3.2 Groundwater Resources

3.2.1 Hydrogeological Characteristics

(1) Field Reconnaissance and Existing Well Investigation

1) Field Reconnaissance

Field reconnaissance with some interview survey was carried out mainly at the 10 villages that had been selected already by the every 11 Townships as the target villages of this Study. These villages are facing larger difficulties for accessing to drinking water in the Township.

The contents of the field reconnaissance were as follows.

- Topographical, geological and hydrogeological characteristics of each Township and the villages.
- Domestic water source, existing tube well and its conditions, water supply conditions, requested drilling site, accessibility by drilling rig, etc. in the village and its vicinities.
- Selection of the site of geophysical survey to be performed in the Phase II study.

Results of the field reconnaissance were presented in 3-A Survey Results of Hydrogeology in the Central Dry Zone of Vol. III Supporting report.

2) Existing Well Investigation

Questionnaire survey for existing wells was carried out together with the field reconnaissance described above.

As WRUD is preparing a well database on WRUD-constructed wells, it was referred as much as possible. Furthermore, a questionnaire survey was conducted in order to grasp the situation of all main wells, which are operated other than the WRUD's management in the Study Area. The wells less than about 3-5 m deep, those were mostly dug wells, were neglected in the survey. Items of location, construction year, water level, pump type installed, a pumping rate, casing program, aquifer depth, etc. were checked.

Information of the existing wells collected through the questionnaire survey was input into the database being built up by the Study Team. Furthermore, 10 to 15 of the existing wells in every Township were selected as the monitoring wells to check water level and water quality. Selection of the monitoring wells was performed considering following conditions.

- Water level can be measured
- Screen positions are known
  If it is not known, to be estimated from the well depth
- Average pumping time in a day is within 12 hours
- Locations cover evenly whole Township area
- Water samples can be taken

The measuring work was instructed by the Study Team to the DDA's counterparts at the beginning of the Phase II study then the counterparts continued it by themselves once a month. The Study Team has lent the instruments for the work.

Furthermore, water quality tests of the monitoring wells in laboratory were performed at least once during the Phase II study.

Location map and list of the existing wells are presented in "6. Formulation of Well Database". List and observation records of the monitoring wells are presented in 3-B of Vol. III Supporting report, and results of water quality test in laboratory are presented in 3-C of Vol. III Supporting report, respectively.

Unfortunately, in spite of the tight instruction by the Study Team, some observation records obtained are doubtful to some extent. The causes of doubt are assumed as follows.

(i) Error of measurement method or operation error of equipment
(ii) Error of reading of equipment indicator or error of writing down

(a) Static water level (SWL)

Static water level among the observation records was studied to know the fluctuation through a year (see Fig. 3.2.1.1(1/4)-(4/4)). The only data that could be obtained through a year were used to study.

The fluctuation of static water level shows some cases indicating the error of the observation. However, it can be said as a whole that the difference of water level between the dry season and rainy season is very small (less than 5(five) feet).

Fig.3.2.1.1 Fluctuation of Static Water Level of Monitoting Wells in the Cetral Dry Zone (1/4)

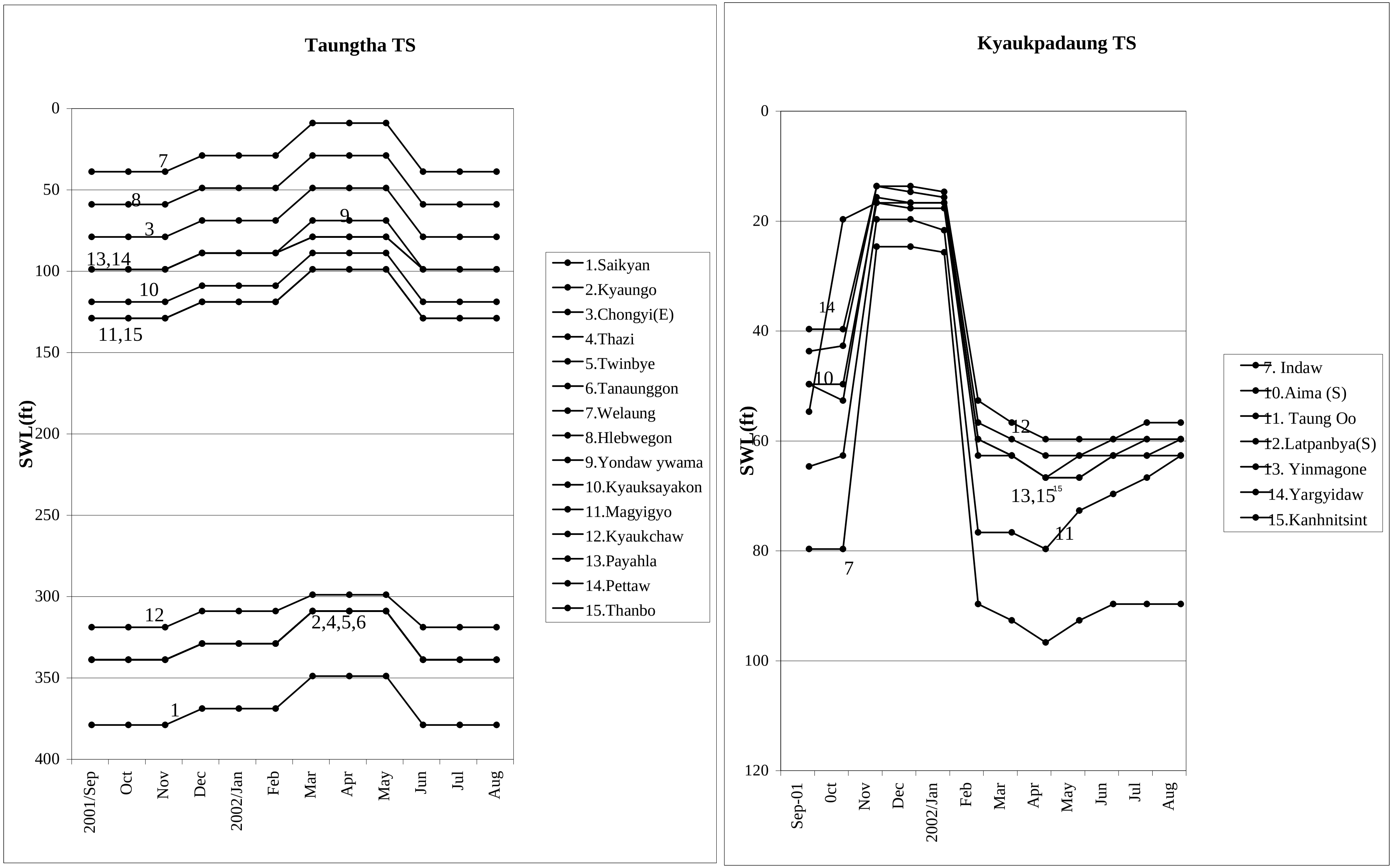


Fig.3.2.1.1 Fluctuation of Static Water Level of Monitoting Wells in the Cetral Dry Zone (2/4)

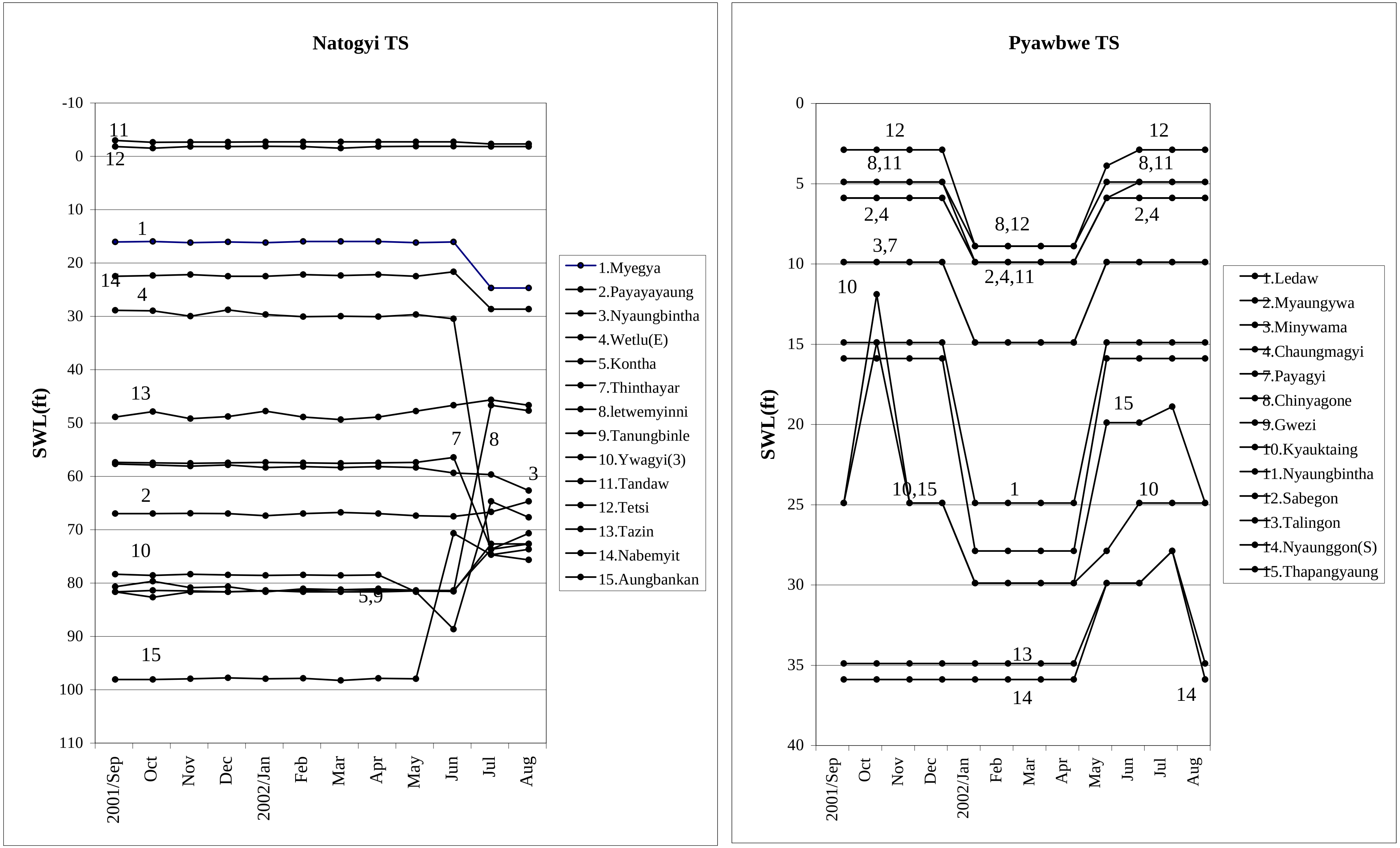


Fig.3.2.1.1 Fluctuation of Static Water Level of Monitoting Wells in the Cetral Dry Zone (3/4)

