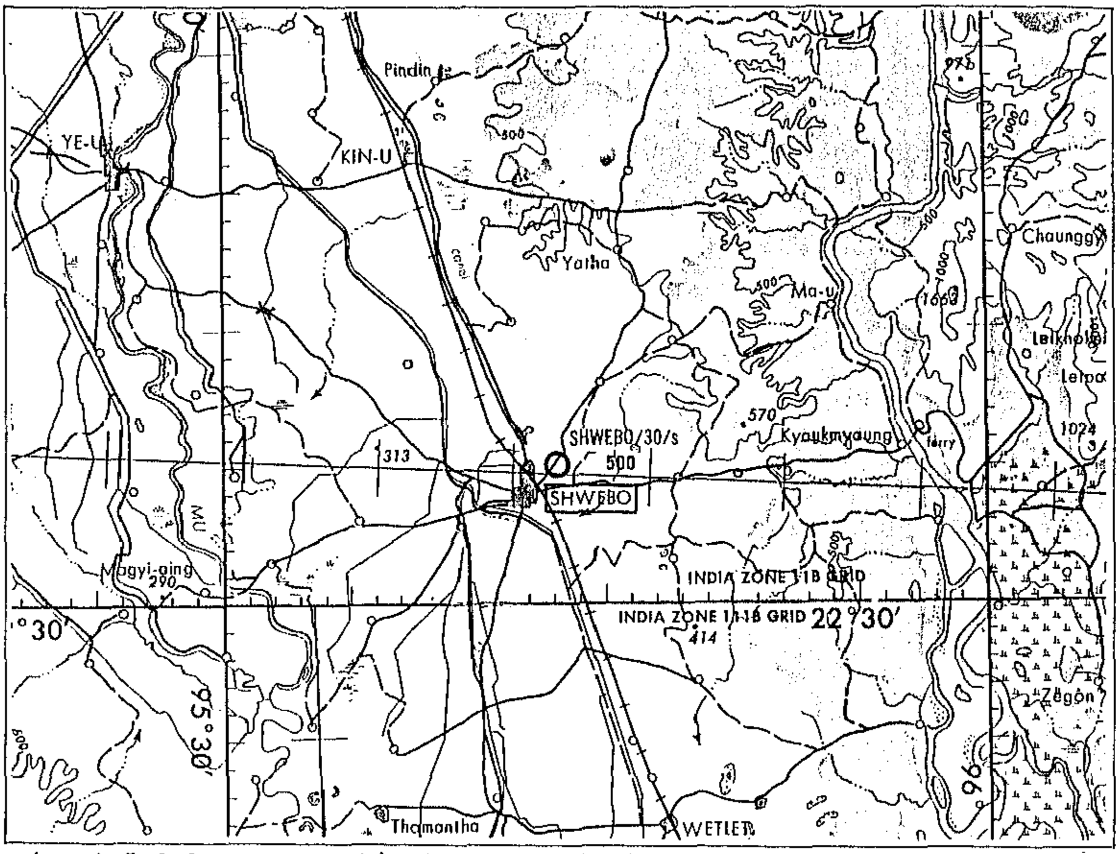


Fig. 4.5.2.1 Topographical Map of Shwebo Scale 1:500,000

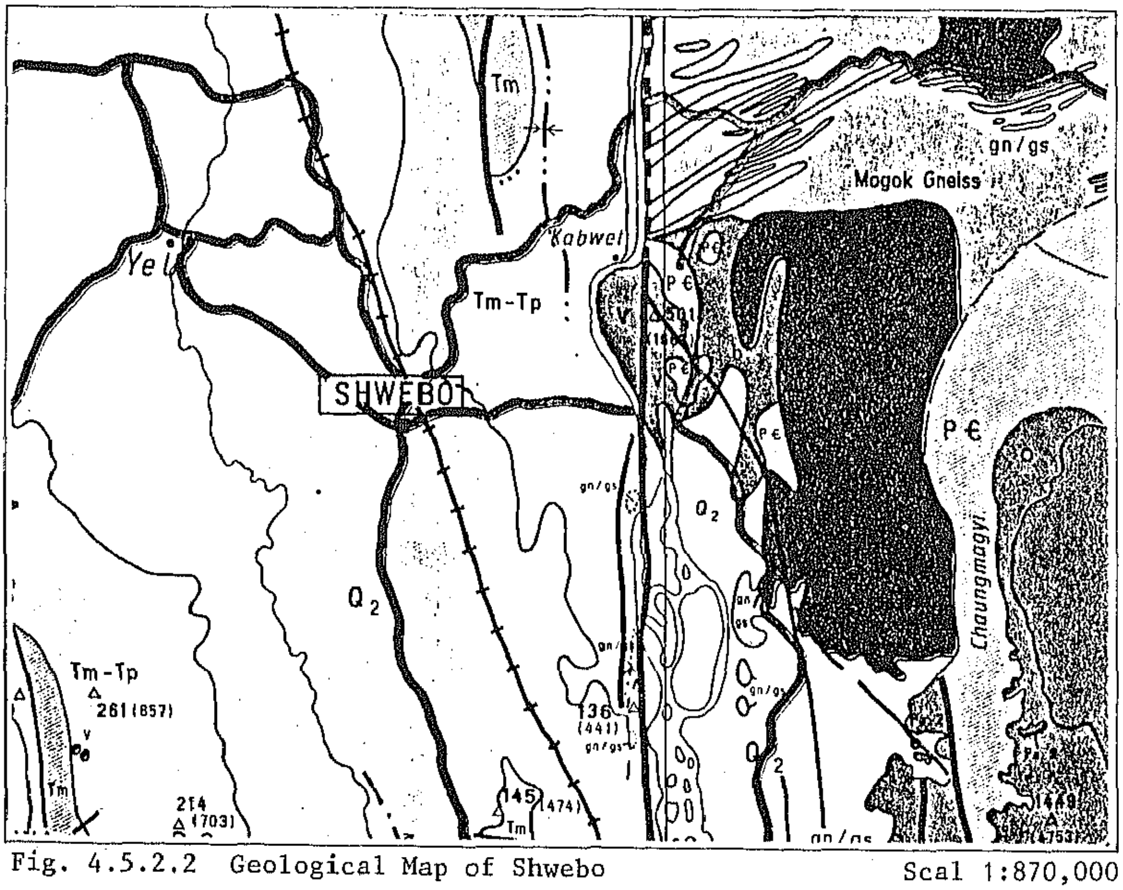


Fig. 4.5.2.2 Geological Map of Shwebo Scal 1:870,000

(2) Hydrogeology

In the Shwebo area, the alluvium layers cover widely in a flat condition without rolling. On the east side, the Irrawaddy formations are distributed as plateaus relatively high compared with the west side.

In the Shwebo area, there are hand dug wells for the ground water in the surface layer distributed at GL-0 to 5m. Tube wells for the ground water are drilled into the other aquifers. The depth of the tube well depends on the depth of the appropriate aquifers. As seen in Fig. 4.5.2.3 for well logs and Fig. 4.5.2.4 for sectional views, the aquifers are divided into three, upper, middle and lower portions, the distribution depth of which are the E-W section, the dip is nearly horizontal, and in the SE-NW section, the dip is in the SE to NW direction. From Fig. 4.5.2.5 for depth distribution, it is seen that the south-east side is shallow and the north-west side is deep. The aquifers in the upper portion consist of white coarse sand particles, and the aquifers in the middle and lower portions consist of blue fine sand particles. The static water level is high as a whole and GL-0 to -11.6m.

According to the existing data, the ground water level in teh Shwebo area is high on the north-east side and low in the south-west side.

The water quality of the ground water in the Shwebo area shows the electric conductivity EC 1.8 to 2.2 x 10^3 μS/cm, which is relatively high, and 4.2 x 10^3 in some cases, indicating that higher dissolved salts are contained as a whole. pH is about 7.5 in many cases.