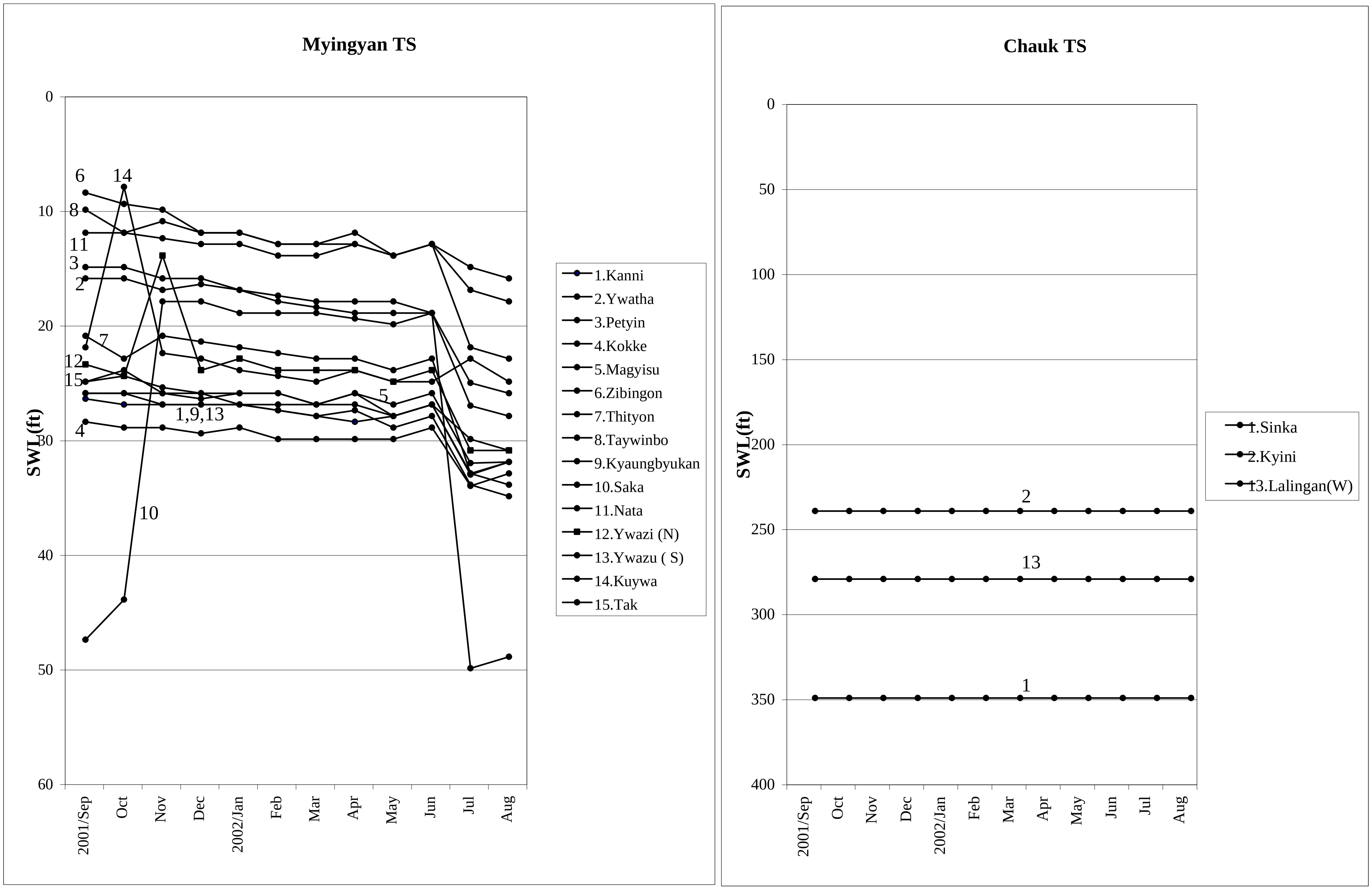
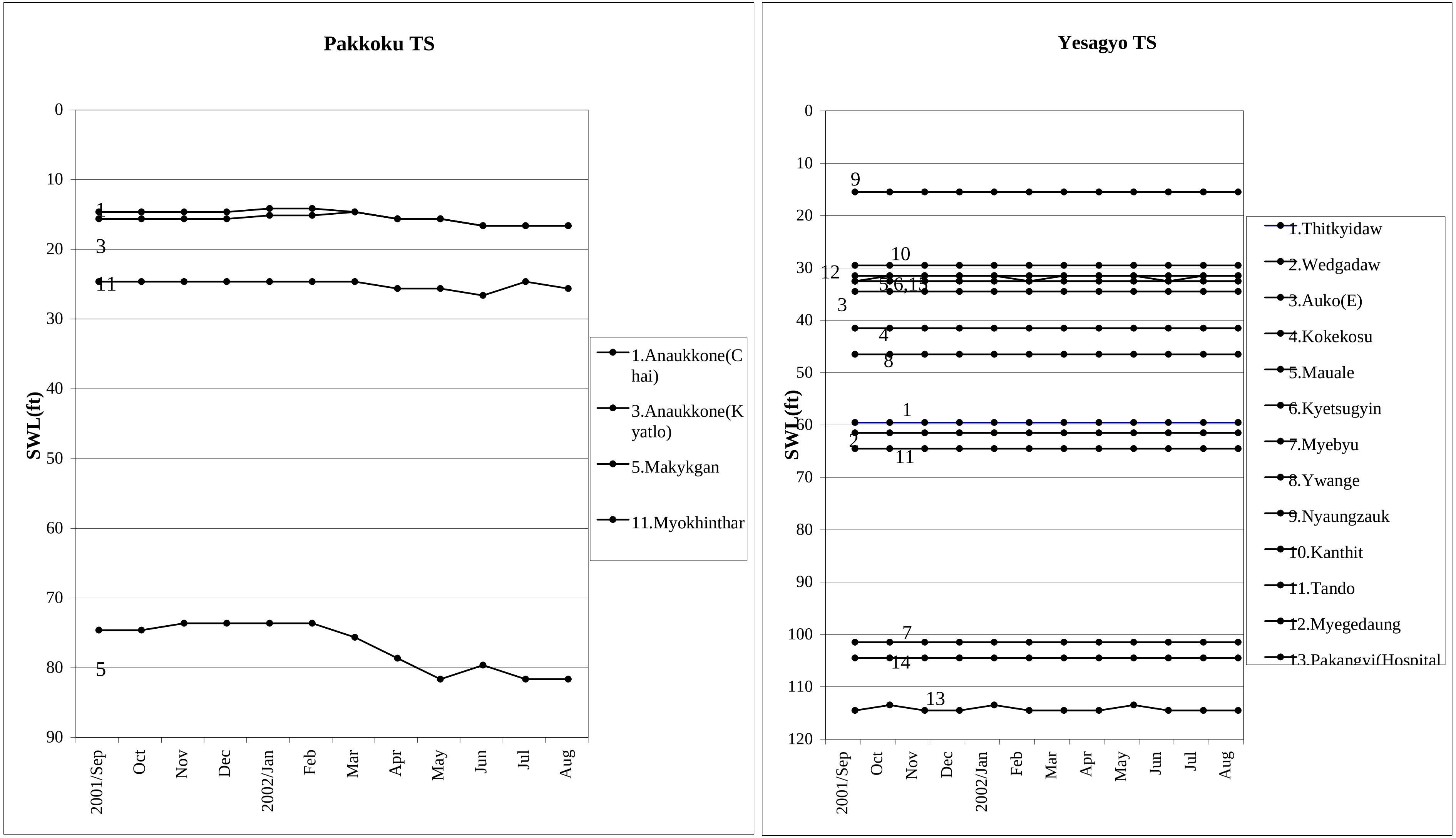


Fig.3.2.1.1 Fluctuation of Static Water Level of Monitoting Wells in the Cetral Dry Zone (4/4)



(b) Water quality

Results of water quality tests in laboratory were presented in 3-D of Vol. III Supporting. Trilinear diagrams (or Piper diagrams) of every 11 Townships were made and presented in Fig. 3.2.1.2(1/9)-(5/9).

In the trilinear diagram, area (Ⅰ) is called “Carbonate hardness, (Ⅱ) is “Carbonate alkali, (Ⅲ) is “Noncarbonate hardness, and (Ⅳ) is “Noncarbonate alkali, respectively. It is said empirically that river water and shallow groundwater are plotted in the area (Ⅰ), fresh confined water is in the area (Ⅱ), and water containing high dissolved salts such as seawater, fossil saltwater, hot spring, mine water, etc. are in the area (Ⅲ) or (Ⅳ).

In all townships excluding Chauk Township, water from the monitoring wells plotted in the area (Ⅲ) or (Ⅳ) of the diagram. That means that groundwater in the Central Dry Zone has much quantity of dissolved salts as general and is affected strongly by the chemical composition or mineralogy of the host rocks during long residence time in the aquifer.

On the other hand, almost all water in Chauk Township are plotted in the area (Ⅱ). That means that almost all groundwater in Chauk Township are normal fresh confined water. However, it is note that only samples of Chauk Township were tested in the different laboratory, and hydrogeological conditions of Chauk Township do not seem to be so different from ones of other Townships (Samples of Chauk were tasted in MOGE: Myanmar Oil and Gas Enterprise, and the others were in WRUD). WQ of test well in Chauk is the same group.

Furthermore, it is necessary to note that in almost all project area, groundwater shows high EC (high TDS)(1,500 μS/cm EC 1,000 mg/lit TDS: NDWQS standard) and even if the low EC area, iron (Fe) contents are over the NDWQS standard (1.5 mg/lit).

Myingyan TS
Pyawbwe

Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (1/11)

Mandalay Division
Taungtha Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Saikyan	1-4	○	2.13	4.36	2.75	1.39	6.20	1.62
2	Kyaungo	2-4	☆	1.18	4.52	2.47	1.44	5.25	15.24
3	Chongyi (E)	3-4	★	8.69	35.76	2.99	4.62	27.35	10.77
4	Thazi	4-4	●	1.61	5.36	3.90	1.84	5.72	3.30
5	Twinbye	5-4	◎	3.91	4.88	3.34	2.10	6.77	3.38
6	Tanaunggon	6-4	◇	2.99	5.44	3.56	2.03	5.78	4.35
7	Welaung	7-4	◆	3.93	10.00	6.07	4.62	7.61	5.07
8	Hlebwegon	8-4	□	2.59	12.28	2.51	3.26	10.07	4.05
9	Yondaw ywama	9-4	■	3.49	10.72	2.38	1.34	14.18	2.65
10	Kyauksayakon	10-4	△	1.14	4.76	2.80	1.25	5.19	2.54
11	Magyigyo	11-4	▲	2.95	8.56	4.18	3.41	6.60	5.78
12	Kyaukchaw	12-4	▽	23.12	29.84	6.34	5.05	22.25	17.67
13	Payahla	13-4	▼	17.99	27.32	4.69	5.70	27.50	14.29
14	Pettaw	14-4	+	0.94	7.16	4.32	1.31	8.38	2.79
15	Thanbo	15-4	×	0.95	2.52	1.25	1.41	1.86	0.72

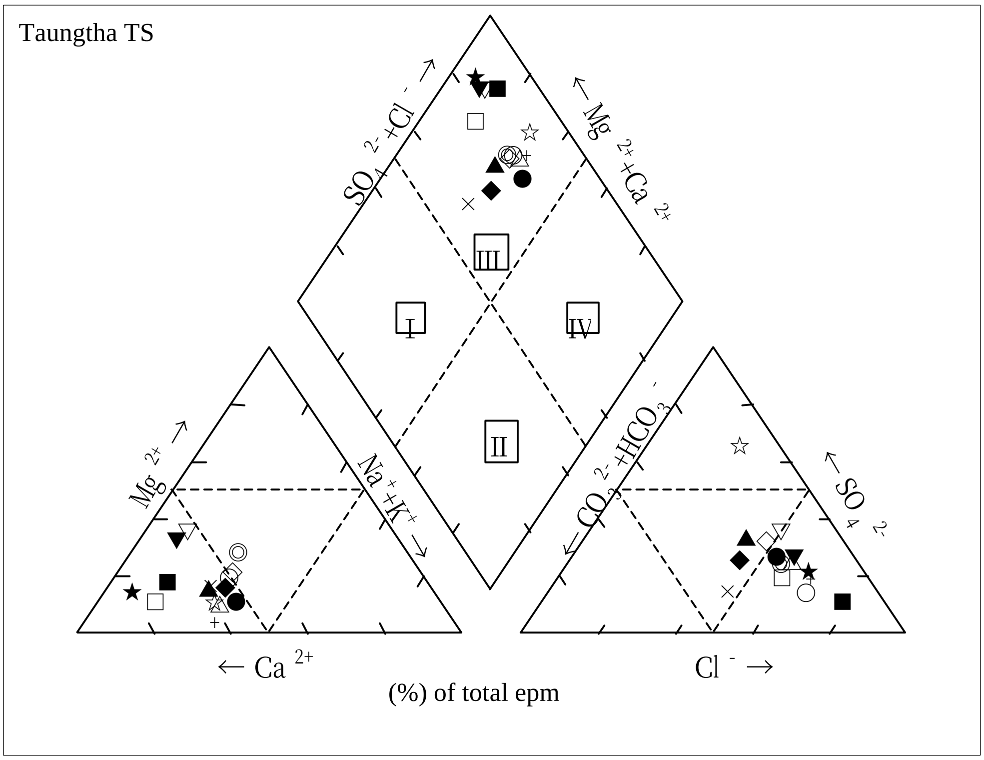


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (2/11)

Mandalay Division

Kyaukpadaung Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^+ + K^+$	$CO_3^{2-} + HCO_3^-$	Cl^-	SO_4^{2-}
1	Saik Htain	1-1	○	0.91	1.76	1.63	1.44	1.33	1.31
2	Lekyee (N)	2-1	☆	1.50	3.80	2.47	1.61	2.71	3.22
3	Thanbo	3-1	★	0.55	3.52	1.01	0.82	1.55	1.88
4	Hnit Kyat Chwe	4-1	●	0.36	2.12	4.51	2.29	2.06	2.56
5	Indai (W)	5-1	◎	0.59	2.68	1.10	0.89	1.72	0.66
6	Indai (E)	6-1	◇	0.58	2.72	0.92	0.98	1.83	1.10
7	Indaw	7-1	◆	1.18	2.48	0.96	1.08	1.52	1.94
8	Sebaukan	8-1	□	1.14	1.76	0.90	0.85	2.03	0.93
9	Bingwe	9-1	■	0.63	2.88	0.83	1.28	2.20	0.58
10	Aima (S)	10-1	△	1.62	2.96	1.16	3.02	2.26	1.85
11	Taung Oo	11-1	▲	0.99	2.60	2.85	1.34	1.80	1.37
12	Lat Pan Bya (S)	12-1	▽	1.14	2.40	0.89	0.69	1.89	1.76
13	Kanhnitsint	13-1	▼	1.34	2.68	1.23	2.33	1.80	1.02
14	Yinmagone	14-1	+	1.41	5.32	5.60	2.92	2.51	3.78
15	Yargyidaw	15-1	×	0.67	2.68	1.68	1.48	1.80	0.72

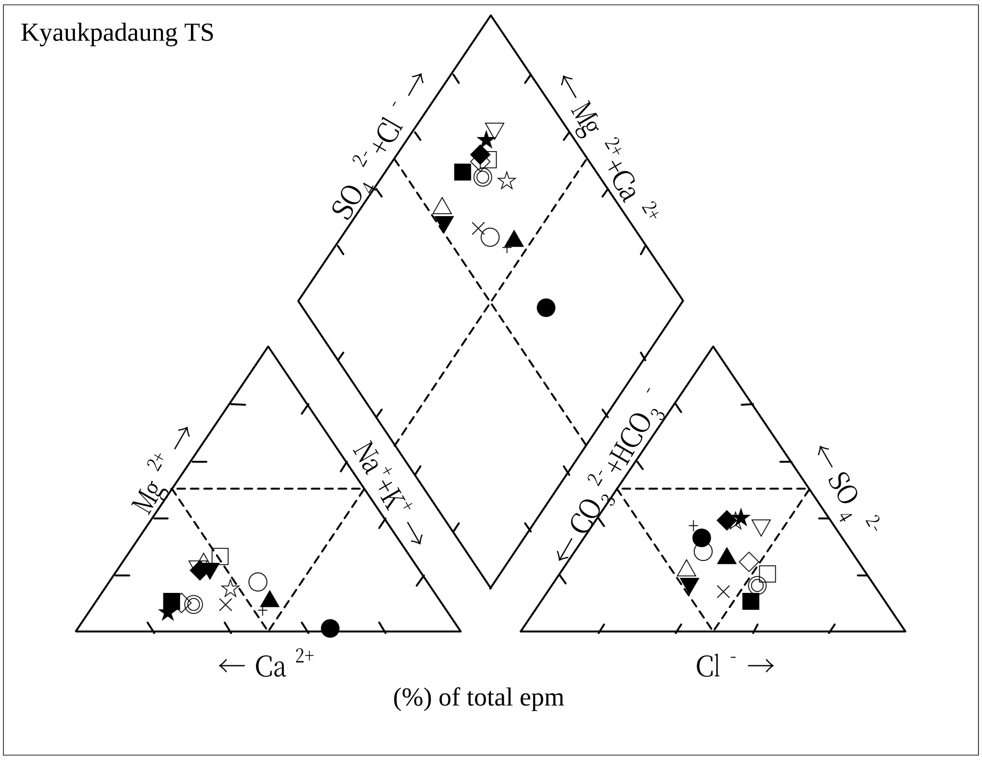


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (3/11)

Mandalay Division
Natogyi Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Myaychar	1-1	○	0.91	3.68	1.16	1.18	3.67	6.90
2	Payayayaung	2-1	☆	…..	…..	…..	…..	…..	…..
3	Nyaungpintha	3-1	★	2.40	5.80	2.83	2.95	4.48	39.03
4	Wetlu(E)	4-1	●	1.54	1.60	2.06	1.64	3.10	11.69
5	Kontha	5-1	◎	2.32	6.80	3.00	2.36	7.64	38.43
6	Phalangon	6-1	◇	2.80	2.28	1.89	1.08	4.26	21.29
7	Thinthayar	7-1	◆	…..	…..	…..	…..	…..	…..
8	Letwe Myinni	8-1	□	2.53	2.96	3.57	1.61	6.40	19.19
9	Htanaungpinle	9-1	■	2.12	5.16	3.31	2.00	5.08	36.93
10	Ywagyi	10-1	△	6.39	9.64	6.50	4.52	13.25	48.49
11	Tadaw	11-1	▲	1.38	4.04	4.42	2.33	4.40	31.31
12	Tetsi	12-1	▽	2.16	6.44	3.85	1.90	8.12	28.91
13	Htanzin	13-1	▼	1.03	3.16	1.51	1.41	3.16	7.80
14	Nabemyit	14-1	+	…..	…..	…..	…..	…..	…..
15	Aungpangon	15-1	×	0.95	4.60	2.55	1.80	3.58	28.00

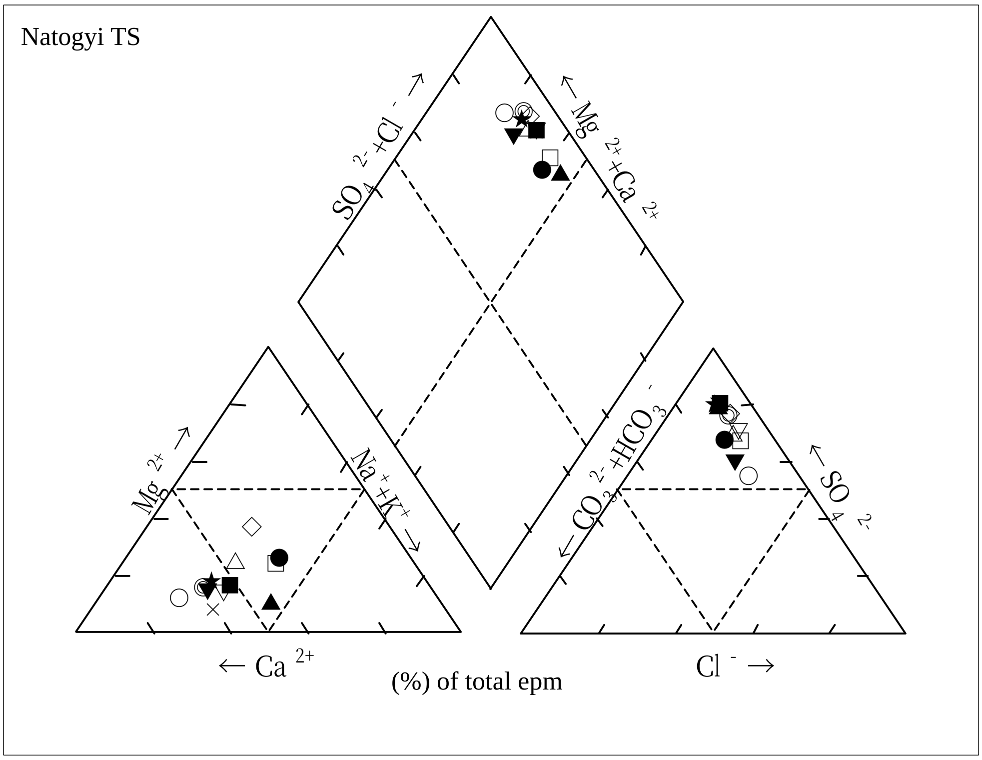


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (4/11)