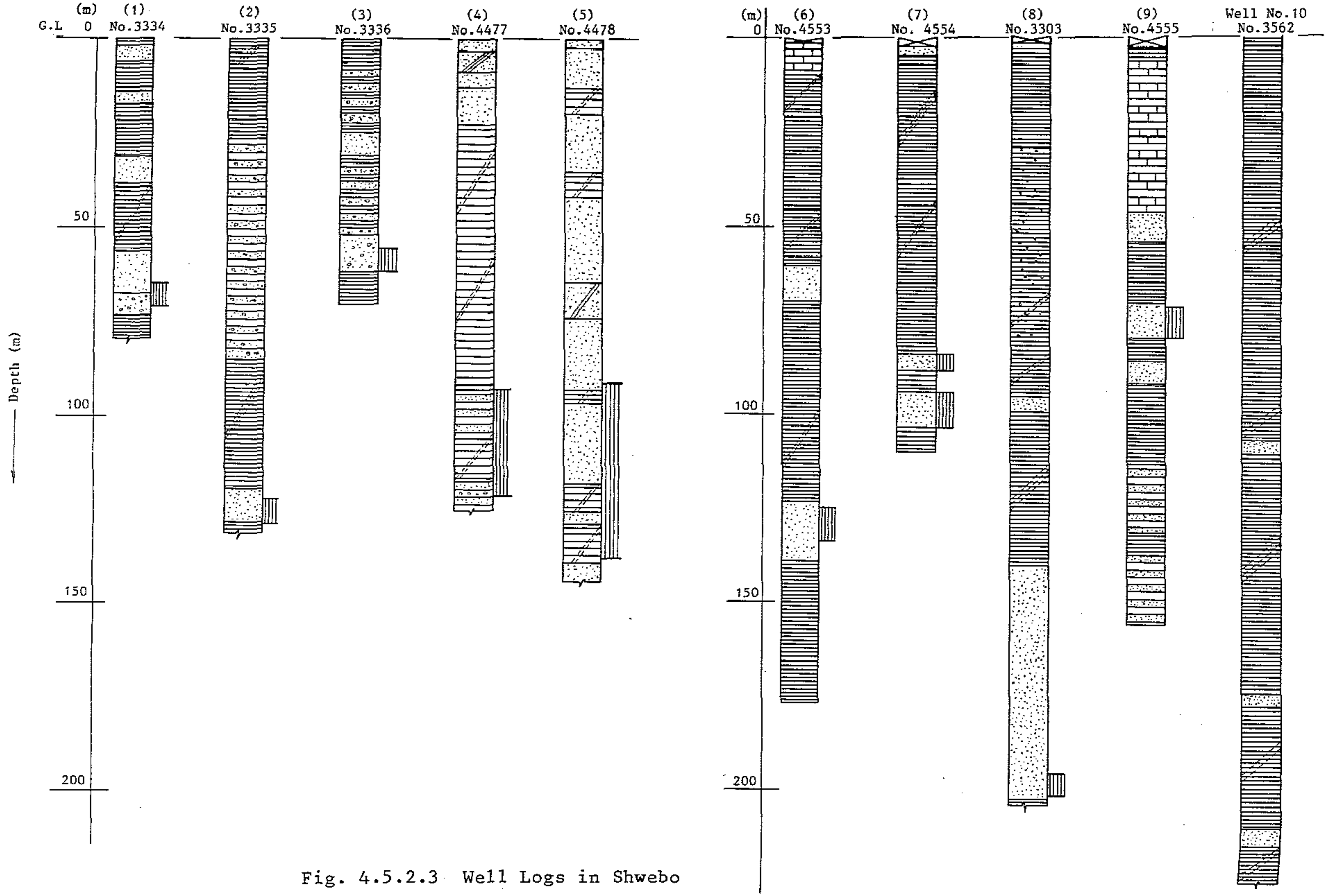


Fig. 4.5.2.3 Well Logs in Shwebo

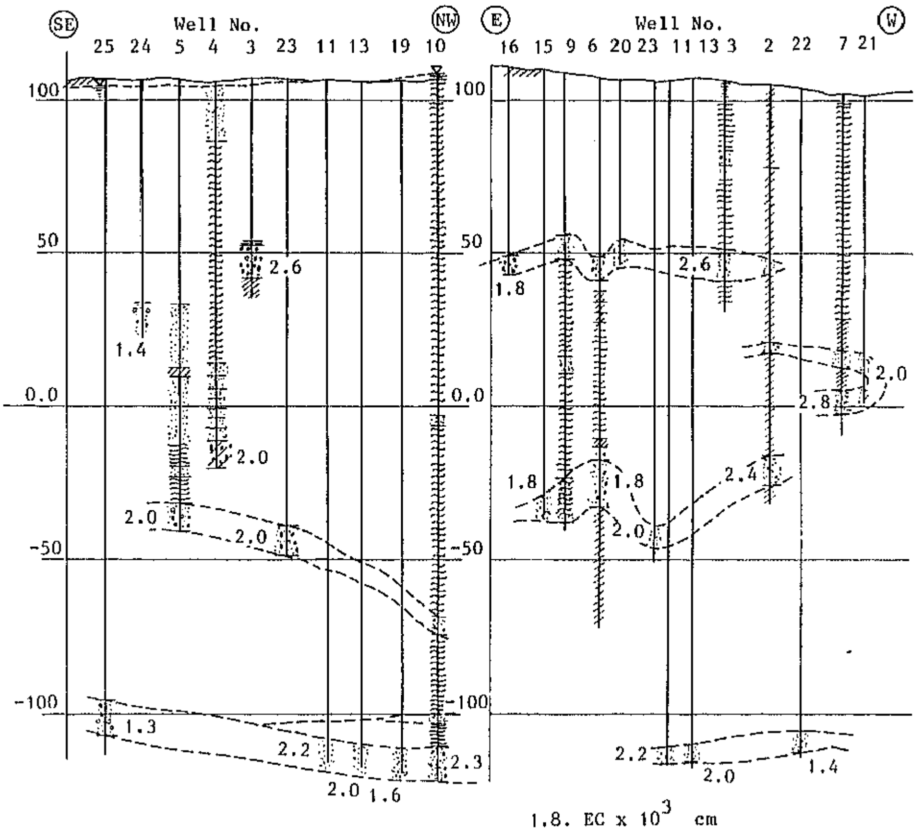
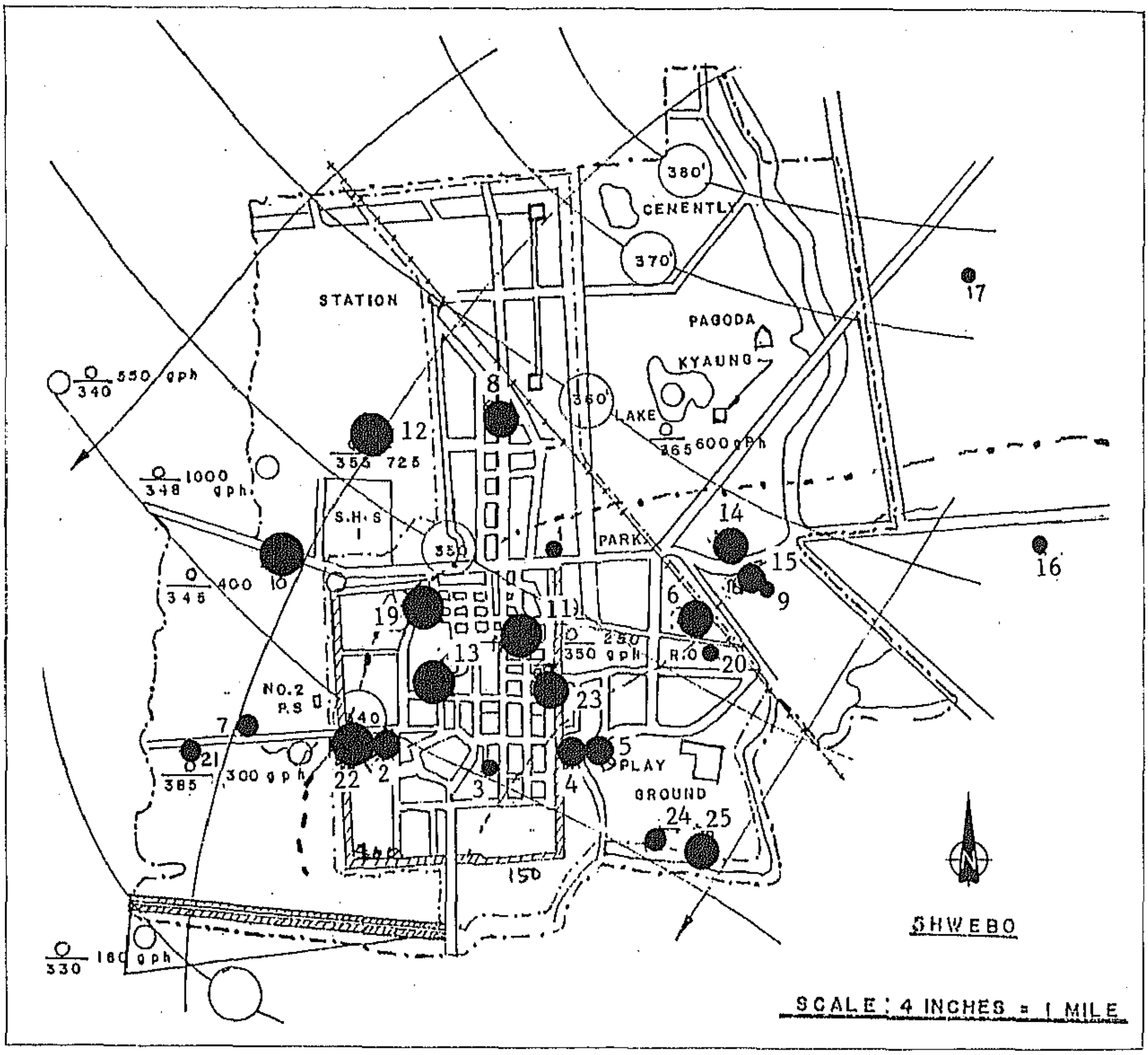


Fig. 4.5.2.4 Section of Tube Wells in Shwebo



Depth (in feet)

≃ 200~300′	≃500~700′
≃ 300~400′	>700′
≃ 400~500′	

Fig. 4.5.2.5 Location and Depth of Existing Tube Wells in Shwebo

2) Aquifer

The aquifers in the Shwebo area are sand and gravel layers of the Irrawaddy formations distributed under the alluvium and diluvium. The aquifers of the Irrawaddy foramtions are mixed n clay layers, and because of the folding structure, the depth varies with the location. As shown in Fig. 4.5.2.4, except the ground water in the surface layer, three aquifers are seen at the depths available for pumping-up of water. Each aquifer consists of sand and gravel, with clay mixed in some parts. Except the lower aquifer, the thickness is uneven in many cases.

According to the existing well logs, sand layers are mixed in the clay layer, and these sand layers are aquifers and strainers are provided in to them.

In the Shwebo area, Electric prospecting was carried out at 12 points are shown in Figl. 4.5.2.6.

The results are shown by the resistivity profile in Fig. 4.5.2.7. Also, the permeable bed distributions at GL-50m are shown in Fig. 4.5.2.8.

① In the upper portion of this area, the permeable bed - aquiclude, and aquiclude - impermeable bed are disstributed irregulary. The resistivity is 30 Ω-m in the main, but low resistivity and high resistivity are also seen.

② In the middle portion, impermeable beds of $\rho < 0.1$ are distributed as thick layers.

③ In the lower portion, layers of high resistivity are distributed as thick layers, but not in some areas. These layers are good aquifers, but in the northern part, they are thin layers.

④ Boundaries of various layers in this area are rolling. The lower layers as good aquifers show varying depth from place to place.

⑤ The permeable bed in the lower portion shows the folding structure, and as shown in Fig. 4.5.2.6, axes of anticline in the northeast-southewest direction are seen at EL-50m. To the southeast of the axes of anticline, the permeable beds are thick, but to the northwest, they are thin.

It is considered that the ground water in this area is stored in the layer corresponding to the peremable beds in the lower portion. The distribution depth is EL-50m on average, but as low as E-100m at some locations. The ground water in this area is in the artesian form.

The aquifers in the Shwebo area are sand and gravel layers mixed in clay layers, and screens for wells are installed in these sand and gravel layers. Few screens are installed in the permeable beds. At this point, the coefficient of permeability will be otained for those wells for which well logs are available. The static water level in each well is distributed near the ground surface. The ground water is artesian.

Table 4.5.2.1 Permeability Coefficient in Shwebo

Well No.	Well No.	Aquifer m (cm)	Draw down H-h (cm)	Discharge $Q(m^3/sec)$	Diameter m (cm)	Permeability k (cm/sec)
No. 1	3334	625	1,159	8,653	15.24	1.67×10^{-2}
No. 2	3335	625	305	6,500	15.24	5.50×10^{-2}
No. 3	3336	625	2,745	3,750	15.24	3.06×10^{-2}
No. 4	4477	3,050	3,206	12,500	15.24	1.79×10^{-3}
No. 6	4553	915	3,995	4,475	15.24	1.71×10^{-3}
No. 7	4554	915	(4,000)	7,250	15.24	2.77×10^{-3}
No. 9	4555	610	4,056	8,125	15.24	4.59×10^{-3}

The permeability coefficient was calculated in accordance with Thiem's formula described in paragraph 3.1.2.2) on assumption of the influence radius (R) of 500m. As seen in the above table, the permeability coefficient is grouped roughly into the orders of 10^{-2} cm/sec and 10^{-3} cm/sec. The former refers to coarse sand layers, and the latter refers to sand and clay alternates or fine and middle sand.

The permeable beds in the present plan are considered to be coarse sand or coarse sand with gravel mixed, and k to be 1.0×10^{-2} cm/sec or higher.

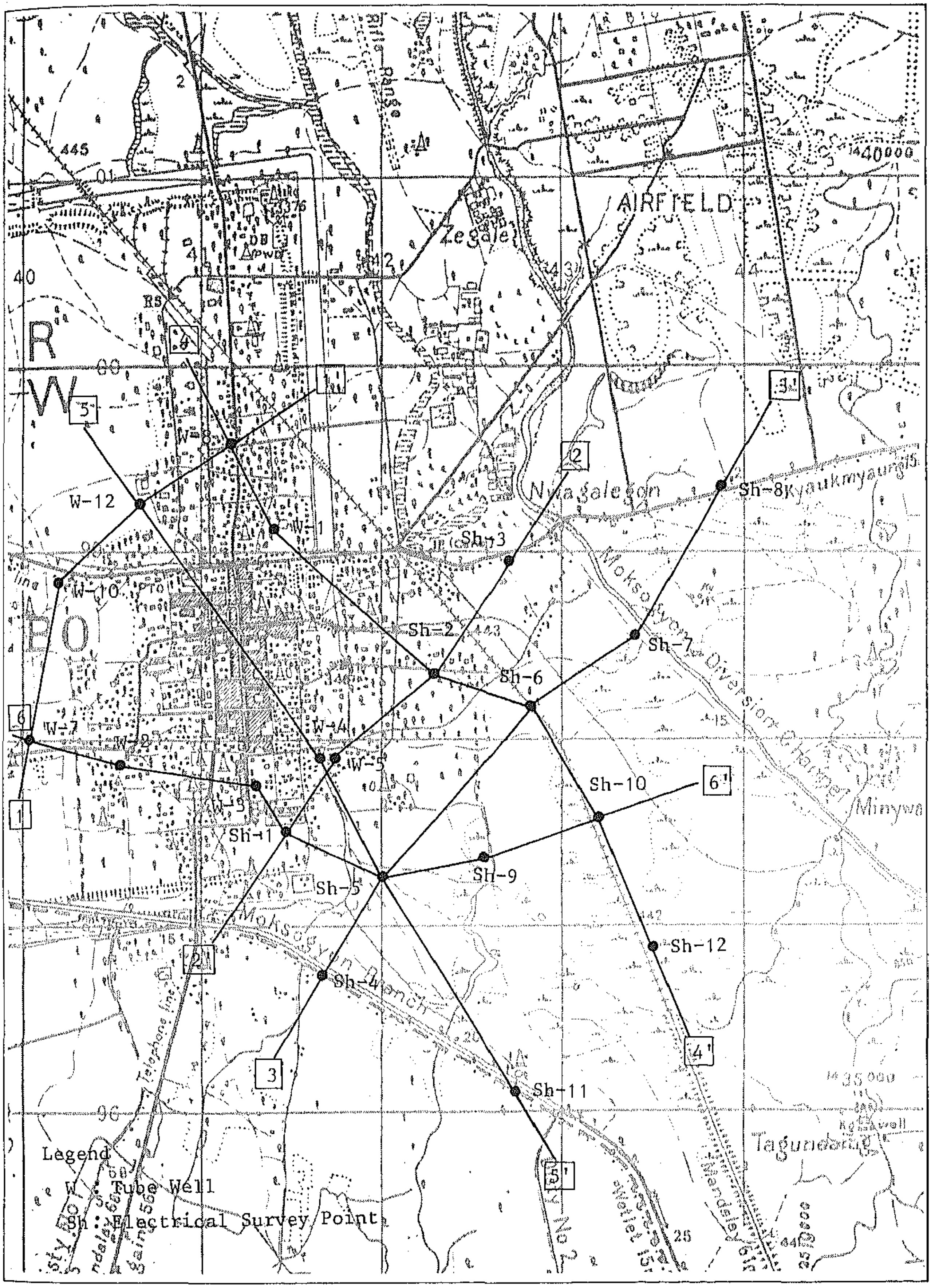
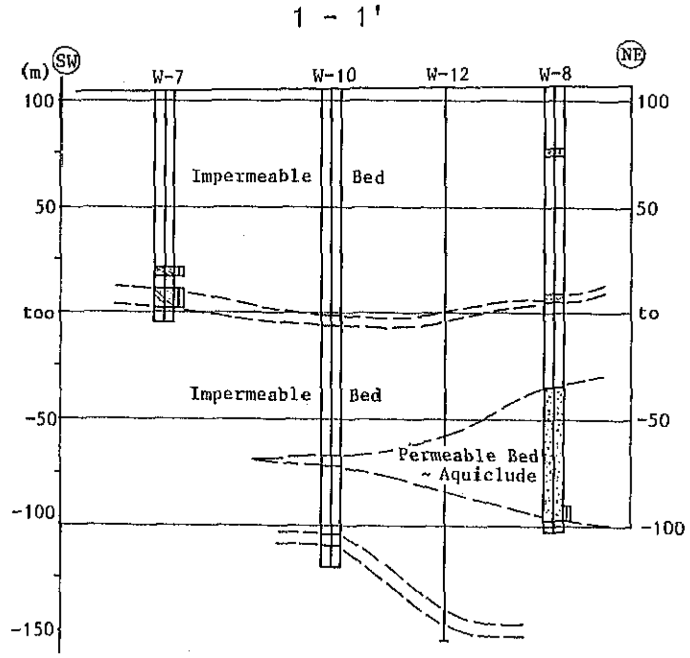
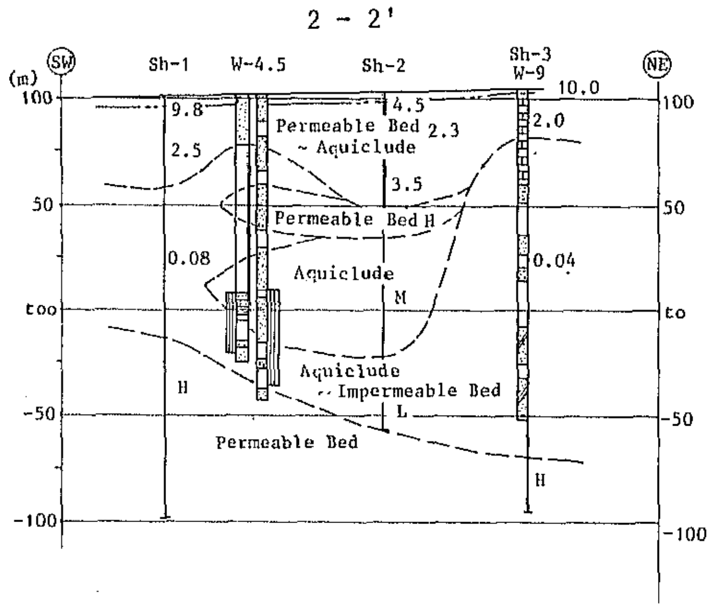