Mandalay Division

Nyaung U Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Khet Lan Kan	1-1	○	1.11	2.56	4.35	1.67	14.10	0.84
2	Tha Nut Pin	2-1	☆	0.59	1.88	2.39	1.25	3.05	0.55
3	Ta Ma Kha	3-1	+	0.59	1.60	2.47	1.11	2.31	1.49
4	Ngathayauk Hospital	4-1	★	1.07	2.52	3.91	1.21	10.91	0.81
5	Tae Ma	5-1	▲	0.67	1.40	2.14	1.02	2.28	1.34
6	Thank Sin Kye	6-1	□	3.38	4.30	9.00	2.07	79.52	3.52
7	Kon Tan Gyi	7-1	▼	1.22	2.92	12.53	1.51	70.56	0.93
8	Nyaung Toe	8-1	◎	3.30	3.42	9.42	2.13	10.74	2.06
9	Let wae	9-1	▽	4.50	3.04	17.48	1.84	85.45	3.42
10	Pyun	10-1	●	1.03	2.48	3.51	1.28	4.54	1.40
11	Nut Pa Lin	11-1	◇	1.26	2.64	4.64	1.80	11.65	0.96
12	Kone Ywa	12-1	△	0.95	2.28	3.95	1.44	3.95	1.76
13	Sinluaing	13-1	×	0.95	2.24	3.35	1.15	7.50	0.72
14	Taungzin Hospital	14-1	◆	0.63	2.16	2.20	1.21	2.37	1.52
15	Kutaw	15-1	■	0.99	2.00	2.90	1.38	7.47	0.75

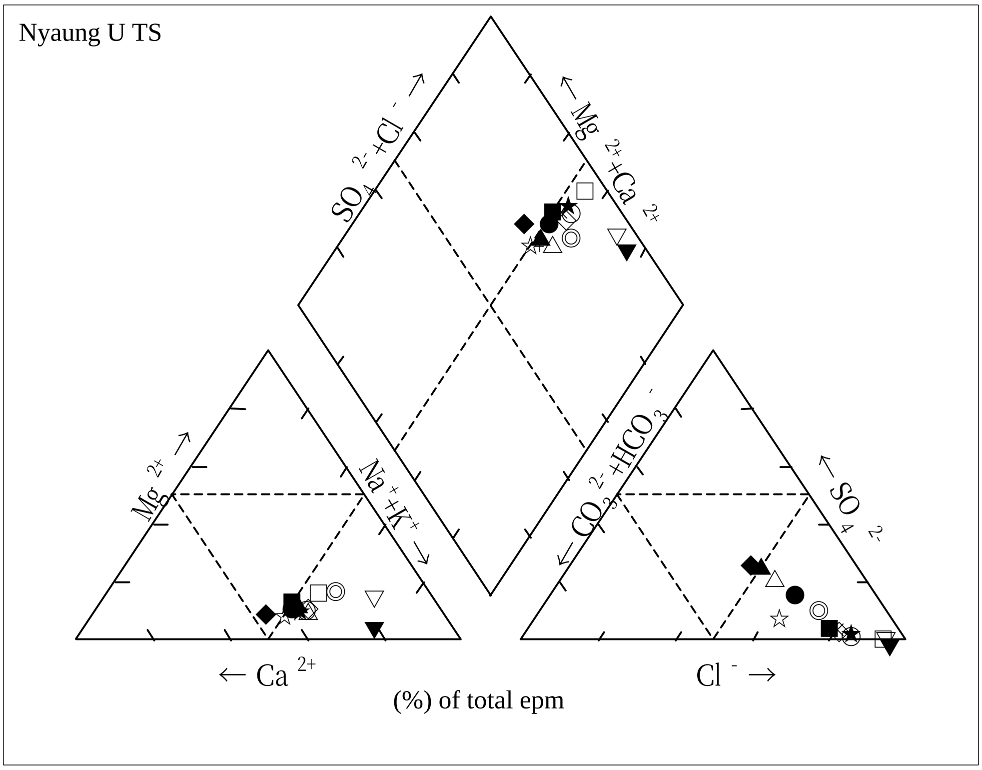


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (5/11)

Mandalay Division
Pyawbwe Township

(epm)

No	Village Name	Sample No	Mark	Mg $^{2+}$	Ca $^{2+}$	Na^++K^+	CO_3^{2-}+HCO_3^-	Cl $^-$	SO_4^{2-}
1	Ledaw	1-8	◇	1.14	2.76	6.38	1.54	17.03	0.87
2	Myaungywa	2-8	□	1.18	2.00	5.26	2.33	2.93	2.98
3	Minywama	3-8	◆	3.87	3.48	8.29	1.41	23.58	2.94
4	Chaunmagyi	4-8	★	2.01	2.32	1.98	1.62	2.34	2.36
5	Shawbyugon	5-8	○	0.75	1.32	4.12	1.21	2.57	2.44
6	Hta Naung Pin Wine	6-8	◎	0.95	1.72	6.08	2.03	5.10	1.76
7	Payagyi	7-8	▽	1.14	3.64	2.45	3.08	2.96	1.20
8	Chinyagone	8-8	☆	2.41	1.60	1.43	1.21	2.09	1.83
9	Gwezi	9-8	●	0.71	3.48	4.49	2.43	3.61	2.62
10	Kyauktaing	10-8	▲	0.79	2.24	6.01	2.00	6.54	0.60
11	Nyaungbintha	11-8	■	0.28	2.28	6.32	2.00	6.06	0.83
12	Sabegon	12-8	▼	2.64	3.16	3.26	2.03	3.75	3.26
13	Talingon	13-8	×	1.03	4.00	4.39	1.61	16.61	0.78
14	Nyaunggon (S)	14-8	△	1.38	3.66	2.87	3.25	2.43	2.40
15	Thanpangyaung	15-8	+	0.99	1.36	5.33	2.36	2.06	3.25

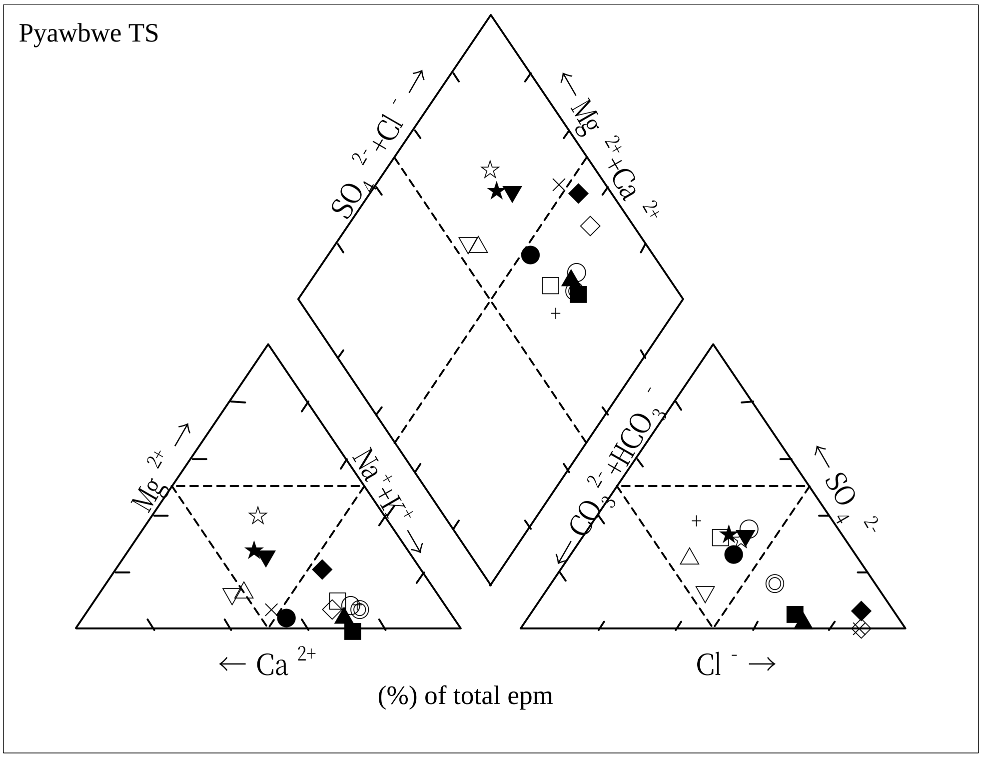


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (6/11)

Mandalay Division
Myingyan Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Kanni	1-1	◆	4.47	9.37	9.09	2.13	22.73	2.42
2	Ywatha	2-1	■	2.88	3.04	4.89	2.36	4.71	3.75
3	Petyin	3-1	□	1.26	3.12	4.91	2.16	6.29	0.96
4	Kokke	4-1	+	18.38	53.20	8.83	3.08	25.38	13.96
5	Magyisu	5-1	○	2.05	4.12	4.66	2.03	6.20	2.60
6	Zibingon	6-1	▽	1.69	5.72	4.03	2.20	6.18	3.16
7	Thityon	7-1	●	2.09	4.24	5.24	3.05	4.48	4.09
8	Taywinbo	8-1	▲	2.75	7.48	4.28	2.52	7.61	4.38
9	Kyaungbyukan	9-1	◇	3.35	6.96	9.10	2.62	12.15	4.83
10	SaKa	10-1	☆	1.37	5.04	3.51	1.44	5.36	3.14
11	Nata	11-1	△	1.62	8.07	9.10	4.13	10.10	4.64
12	Ywazi (N)	12-1	▼	1.81	6.76	5.04	2.49	6.85	4.29
13	Ywazi (S)	13-1	★	1.85	5.36	8.86	3.02	8.12	4.94
14	Kuywa	14-1	◎	1.96	5.48	8.86	2.59	7.73	6.08
15	Tak	15-1	×	2.52	9.40	5.50	4.65	6.54	6.24

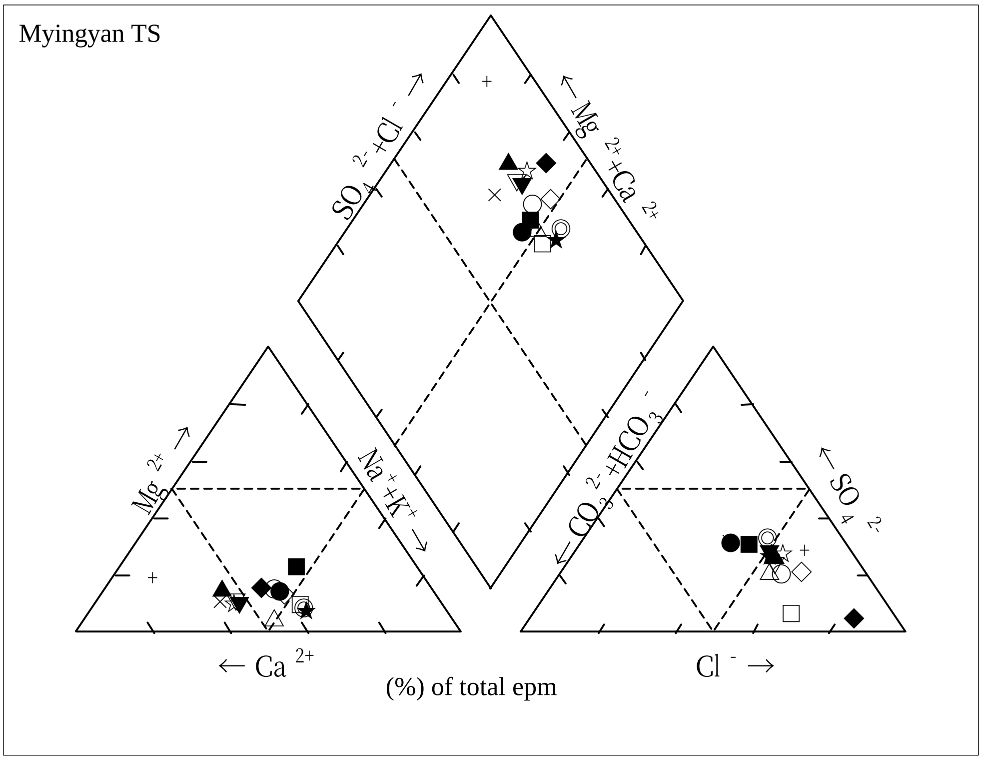


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (7/11)