Fig. 4.5.2.6 Location of Tube Well and Electrical Survey Point in Shwebo





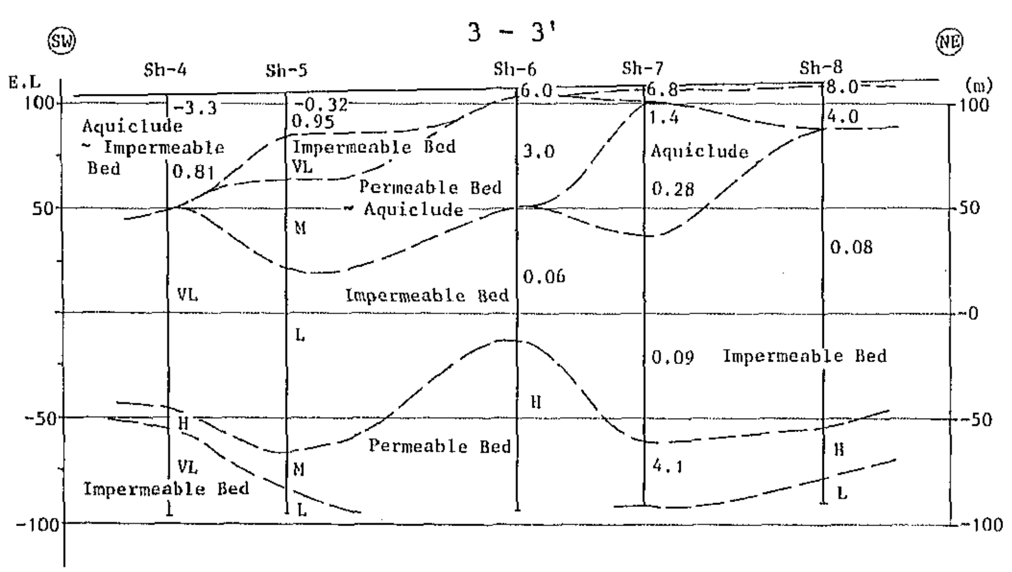
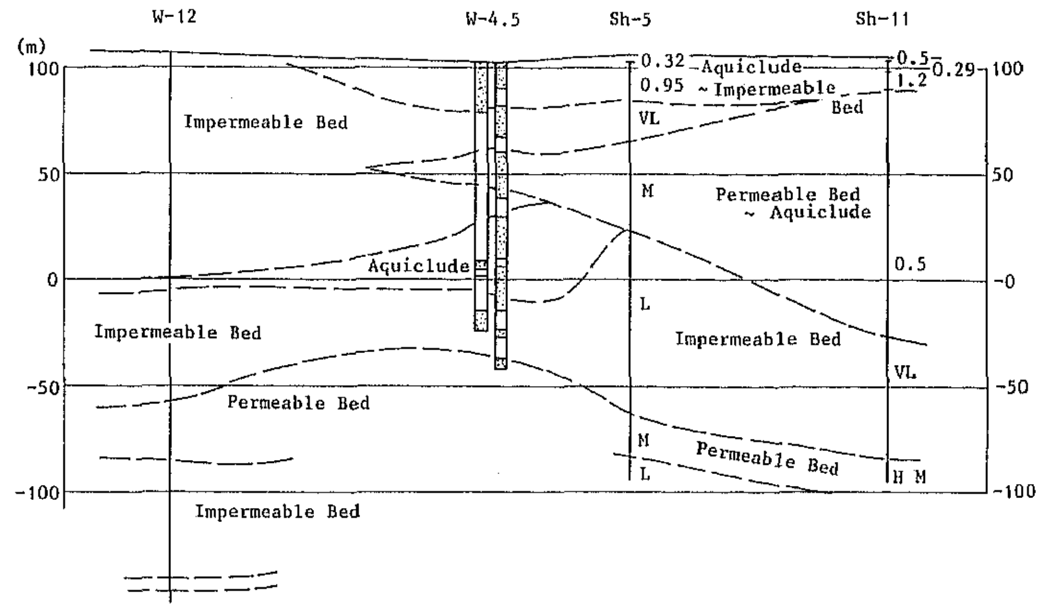
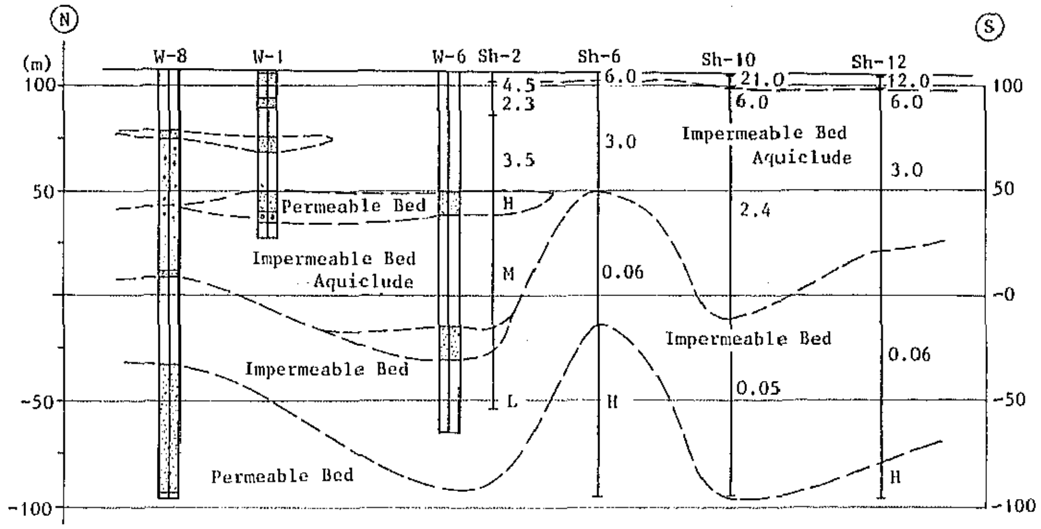


Fig. 4.5.2.7 Resistivity Profiles of Shwebo (1)

4 - 4'



5 - 5'



6 - 6'

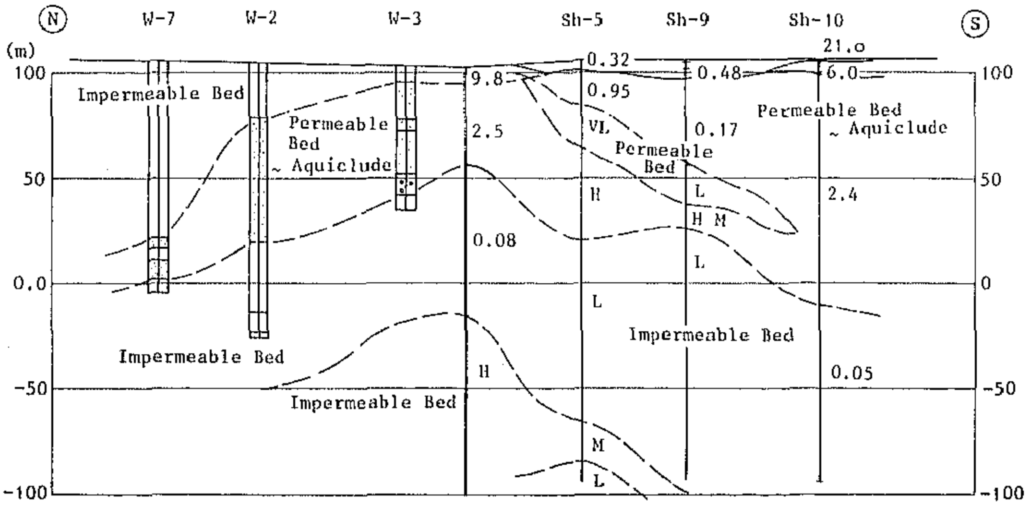


Fig. 4.5.2.7 Resistivity Profiles of Shwebo (2)