Magway Division
Chauk Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Sinka	1-4	○	4.08	0.48	6.47	5.36	3.81	1.85
2	Kyini	14-5	×	2.48	1.20	6.52	5.92	3.38	0.89
3	Kannigyi			…..	…..	…..	…..	…..	…..
4	Teingan	9-4	■	3.84	0.96	4.20	4.96	2.26	1.78
5	Ywathit	11-4	▲	0.64	0.32	8.10	7.04	1.13	0.89
6	Magyizauk	6-4	◇	8.39	3.76	21.27	2.08	25.10	6.24
7	Sale	12-4	▽	3.84	0.96	2.74	6.23	1.13	0.17
8	Wayakon	5-4	◎	10.55	3.04	16.67	1.48	24.25	4.52
9	Gwegyo	3-4	★	2.56	1.43	6.60	6.96	2.54	1.10
10	Kupyu	10-4	△	0.64	1.28	4.80	3.88	2.26	0.58
11	Nyaungzin	13-4	▼	2.48	0.96	3.90	4.13	1.97	1.23
12	Gwebin	8-4	□	4.00	0.80	8.01	4.92	6.20	1.68
13	Lalingan (w)	7-4	◆	0.96	0.40	7.75	6.40	2.54	0.17
14	Shwebaukkan	2-4	☆	1.60	0.40	12.00	8.20	3.67	2.12
15	Awzadaw	14-4	+	2.24	0.64	13.92	11.80	3.38	1.61
16	Magyigone	4-4	●	2.64	0.40	10.87	10.24	2.82	0.84

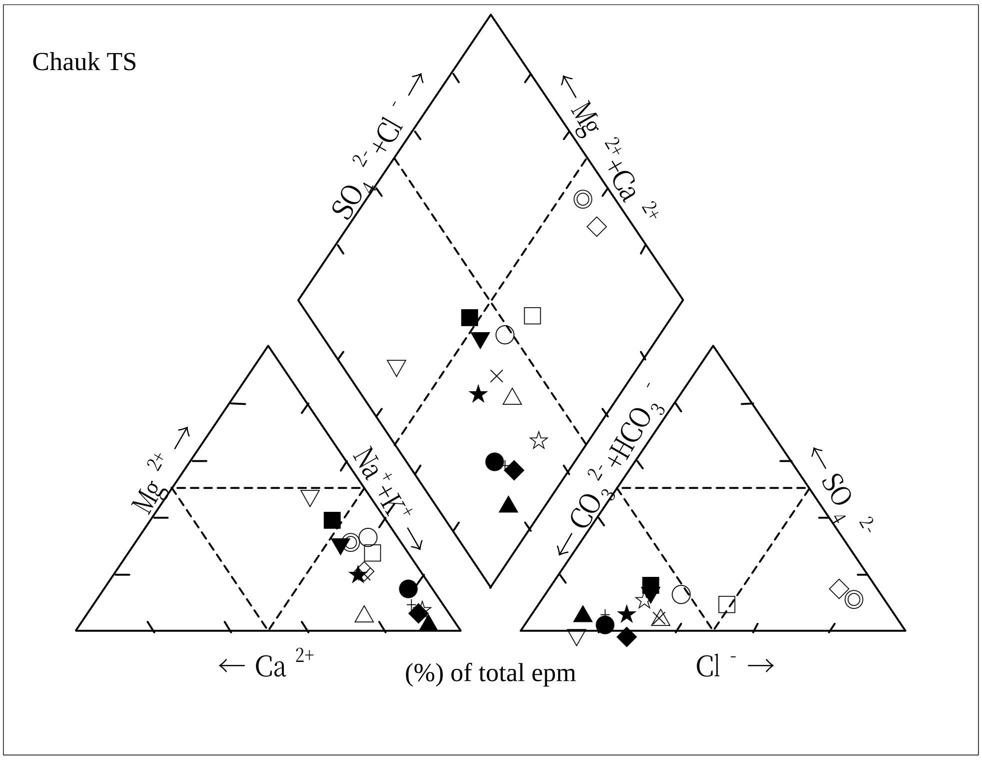


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (8/11)

Magway Division
Magway Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Nankatkyun	1-1	○	0.79	3.36	2.57	1.34	4.82	0.60
2	Nyaungbinywa	2-1	☆	0.87	3.88	1.46	0.98	4.37	0.66
3	Daungthe	3-1	★	0.67	2.08	0.85	1.23	1.95	0.51
4	Kyagan	4-1	●	1.11	4.40	0.93	2.72	1.89	1.84
5	Kyitsonbwe	5-1	◎	1.74	3.40	2.47	2.75	1.95	3.44
6	Gaungdaw-U	6-1	◇	3.04	3.80	2.39	4.33	2.62	2.31
7	Seikya	7-1		…..	…..	…..	…..	…..	…..
8	Auzagon	8-1	◆	1.30	2.12	3.29	1.57	4.12	1.03
9	Thityagauk	9-1	□	0.94	6.20	1.18	3.25	2.96	2.17
10	Alebo	10-1	■	1.46	2.24	3.85	2.20	2.14	3.19
11	Myingon	11-1	△	1.86	2.04	3.90	1.25	4.54	0.35
12	Migyaungye	12-1		…..	…..	…..	…..	…..	…..
13	Samagyi	13-1	▲	1.57	3.16	1.45	2.98	1.83	1.41
14	Popagon	14-1		…..	…..	…..	…..	…..	…..
15	Myingin	15-1	▽	2.00	5.04	1.58	1.64	5.44	1.52

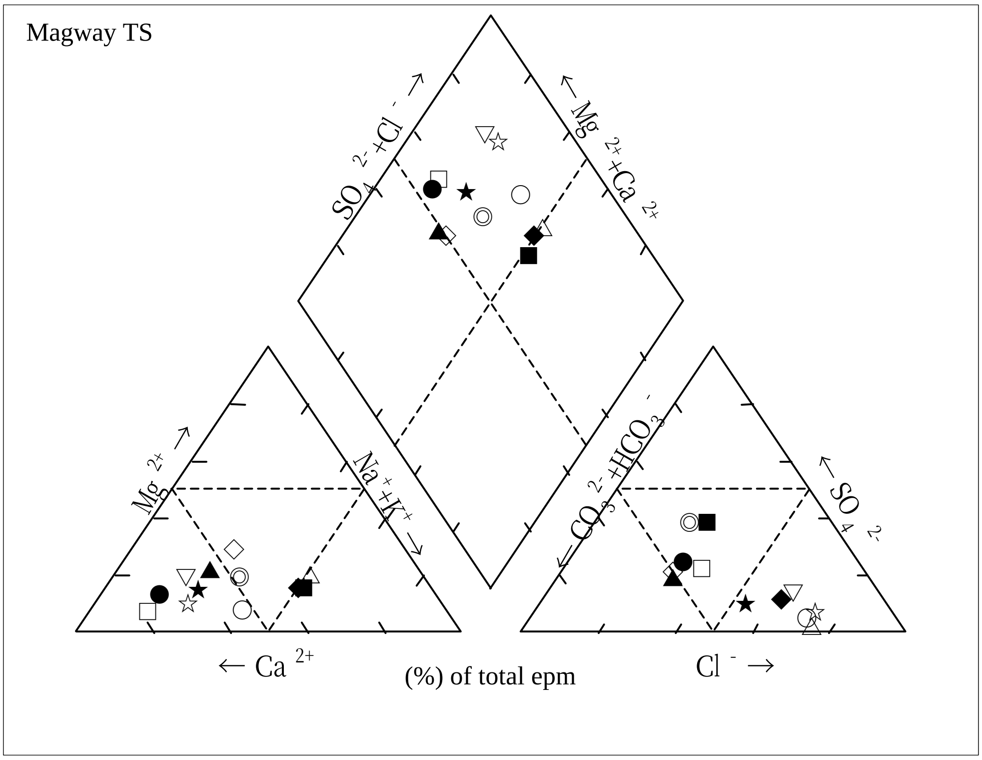


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (9/11)

Magway Division
Pakokku Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Anauk Kone	1-1	○	1.58	3.88	2.59	2.29	3.13	2.24
2	Kanma	2-1	☆	5.18	17.36	1.82	0.92	24.84	3.93
3	Anauk Kone	3-1	★	1.11	3.56	2.89	1.28	3.58	2.92
4	Sabe	4-1	●	1.54	3.04	1.31	0.95	1.44	1.17
5	Makykgan	5-1	◎	1.58	4.56	3.18	1.44	3.78	1.82
6	Myitche(S)	6-1	◇	1.85	6.04	2.84	3.21	3.67	3.48
7	Kaing-3	7-1	◆	1.50	4.20	0.86	1.41	2.45	1.76
8	Inpin	8-1	□	0.63	3.40	0.60	1.31	1.49	1.73
9	Chutkan	9-1	■	2.00	6.16	3.18	3.02	4.79	3.58
10	Myin Gyaing	10-1	△	0.51	2.72	0.62	0.98	1.66	0.39
11	Myokhinthar	11-1	▲	0.79	1.96	3.17	1.28	3.38	0.60
12	Kyiywar	12-1	▽	2.20	6.56	7.36	3.28	26.20	0.62
13	Patai Chane	13-1	▼	1.73	5.16	4.82	4.10	4.94	3.39
14	Magyipinpu	14-1	+	2.17	4.20	2.32	2.85	3.19	3.73
15	Be Gyi-1	15-1	×	1.37	6.96	2.09	2.75	2.48	3.12