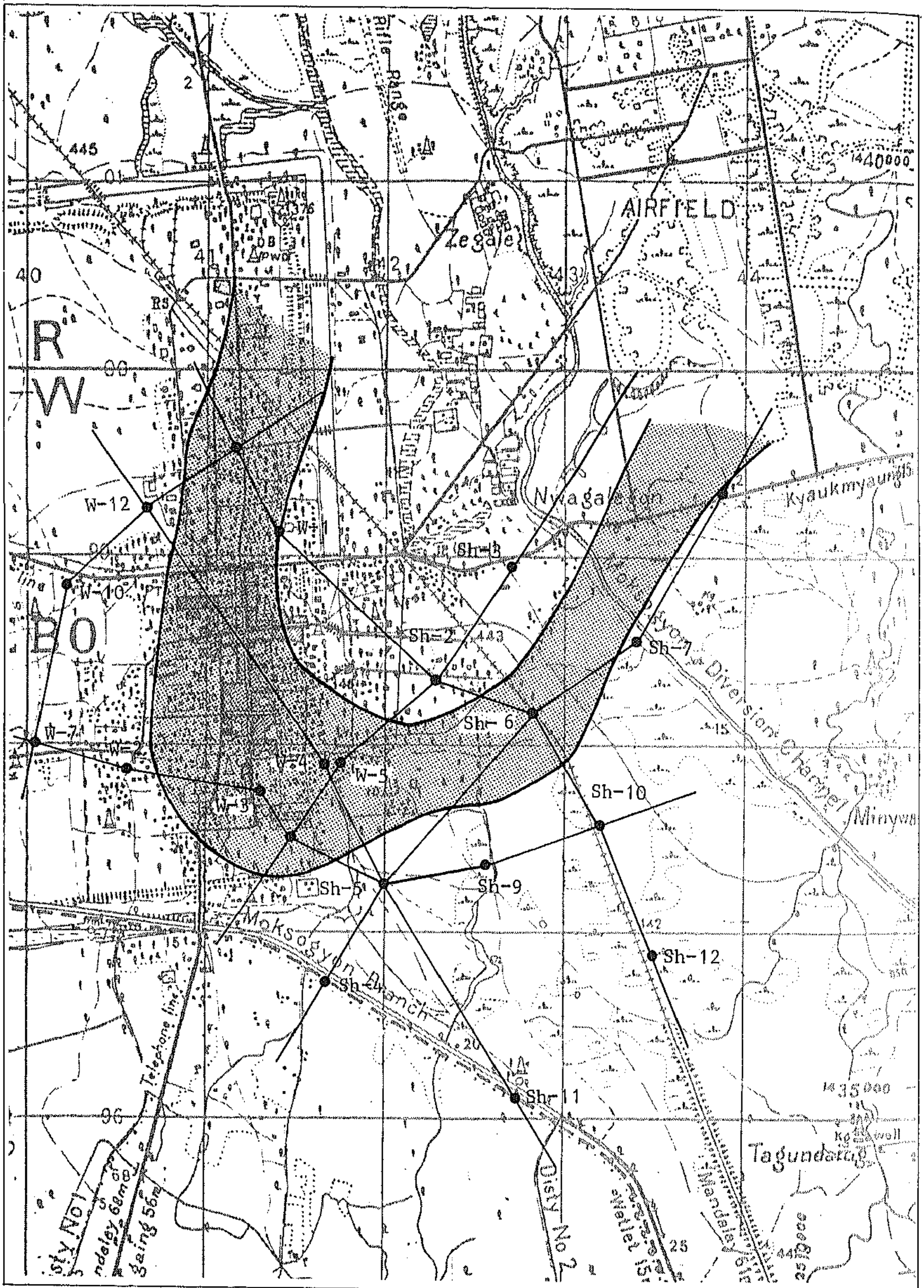


Fig. 4.5.2.8 Distributed Area of Permeable Bed EL-50m

3) Ground Water Storage and Water Quality

(1) Ground Water Storage

The annual precipitation P and potential evapotranspiration E are as follows.

Precipitation $P = 869$ mm

Evapotranspiration $E = Ep \times 0.7$

$= 2{,}009 \times 0.7 = 1{,}406$ mm

(The value of evapotranspiration in Monywa is used.)

Considering throughout the year, the ground water recharge G becomes as follows.

$G = P - E = 869 - 1{,}406 = -537$ mm

This means that the evapotranspiration exceeds the precipitation, and no ground water recharge takes place. The same may be said regarding the rainy season, too.

However, the ground water recharge actually in this area is that from the hills in the north-eastern part of Shwebo and from the Irrawaddy river. At this point, let us consider the recharge from the hills only.

The precipitation in the rainy season in Shwebo is about 790 mm. Assuming that 70% flows out to rivers, etc. and 30% is recharged, the recharge area is 10 x 10 = 100 km^2, then, the ground water supply into the Shwebo area is

$Q = 0.79 \times 0.25 \times 1.0 \times 10^8 = 1.97 \times 10^7\ m^3/yr$

Thus, the annual water recharge is $2 \times 10^7\ m^3/yr$. If the recharge from the Irrawaddy river Mu river is combined, there will be no problem in the ground water recharge in this area. However, if the precipitation decreases, the water recharge gets in sufficient. It is necessary to grasp the behavior of the ground water level adequately.

The ground water storage will be calculated from the volume adn porosity of the aquifers as follows.

$V = A \times S \times E$

where A: subject area 6 km^2

S: aquifer thickness 30m

E: porosity 15%

$V = 6.0\ km^2 \times 30\ m \times 0.15 = 27 \times 10^7\ m^3$

This value ignores the ground water make-up and flowout and shows the quantity stored in the present aquifer.

(2) Water Quality

In order to check to see if the ground water in this area is suitable for drinking, water tests (on-site test and laboratory test) were conducted.

At the site, EC, pH and water temperature were measured. EC is 1,800 to 2,300 μS/cm in most cases, but 4,200 μS/cm in maximum cases, indicating high salinity, or as small as 1,300 to 1,600 μS/cm. pH is 7.5 in most cases but 7.3 in some cases. Water temperature is as high as 30 to 32°C, suggesting that the water has long been in retention.

High EC is seen frequently in those wells shallower than 90m or deeper than 210m. EC of those wells 90 to 210m deep is below 2,000 $\mu S/cm^2$ in many cases.

The laboratory test was conducted for three points in total of two places (Kyidawsu, Youth Development Camp) deeper than 200m and one place of 85m (Gandama Yon Monastery).

The test results are shown in Table 4.5.2.2.

Table 4.5.2.2 Water Quality

		Kyidawsu	Gandama Yon Monastery	Youth Development Camp
1	Appearance	Slightly turbid	Clear	Clear
2	Total solids	1,130 mg/ℓ	710 mg/ℓ	650.0 mg/ℓ
3	Total hardness	235 "	60 "	48.0 "
4	Permanent hardness	- "	7 "	10.0 "
5	Calcium hardness	170 "	50 "	340 "
6	Total iron	3.4"	0.05 "	0.12 "
7	Chloride	525 "	260 "	216.0 "
8	pH	7.5"	7.3"	7.3 "
9	EC	2,300 μS/cm	1,400 μS/cm	1,300 μS/cm
10	Temp	30°C	20°C	29°C

The tube well at Kyidawsu shows total solids content 1,130 mg/ℓ, total hardness 235 mg/ℓ and chloride 525 mg/ℓ, and the water exceeds WHO standards and is not suitable for drinking. The water at the other two places satisfies WHO standards and can be adopted for drinking.

The ground water intake points and well specifications will be determined by investigations with exploration wells.

4) Discharge Rate per Well, Spacing between Wells, and Well Depth

(1) Discharge rate per well

The discharge rate per well must be grasped by conducting a pumping test. At this point, however, in accordance with Thiem's formula, the discharge rate per well will be estimated. The lowering of water level S is found as 7.10m by the following calculations for the spacing between wells 600m (influence radius 300m).

$$S = R/3000\sqrt{k} = 300/3000 \times \sqrt{1 \times 10^{-4}} = 10m$$

where R in 300m and k is 1 x 10^{-4} m/sec.

The possible discharge rate is

$$Q = \frac{2\pi Dk\ (H - h)}{2.3\ \log R/r}$$

$$= \frac{2\pi \times 30 \times 1 \times 10^{-4} \times 10}{2.3\ \log 300/0.10}$$

$$= 0.0235\ m^3/sec = 1,520\ m^3/18\ hr$$

Therefore, it is considered that in this area 1,520 m^3/18 hr can be secured. However, considering the thickness and permeability of the aquifers, and ground water recharge, it will be necessary to set the discharge rate at about 700 m^3/18 hr.

(2) Spacing between Wells

The spacing between wells shall be such that is does not cause decrease of the discharge rate due to neighboring casing drawdonw of the water level, and does not cause interference between wells.

For this area, considering the ground formations, conditions of aquifers and the discharge rate per well according to the existing data, the minimum spacing between wells will be taken as 600m.

(3) Well Depth

Regarding the well depth, considering the depth of storage of the aquifer of about 200m as the lower limit, the average depth of production wells will be taken as 206m (6m for sand pit).

4.5.3 Planning the Water Supply System

1) Project Area

The town area spreads around the eastern end of the old castle and is surrounded by rice fields. This town has no water supply system. Thefefore, the town area excluding the rice fields and military area is covered in the project area.