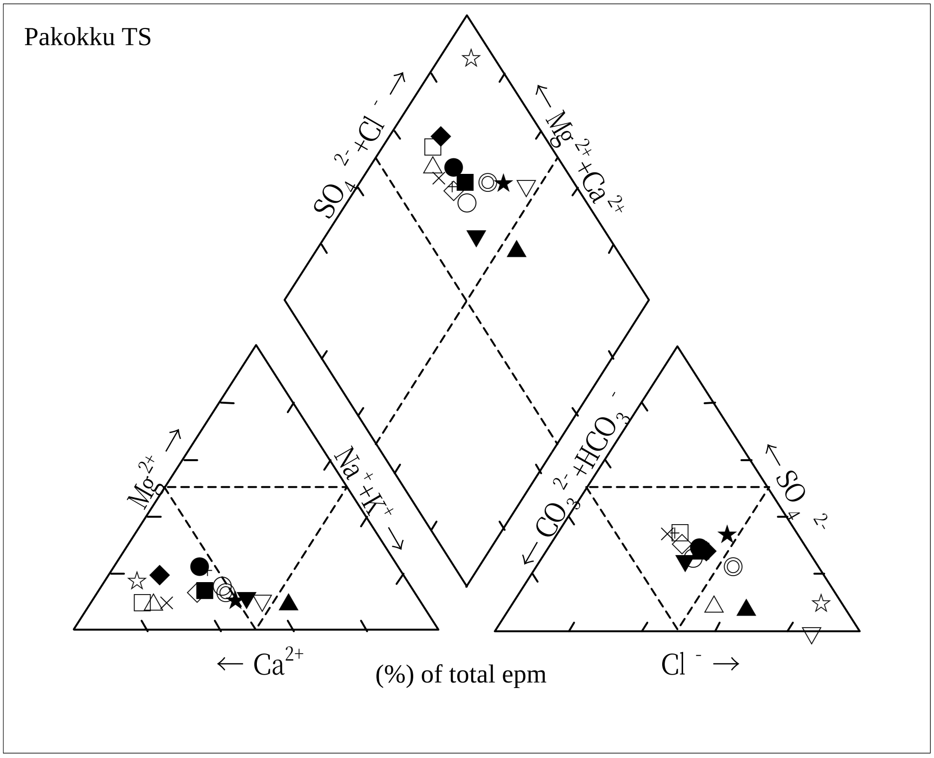


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (10/11)

Magway Division
Myothit Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3^{-}$	Cl^{-}	SO_4^{2-}
1	Thamye	1-1	○	0.71	3.44	3.07	2.88	1.95	2.41
2	Leadaingzin	2-1	☆	1.86	2.16	2.18	2.39	2.28	1.45
3	Gwaydaw	3-1	★	1.70	3.12	1.42	1.34	3.24	1.71
4	Natywa	4-1	●	2.88	1.72	0.94	1.38	2.00	2.19
5	Aungmyinthar	5-1	◎	1.54	3.60	1.47	2.88	1.72	2.02
6	Pogyi	6-1	◇	1.86	2.64	1.53	2.66	1.97	1.41
7	Myinsu	7-1	◆	0.20	3.44	0.89	1.51	2.06	0.98
8	Yondaw	8-1	□	3.63	2.08	2.31	1.97	3.36	2.76
9	Wagyiaing	9-1	■	1.89	3.20	2.36	2.59	2.90	1.96
10	Ngwele	10-1	△	1.18	3.36	1.21	1.80	2.31	1.65
11	Twinle	11-1	▲	2.17	3.88	1.18	1.38	4.23	1.65
12	Shwebanbin	12-1	▽	7.67	15.04	3.12	1.11	25.44	5.82
13	Myegyo(E)	13-1		…..	…..	…..	…..	…..	…..
14	Taloukbin	14-1	+	3.00	2.48	2.49	1.88	3.78	2.28
15	Ywayhit	15-1	×	1.62	3.48	1.11	2.82	1.72	1.77
16	Myay Char	16-1	▼	0.24	3.84	2.01	3.05	1.92	1.22

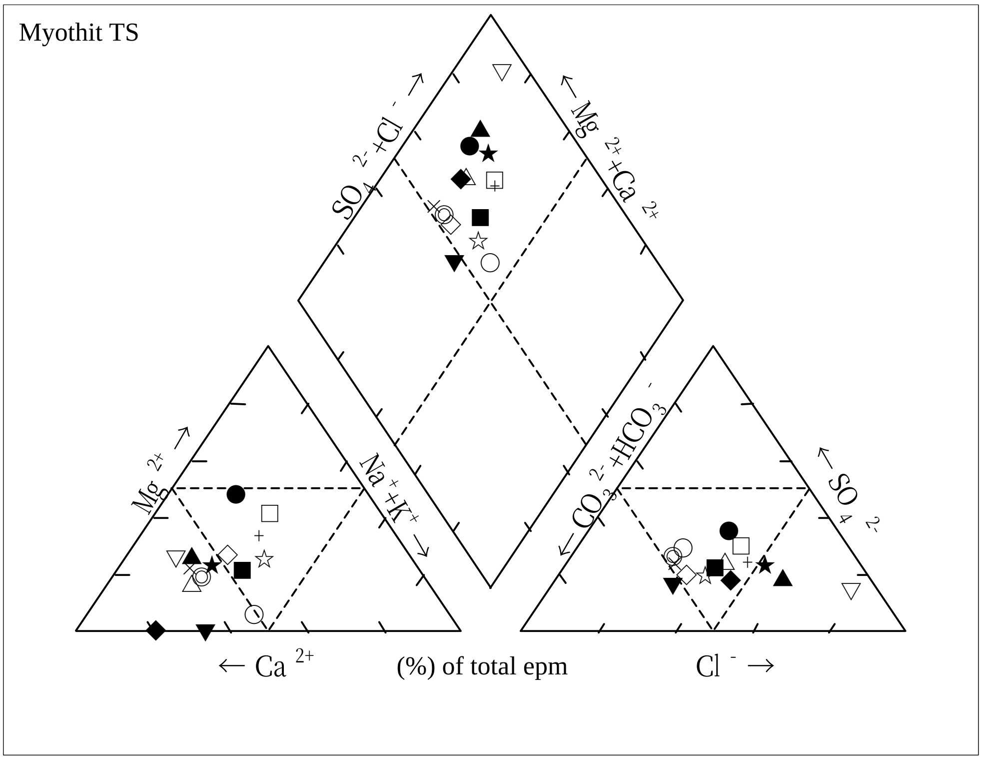
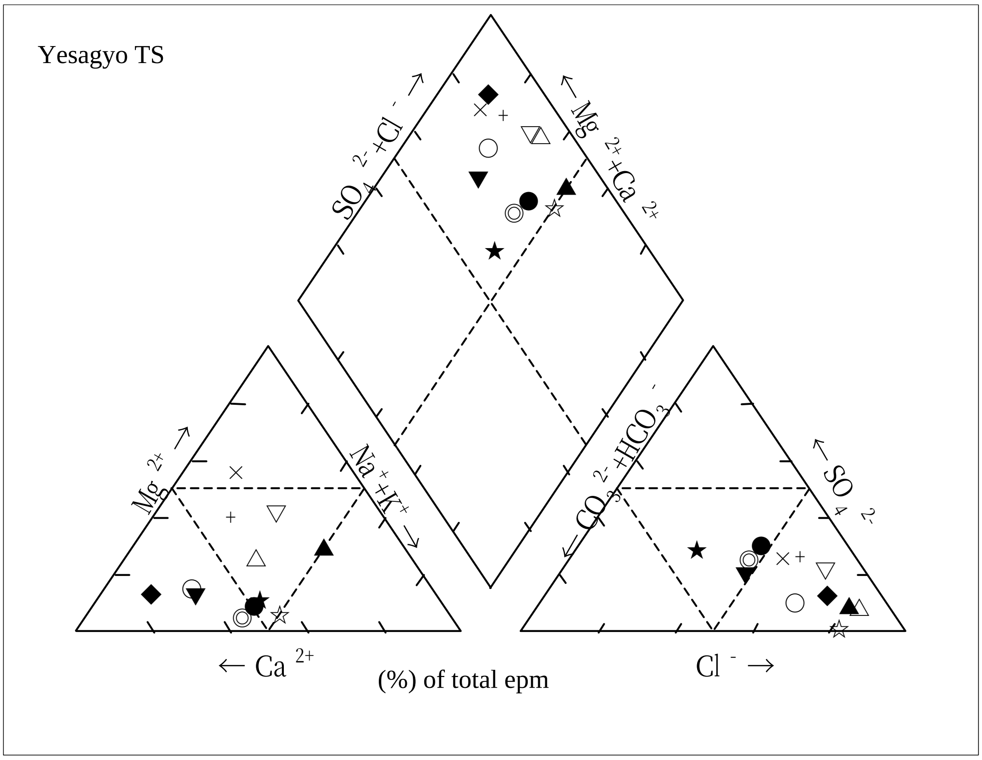


Fig.3.2.1.2 Trilinear Diagram of Monitoring Wells (11/11)

Magaway Division
Yasegyo Township

(epm)

No	Village Name	Sample No	Mark	Mg^{2+}	Ca^{2+}	Na^{+}+K^{+}	CO_3^{2-}+HCO_3^{-}	Cl^{-}	SO_4^{2-}
1	Thitkyidaw	1-1	●	1.14	4.08	3.67	1.67	4.09	2.95
2	Wetgadaw	2-1	◎	0.79	4.80	3.71	2.26	4.23	2.68
3	Auko(E)	3-1		…..	…..	…..	…..	……	…..
4	Kokekosu	4-1	▼	1.69	6.00	2.47	2.88	4.88	2.43
5	Mauale	5-1	★	1.38	4.04	3.84	3.41	2.88	3.03
6	Kyetsugyin	6-1	○	0.95	3.04	1.12	1.02	3.30	0.72
7	Myebyu	7-1	×	3.95	1.80	0.86	1.05	3.64	1.96
8	Ywange	8-1	+	5.29	4.24	2.55	1.28	7.90	4.02
9	Nyaungzauk	9-1	◆	0.79	3.28	0.58	0.39	2.71	0.60
10	Kanthit	10-1	△	5.24	6.51	5.76	1.48	26.59	3.98
11	Tando	11-1		…..	…..	…..	…..	…..	…..
12	Myegedaung	12-1		…..	…..	…..	…..	…..	…..
13	Pakangyi	13-1	☆	0.91	3.80	4.59	1.87	11.34	0.69
	(Hospital)								
14	Sitha	14-1	▲	6.16	3.32	9.04	2.59	29.47	4.68
15	Sigyo Ywathit	15-1	▽	5.25	2.80	3.49	1.08	10.63	3.99



(2) Geophysical Survey

1) Objective of Geophysical Survey

The objective of geophysical survey was to clarify the distribution of the aquifer and to assume the potential of groundwater development in the Study Area.

This survey was performed to search for resistivity structure in 110 villages (10 villages in every 11 Townships in Mandalay and Magway Divisions), which had been selected by DDA from the viewpoint of high difficult to obtain the domestic use water. As a survey method, Vertical Electrical Sounding was carried out at 2 points, which were named V1 and V2, in each target village. The point V1 was an assumed drilling site proposed by villagers and the survey team selected the point V2 from a geological point of view.