2) Planned Water Supply Population

The total population of this town as of 1983 is 52,159. Of them, 3,239 persons dwell in the military area and have something to do with the military. The have their own water supply facilities. The remainder 48,920 are counted as the present population. The past average population growth rate is 2.1%. Theferore, the planned water supply population y is

$$y = 48{,}920\ (1 + 0.021)^8$$
$$= 57{,}769 \text{ persons}$$

Thus, the planned water supply population is 57,800 persons.

3) Planned Water Supply Amount

Planned water supply amount

= planned water supply population

x planned daily maximum supply per capita

= 57,800 persons x 105 ℓ pcd

= 6,069,000 ℓ/day

= 6,100 m^3/day

4) Division into Water Supply Blocks

The drinking water to the project area is conveyed from the ground-water source being planned at the boundary of the southeastern part of the town. For the water distribution to water supply areas, it is necessary to install elevated tanks since the land is flat. Investigation was made in two cases, in one of which a single elevated tank is constructed and in the other, plural tanks are installed.

In the case of a single tank, the tank capacity should be large as required by the large planned water supply amount, an effective tank heigh tof nearlly 20m should be required since the water supply area is wider, and the maintenance and management might be combiersome. For these reasons, the water supply area is divided into three blocks, each of which is given an independent water supply system. (Refer to Fig. 4.5.3.2.).

The planning specifications for each block are as shown in the following table.

Table 4.5.3.1 Planning Specifications by Blocks

Block \ Specifi-ations	Planned water supply population (Person)	Water supply area (ha)	Population density (person/ha)	Planned water supply amount (m^3/d)
A	19,800	202.4	97.8	2,080
B	19,100	127.9	149.3	2,010
C	18,900	207.9	90.9	1,990
Total	57,800	538.2	107.4	6,080

5) Facility Planning

The expected areas for wells are located outside the planned water supply areas. The land is flat and each block has no high land which can be utilized for the construction of a reservoir. For these reasons 3 of the basic system will be applied. The number of planned wells required per block is taken as 3 since the planned pumping capacity per well is 700 m^3/day.

Block A: 2080 ÷ 700 = 2.97 → 3

Block B: 2010 ÷ 700 = 2.87 → 3

Block C: 1990 ÷ 700 = 2.84 → 3

Fig. 4.5.3.3 shows the layout of the facilities.

6) Outline of Facilities

Table 4.5.3.3 shows specifications and quantities for facilities.

Fig. 4.5.3.4 and Fig. 4.5.3.5 show water transmission pipeline and distribution pipeline networks, respectively. For the planned wells and elevated tanks, refer to the reference drawings given at the end of this chapter.

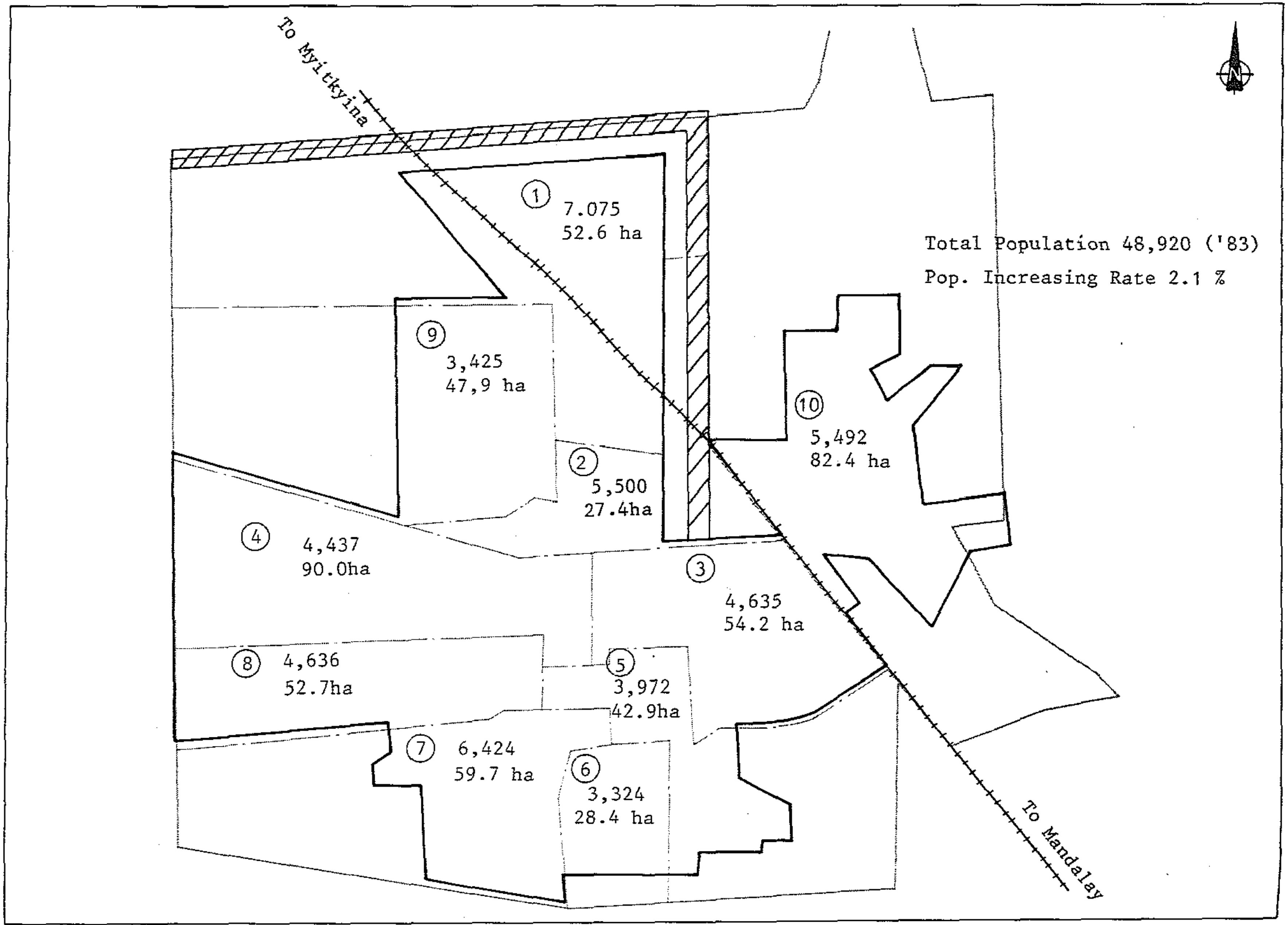


Fig. 4.5.3.1 Present Population and Area of Each Ward in 1983

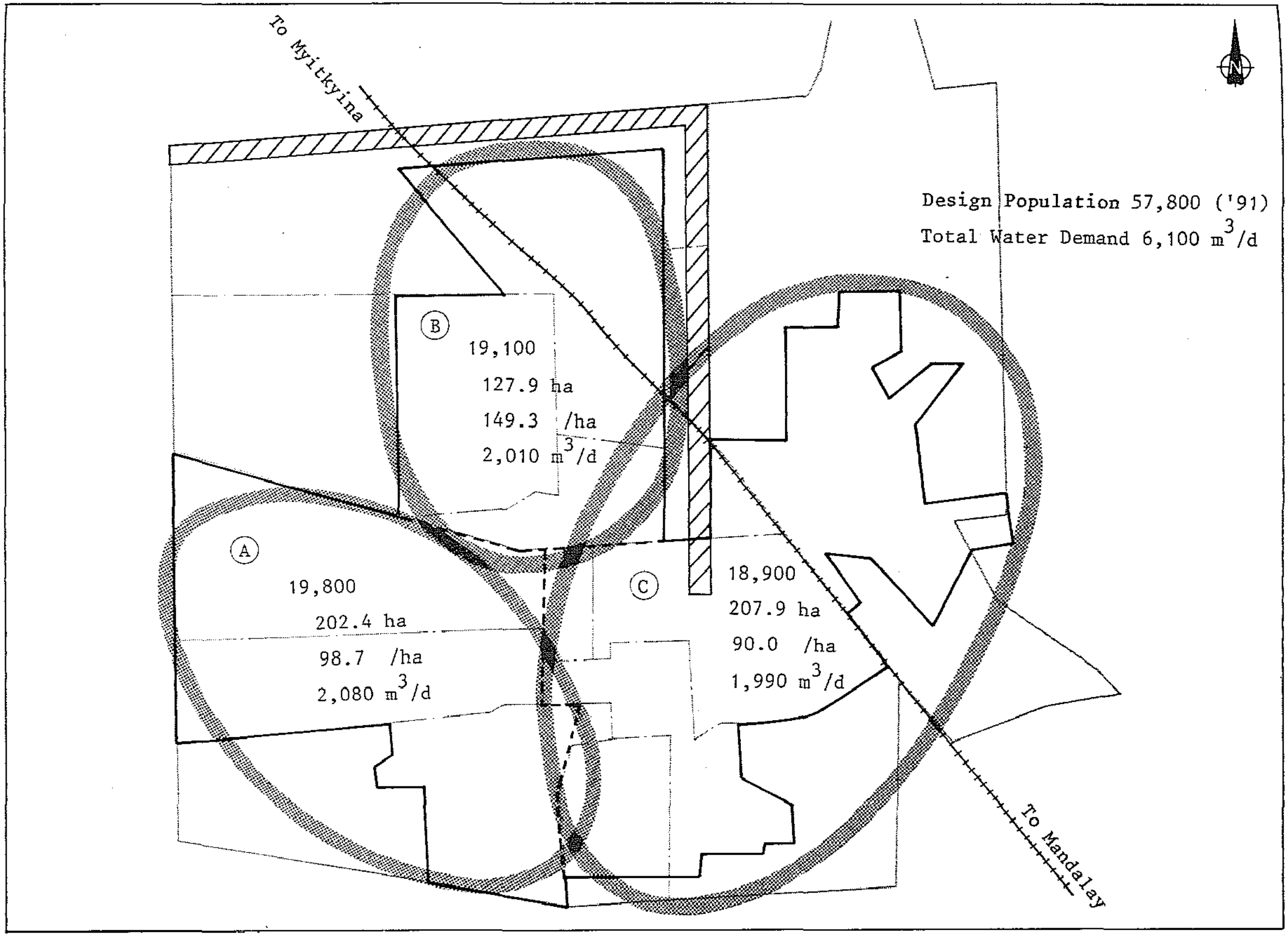


Fig. 4.5.3.2 Distribution of Design Population

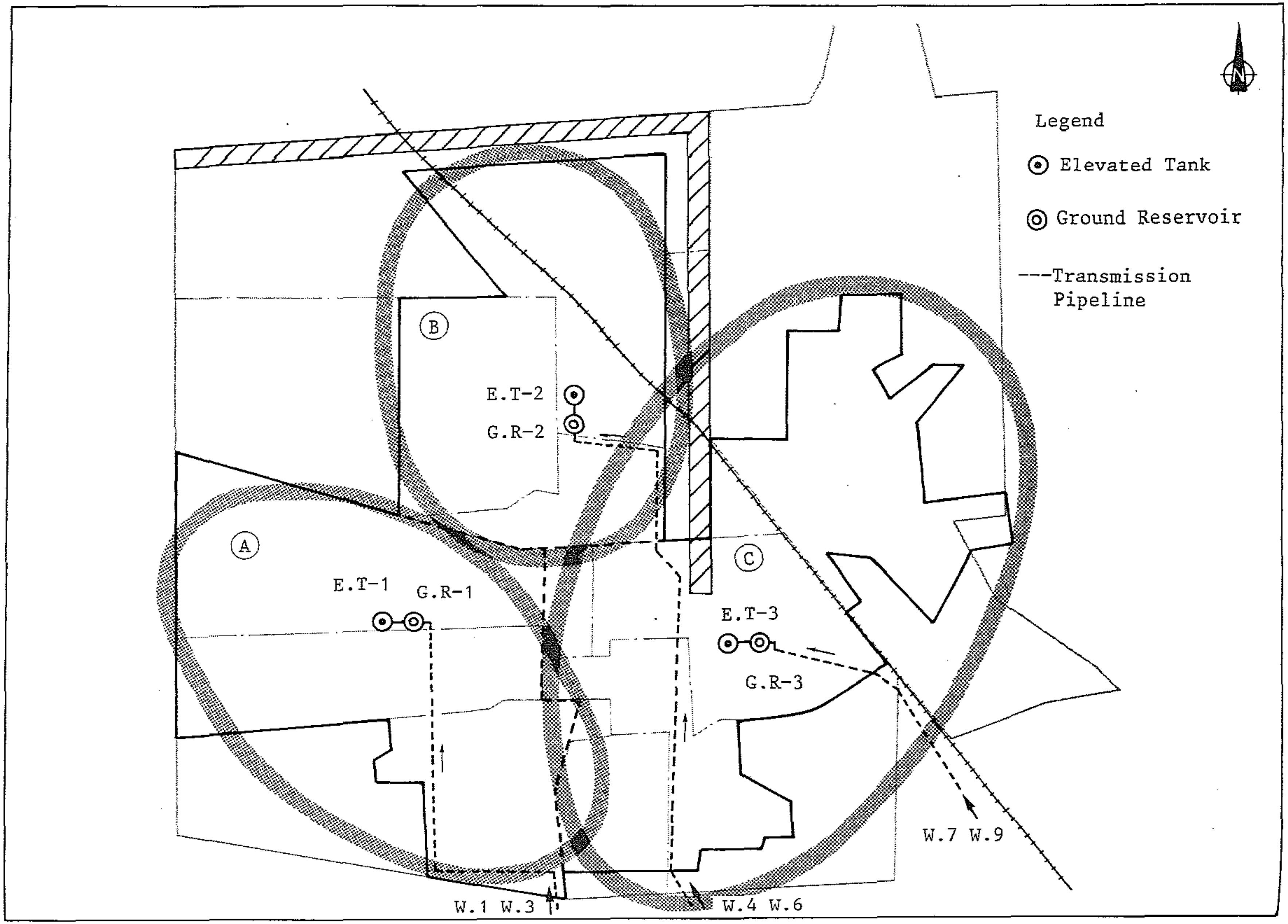


Fig. 4.5.3.3 Layout Plan of Proposed Facilities

Table 4.5.3.2 List of Proposed Facilities

Facility	Item	Classification	No.	Remarks
Water intake facility	Production well	Planned intake rate $700m^3/d$ φ200mm x H206m	9	Casing H = 186m Screen H = 20m
	Exploration well	φ150mm x 250m	5	Casing H = 230m Screen H = 20m
	Observation well	φ100mm x 206m	7	Casing H = 196m Screen H = 10m
	Intake pump	φ80mmx0.648m^3/min x 11kW	9	W-1 to W-9
	Pump room	Brick construction 4m x 4m Building area $16m^2$	9 buildings	
Water transmission facility	Water transmission pipe	φ150mm x φ250mm T type ductile cast iron pipe class 3	9540m	
		Various reducers	1 set	
	Sluice valve	φ150mm to φ200mm	9	
	Air valve	φ20mm	13	
Water distribution facility	Junction well well	Capacity $170m^3$ Underground RC construction	2	JW-2, JW-3
		Capacity $175m^3$ Underground RC construction	1	JW-1
	Elevated tank	Capacity $41.3m^3$ to $43.3m^3$ FRP panel Hight 15.0m Steel base stand	3	ET-1 to ET-3
	Booster pumps	φ150mm x 0.648m^3/min x 11kW	3	
	Distribution pipes	φ75mm to φ200mm T type ductile cast iron pipe class 3	25,670m	
		Various reducers	1 set	
	Sluice valves	φ75mm to φ200mm	60	
	Air valves	φ20mm		
Electric facility	Substation equipment	3φ4W 11kV/0.4 150 kVA	1 set	
	Transmission	DW 14□ to 100□ CV 14□ x 4x	23.4km	
		Accessories	1 set	