Based on the results of hydrogeological survey and the above Vertical Electrical Sounding, Horizontal Electrical Profiling was carried out at 2 to 5 target villages chosen in order to grasp the aquifer condition or the existence of fissure water in the comparatively shallow layer in each Township.

Schlumberger method was applied for the configuration of Vertical Electrical Sounding and Horizontal Electrical Profiling as well. The depth of Vertical Electrical Sounding was up to 300 meters in principle because the proposed well depths were assumed between 200 meters and 300 meters. The depth for Horizontal Electrical Profiling was about 50m.

The work volumes of the geophysical survey and principal specification are as shown in Table 3.2.1.1.

Table 3.2.1.1 Work Volume of Geophysical Survey

Method	Configuration	Survey depth	Line length	Number of village (village/Township)	Total number of survey points or survey lines
Vertical Electrical. Sounding	Schlumberger	300m	-	10 villages ×11 Townships	220 points
Horizontal Electrical Profiling	Schlumberger or VLF	50m	300m	2-5 villages ×11 Townships	31 lines

2) Schlumberger Method

Fig. 3.2.1.3 shows the electrode configuration of Schlumberger method.

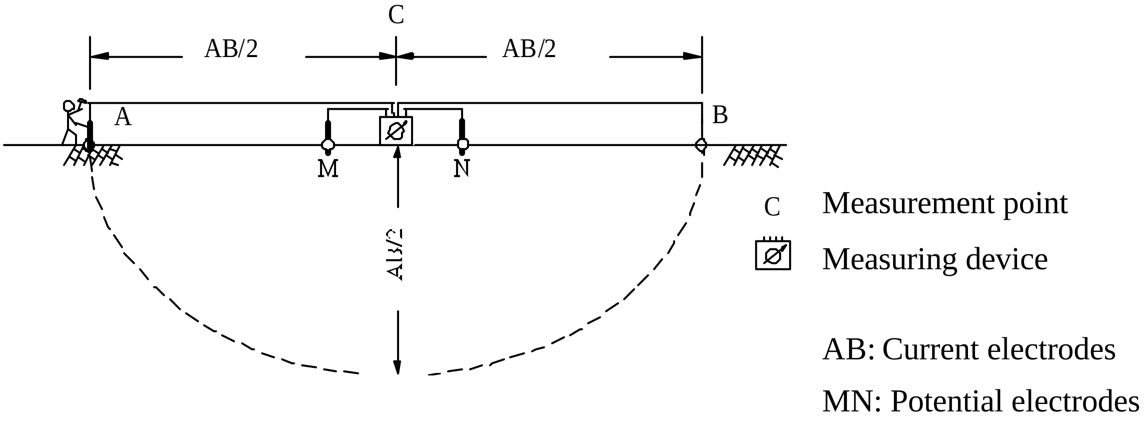


Fig. 3.2.1.3 The Electrode Configuration of Schlumberger

The measuring device should be placed at the center(C) between M and N, which function as potential electrode. Current electrodes A and B, should be installed in the line symmetry at interval AB/2. When an electric current (I) runs between A and B, the potential value (V) occurs between M and N. Therefore an apparent resistivity is given by the following formula.

$$\rho_a = \frac{\left(\frac{\overline{AB}}{2}\right)^2 - \left(\frac{\overline{MN}}{2}\right)^2}{\overline{MN}} \times \frac{\Delta V}{I}$$

ρ_a : Apparent resistivity
$\triangle V$: Potential Value
I : Current Value

In measuring of an apparent resistivity, a shorter interval between A and B reflects a shallower underground structure and on other hand a longer interval between A and B reflects a deeper structure. Therefore, the length between A and B should be expended step by step up to the proposed depth. Plotting of these apparent resistivity values forms Vertical Electrical Sounding Curve. The length between A and B should generally be from 5 to 20 times as larger as the same between M and N so as to avoid noises of measurement. This time, about 20 times was adopted for the relation of the above two lengths. The length of AB/2 was begun at about 3 meters then extended up to 300 meters in principle. However, in cases of Nyang-U and Chauk Townships, a distance of 500 meters was applied.

Horizontal Electrical Profiling was carried out to prospect for disorders of geological stratum by measuring the apparent resistivity changes of the same depth along the survey line. In order to detect the change of resistivity structure up to 50 meters subterranean, intervals of AB/2=50m and MN/2=10m were applied and the apparent resistivities were measured by moving the whole circuit system along the survey line.

3) Analysis of Vertical Electrical Sounding

The measured values of the sounding are plotted in a logarithm-logarithm graph to draw a Vertical Electrical Sounding Curve. The vertical axis of the graph shows an apparent resistivity value and the horizontal axis shows a distance (AB/2).
The underground resistivity structure of the surveyed point is assumed by comparing the above Vertical Electrical Sounding Curve to the Standard Curve, which has been prepared as a series of resistivity models corresponds practically to the variety of the particular rock.
Through comparison as mentioned above, the most similar resistivity model shall be selected as an initial model for the analysis. Then this model shall be developed to the final model by computation using RESIX software, which is widely applied in the 1st dimensional analysis of Vertical Electrical Sounding method. The RESIX is an automatic inversion program software in order to determine the final resistivity model by approximating the theoretical curve of the initial model to the actually surveyed curve through the least-squares method.

4) Result of survey

There is a high correlation between the type of rock and the value of resistivity. It is generally accepted that rocks formed in the more ancient times generally show the higher value and sedimentary rocks show lower value than volcanic rocks. Moreover, sedimentary rocks of marine original show lower value than sedimentary rocks of terrestrial original. These correlations are shown in Table 3.2.1.2.

Table 3.2.1.2 Resistivity Range of Rocks (Unit ohm-m)

Geologic age	**Marine sand, shale, graywacke**	**Terrestrial sand,clay stone, arkose**	**Volcanic rocks (basalt, ryolite, tuffs)**	**Granite, gabbro, etc.**	**Limestone, dolomite, anhydrite,salt**
Quaternary, Tertiary	1-10	15-50	10-200	500-2,000	50-5,000
Mesozoic	5-20	25-100	20-500	500-2,000	10-10,000
Carboniferous	10-40	50-300	50-1,000	1,000-5,000	200-100,000
Pre-Carboniferous Paleozoic	40-200	100-500	100-2,000	1,000-5000	10,000-100,000
Precambrian	100-2,000	300-5,000	200-5,000	5,000-20,000	10,000-100,000

Source: G. R. Keller, in "Handbook of Physical Constants," rev. ed., Geol. Soc. Am. Mem. 97. 1966.

From the hydrogeological point of view, the Quaternary deposit and the Irrawaddy Formation are generally assumed to be the promising formations for developing of fresh groundwater. On the other hand the Pegu Group has a very low possibility of aquifer existence.

According to the experience of WRUD (Water Resources Utilization Department under the Ministry of Agriculture and Irrigation), good aquifer in the Central Dry Zone is generally assumed at 20-40 ohm-m in electrical resistivity value.

Each layer analyzed in this Study was categorized into the following ranges in accordance with resistivity value detected:

5 10 15 20 40 80 (Ω・m)

UL	VL	L	M	H	VH	UH

The most promising aquifer is expected to be in the range of H. As the range goes from M to L, a water quality risk like saline or bitterness should become higher gradually. The ranges of VL and UL correspond to clayey layer or aquifer with high saline water. On the other hand as the range goes from VH to UH, groundwater volume to be developed should become less and less. Accordingly the possibility of groundwater development in each survey points is classified into the following three ranks.

A	Range H detected thick and High possibility of existence of aquifer
B	Resistivity layers of 20 ohm-m (Range M) or less are predominant and Low possibility of existence of aquifer
C	Resistivity layers of 10 ohm-m (Range VL) or less are predominant and Very low possibility of existence of aquifer

The underground resistivity structure of in each Township is shown in a series of figures from Fig.3.2.1.4 to Fig.3.2.1.14 and in Table 3.2.1.3, and the horizontal electrical profiling is also shown in a series of figures from Fig.3.2.1.15 to Fig. 3.2.1.25.

In addition, the result of one-dimensional analysis, the Vertical Electrical Sounding Curve of the final model and practice value of each point is presented in 3-A of Vol. III Supporting Report, and the result of Horizontal Electrical Profilings is in 3-B of Vol. III Supporting Report. The geophysical overviews including the geological structures for each Township are summarized as follows:

(a) Taungtha Township (see Fig. 3.2.1.4)

Three villages (No.2 Kanthonesint, No.3 Tabaukkon and No.6 Twinbye), which are located in the western part of the Township, were evaluated at the rank A. Because these villages are located in the distribution area of the Irrawaddy formation, which is normally recognized to have a good aquifer. In the central part of the Township, two villages (No.5 Dahatan, No.7 Kyaukpon) are located on the Irrawaddy formation. However, its resistivity structures show the range M or lower. In the eastern part of the Township, five villages were situated on the Pegu Group. Its resistivity structures were classified into the range VL or lower. Therefore the survey points in the central and the eastern of the Township were evaluated at the rank B or C, which means low possibility of existence of aquifer. In the southeastern part of the Township, since No.10 Sizongon were detected at the range M or H in the resistivity structure, a possibility of existence of aquifer was expected. However, depending on reexamining the geological condition, it was confirmed that this village was located on the Pegu Group and some neighboring villages were also detected at the range VL or UL. Then, the reason why such high ranges of resistivity were detected in No. 10 Sizongon was assumed that there might be a high possibility of existence of massive sandstone layer. Therefore No.10 Sizongon was concluded to have a poor possibility for development of groundwater.

The horizontal electrical profiling was carried out in three villages in the western part of the

Township (see Fig.3.2.1.15). The profiles were shown a small change in the apparent resistivity value within a range of 50m in depth. Their resistivity structures were evaluated at the range H or VH. Accordingly it was assumed that an aquifer would continue with simple structure in these areas.

(b) Kyaukpadaung Township (see Fig. 3.2.1.5)

Most of the survey points in the Township were evaluated at the rank A except No.10 Lwinpinkone village, which is located in the southern part of this Township. In the villages of No.1 Gweydaukkone, No.4 Htantawgyi, and No.5 Kanbauk, the two survey points in these villages were evaluated at the rank A in possibility of groundwater development. Since the Irrawaddy Formation is widely distributed from the central to the northern parts of the Township, it can be said that this Township generally has a high possibility of existence of aquifer. Out of the 10 study villages, No.10 Lwinpinkone village is only located on the Pegu Group, so the resistivity structures was classified into the range M or lower.

The horizontal electrical profiling was carried out in four villages in the central part of the Township (see Fig. 3.2.1.16). As the profiles of No.3 Tangakan village and No7 Sagyaw village show some declined points in apparent resistivity value, it was assumed that the presence of discontinuity of geological structure such as faults. On the other hand the profiles of No.4 Htantawgyi and No.6 Sudat villages show a small change of the apparent resistivity value. Their resistivity structures were evaluated the rangs from H to UH. Accordingly it was assumed that an aquifer would continue simply in these areas.