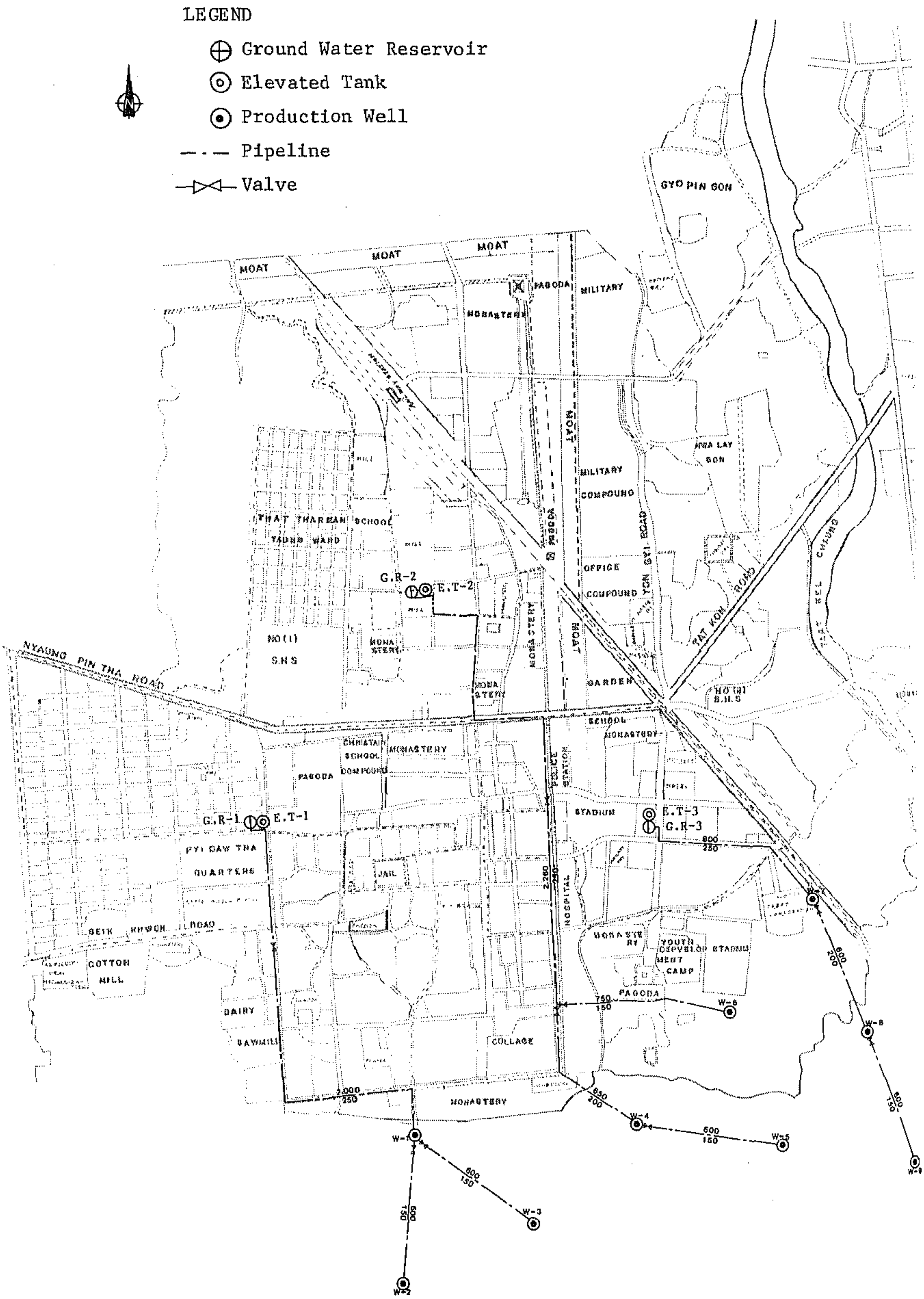


Fig. 4.5.3.5 Layout of Transmission Pipeline

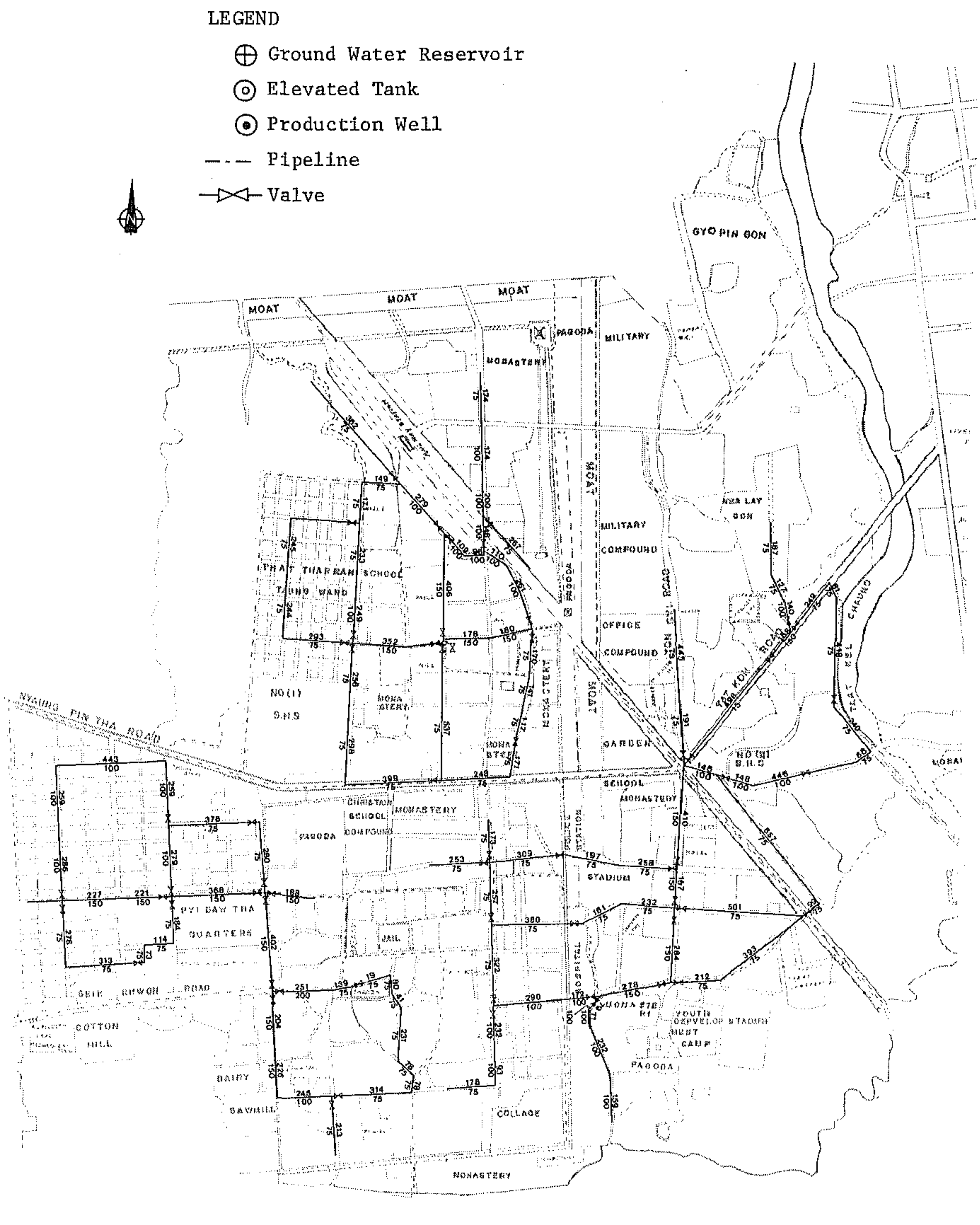


Fig. 4.5.3.6 Network of Distribution Pipeline

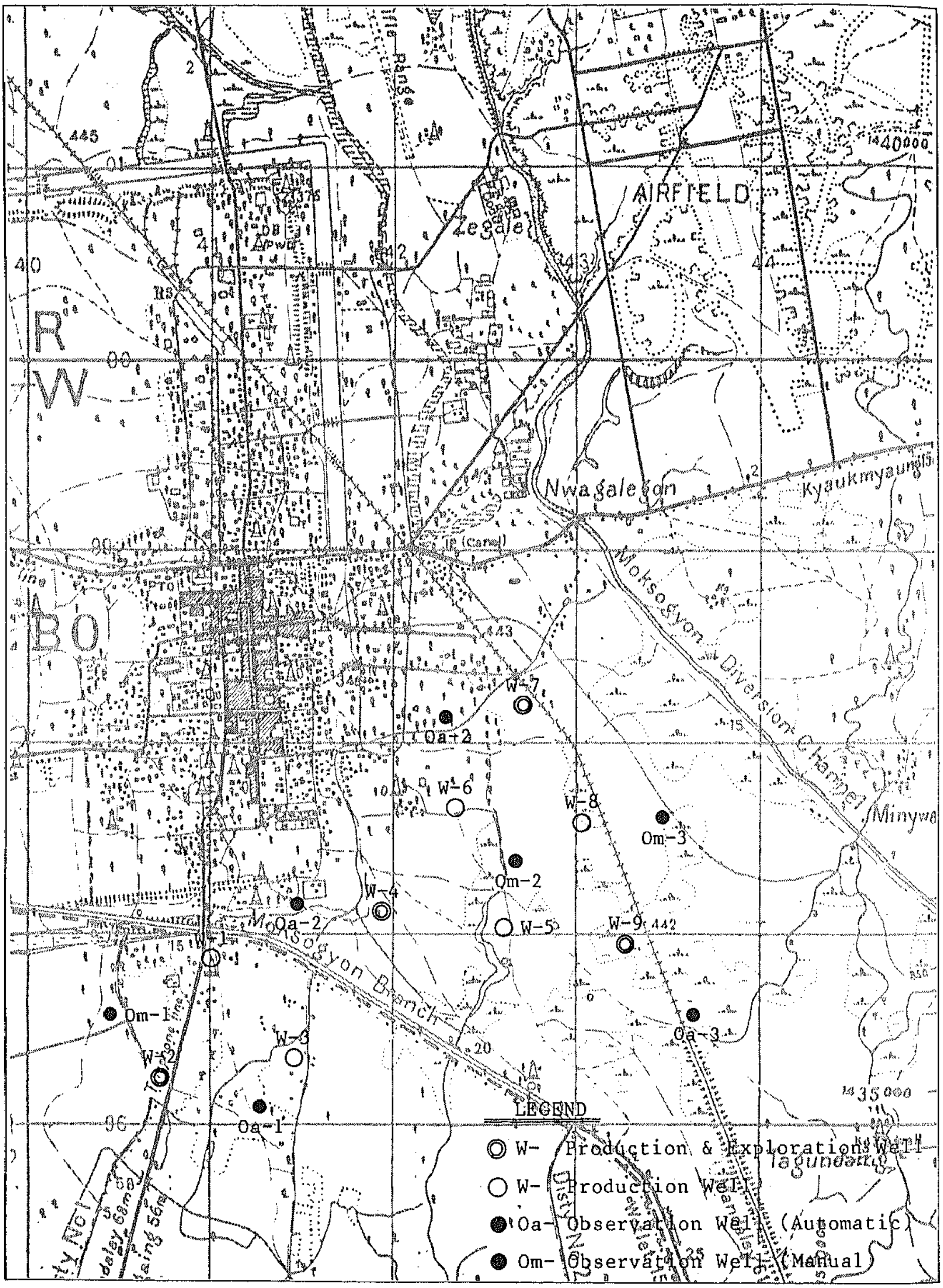


Fig. 4.5.3.6 Layout of Proposed Wells