(c) Natogyi Township (see Fig.3.2.1.7)

Most of the survey points in the Township were evaluated at the rank B or C. In the central part of this Township, the resistivity structures of No.3 Morgan W. were evaluated at the range H, even if it locates on the Pegu Group. However, depending on reexamining the geological condition, it was confirmed that this village was located on the Pegu Group and some neighboring villages were also detected at the range L or VL. Then, the reason why such high ranges of resistivity were detected in No. 3 Morgan W was assumed that there might be a high possibility of existence of massive sandstone layer and poor groundwater. Therefore No.3 Morgan W was concluded to have a poor possibility for development of groundwater.

Among the survey villages No.1 Pegyet, No.4 Thangwa are located on the Irrawaddy formation, however, the range L or lower were predominant in the resistivity structure. Therefore the both villages were evaluated at the rank B in possibility of groundwater development. In case of No.1 Pegyet, while the range H was detected around 160m or more in depth, it was evaluated at the rank B, assuming the test well to be constructed shall have a 200m depth.

The horizontal electrical profiling was carried out in two villages in the eastern part of this Township (see Fig. 3.2.1.17). The profiles show a small change of the apparent resistivity value and the resistivity rank VL. Therefore it was assumed that a clayey layer or a layer with saline water aquifer should be predominant in this area and the possibility of the groundwater development was not so high within a range of 50m in depth.

(d) Nyang-U Township (see Fig. 3.2.1.17)

According to the survey result, the rank A is predominant widely in the parts from the center to the east of this Township. Five surveyed villages, No.1, Kantharyar, No.2 Kuywa, No.3 Phalankan, No.4 Setsetyo, and No.8 Myetkhataw were evaluated at the rank A. On the other hand, the rank B is predominant in the western part of the Township. These survey results coincide with a geological observation that the Irrawaddy Formation is distributed from the central to the eastern parts of the Township and the Pegu Group is distributed in the western part.

The existing well data show that groundwater levels should exist about 200 meters in depth in the southeast part of the Township. A resistivity boundary also appeared around 200m in depth of each resistivity columnar of No.3 Phalankan, No.4 Setsetyo, No.8 Myetkhataw and No.9 Ywalu villages. Therefore it was assumed that the depth of the resistivity boundary should coincided with the existence of the groundwater level. Although these survey points were classified at the range H within depth from 0m to 100m, groundwater volume in the aquifer was estimated to be rather small, judging from the existing well data. Therefore it was proposed that the depth of the test well to be constructed in this study should be about 300m in case these villages would be selected.

The horizontal electrical profiling was carried out in five villages in the central and eastern part of this Township (see Fig. 3.2.1.18). The profile of No.2 Kuywa shows a small change of the apparent resistivity value, it suggest that the presence of discontinuity of geological structure. The resistivity structure was ranged at VH or UH within 50m in depth. Although the water volume to be developed in this area was not sure, a high possibility of groundwater development was expected by drilling wells with a depth of 300m. The profiles in other four points show a poor change in the apparent resistivity value and the resistivity rank VH or UH. It was expected that the possibility of the groundwater development would be rather high in this Township.

(e) Pyawbwe Township (see Fig.3.2.1.8)

From the hydrogeological point of view, the Quaternary sediments are distributed in the eastern part of the Township, The Irrawaddy Formation and the Pegu Group are distributed in the central part and the western part.

The result of the survey, in three villages such as No.3 Yebyu, No.4 Paukaingyo and No.6 Thabok, which are located in the eastern part of this Township, the resistivity structures were evaluated at the ranges from M to UH. Especially in No.4 and No.6 villages the possibility of aquifer was evaluated at the rank A. The reason of occurrence of high resistivity in the eastern part of the Townships was assumed that the ground surface was covered with the Quaternary sediments very thinly. And the high resistivity might reflect that the most of the underground basement should be predominant of granite or crystalline schist. Therefore, a target of groundwater development in the eastern part was assumed the fissure water among the hard rocks.

The villages located in the central and the western part where the Irrawaddy Formation is more predominant than the eastern part, however, the possibility of aquifer were evaluated at the range B or C.

The horizontal electrical profiling was carried out in two villages, which are located on the Irrawaddy Formation in the central part of this Township (see Fig. 3.2.1.19). The profiles show a small change in the apparent resistivity value around the range VL. Therefore it was assumed that a clayey layer or a layer with saline water aquifer should be predominant in this area.

(f) Myingyang Township (see Fig.3.2.1.9)

Most of the survey points in this Township were evaluated at the rank B or C in possibility of development of groundwater. However, No.1 Chinmyikyin village and No.9 Gwebinyo villages were evaluated at the rank A because there was a layer classified into the resistivity range H around 100-160m in depth in No.1 Chinmyikyin and also a layer with the range VH around 100 - 220m in depth in No.9 Gwebinyo.

From the point of geological characteristics in this Township, The Pegu Group is distributed in the northern part and the southeastern part, the Irrawaddy Formation is distributed in the central part, and the Quaternary sediments and the Irrawaddy Formation are distributed in the southern part. Although No.8 Saka is supposed to be situated on the Quaternary sediments, which can be generally expected to have a good aquifer, the rank B was evaluated because a layer with the resistivity classification VL was detected from the ground level until more than 200m in depth. Accordingly this Township was evaluated at a lower rank in possibility of groundwater development.

The horizontal electrical profiling was carried out in No.1 and No.2 villages in the northern part of this Township (see Fig. 3.2.1.20). The profiles in No.1 village show lots of changes of the apparent resistivity value up to 50m in depth. This suggests that the presence of discontinuity of geological structure. The profiles of No.2 village show a very small change of the apparent resistivity value. The classification of resistivity was the range VL, therefore it is assumed that a clayey layer or a layer with saline water aquifer should be predominant in this village.

(g) Chauk Township (see Fig. 3.2.1.10)

Most of the survey points in this Township were classified into the range VH or UH. From the point of geological characteristics in this Township, The Irrawaddy Formation is distributed in the northern part and the central part, The Quaternary sediments and the Irrawaddy Formation are distributed in the southern part. The Pegu Group is distributed in a small area in the northern part of the Township. Three villages (No.3 Sangan, No.5 Kywedatywama and No.9 Yela), which are located in the eastern part of this Township, were classified into the rank A, since a layer with the resistivity range H was detected.

The horizontal electrical profiling was carried out in two villages in the eastern part of this Township (see Fig. 3.2.1.21). The profiles of No.8 village show changes of apparent resistivity value. This suggests that the presence of discontinuity of the geological structure. The classification of resistivity was the ranges from VH to UH and it was assumed that a dry layer should continue until 50m in depth. The profiles of No.3 village show a few changes of apparent resistivity value. Therefore it is assumed that the simple geological structure would continue in this area.

(h) Magwey Township (see Fig. 3.2.1.11)

The survey points in the northwestern part of this Township were classified into the resistivity range H to UH, and the same in the southeast part were classified into the range H to VL. From the point of geological characteristics in this Township, The Irrawaddy Formation is distributed in almost the whole Township, except the southern and the eastern part where the Pegu Group is distributed and, No.2, No.3 and No.8 village are located on it. According to the existing well data, there is an anticline extending northwest to southeast through the east distribution area of the Pegu Group. Judging from the existing well data, it is assumed that the difference of resistivity structure in the northwestern part and the southeast part might reflect the existence of the in deep.

The horizontal electrical profiling was carried out in No.1 village in the northwestern part and No.8 village in the southeastern part of this Township (see Fig. 3.2.1.21). Although the high apparent resistivity value was measured at No.8, judging from the both measured values, it was assumed that the data should be affected by noises therefore the change of apparent resistivity should be very few in the both villages. As the classification of resistivity was evaluated at the range from VH to UH, it was assumed that a dry layer should continue in these areas.

(i) Pakokku Township (see Fig. 3.2.1.12)

Most of the survey points in this Township were classified into the resistivity ranges from M to VH. Two villages (No.2 Magyithonepin, and No.4 Anaukponekan) were classified at the rank A. From the point of geological characteristics in this Township, the Irrawaddy Formation is distributed in the central wide area and the Pegu Group is in the comparatively small area near both at west and east ends. Therefore the existence of a good aquifer is expected. According to the existing well data, the groundwater level is in 50-100m in depth and becomes shallow to the Ayearwaddy River.

The horizontal electrical profiling was carried out at four villages located in the central part of this Township (see Fig. 3.2.1.23). The profiles of No.3 village and No.4 village show a very small change in the apparent resistivity value. The classification of resistivity was evaluated at the range from H to UH, therefore it was assumed that a layer with aquifer would continue simply in this area. In No.5 village the apparent resistivity value was detected to fall gradually from the northern to the southern parts, however, it was judged that the phenomenon should appear by the influence of existence of layers with the resistivity ranges UL and L in the shallow underground at the survey point V1, which is located in the south of the village. Therefore it was assumed that there is no change of geological structure in this village. In No.7 village the profile shows a small change of the apparent resistivity value. As the classification of resistivity was evaluated at the range L, it was assumed that a clayey layer or an aquifer with salt water should continue.

(j) Myothit Township (see Fig.3.2.1.13)

Most of the survey points in this Township were classified into the resistivity range from M to VH. Three villages (No.1 Thamya, No.2 Ledaingzin N & S and No.6 Myinsu) were evaluated at the rank A. From the point of geological characteristics in this Township, the Irrawaddy Formation is distributed over the whole area, and the Quarterly sediments covers on the Irrawaddy Formation in No.7 village. Depending on the existing well data, the groundwater level of No.1 village, which is located in the northern part, was estimated at 120m in depth, and the same of No.4, and No.5, which are located in the central part, were at 55-75m. And the same of No.9 village in the southern part was at 25m as well.

The horizontal electrical profiling was carried out at two villages in the central part (No.4, No.6) (see Fig. 3.2.1.24). From the hydrogeological point of view, the existence of fault was suspected near No.4 village, however, a remarkablly unusual belt was not detected through the VLF-EM electromagnetic method survey which was carried out by the Study team. As the profiles of No.6 village show comparatively large changes of the apparent resistivity value, whose resistivity classifications were at the range VH, the presence of discontinuity of geological structure was assumed.

(k) Yesagyo Township (see Fig.3.2.1.14)

Most of the survey points were classified at the resistivity range L, which means a low possibility of existence of good aquifer in this Township. Excerpt in No.8 village the resistivity range was classified into the range H around 25m - 85m in depth, and in No.6 village the resistivity range VH was detected around 30m - 210m in depth. From the point of geological characteristics in this Township, The Irrawaddy Formation is distributed in the northern part, the Pegu Group is distributed in the central and the southern part, and the Irrawaddy Formation is distributed at the southern end, where No.10 village is located. The possibility of the groundwater development in this Township was evaluated at the rank B and C as a whole.

The horizontal electrical profiling was carried out in three villages in the northern part of this Township where the Irrawaddy Formation is predominant (see Fig.3.2.1.25). The profiles of these villages show a small change of the apparent resistivity value. As the classification of resistivity was evaluated at the range L to VL, it is assumed that a clayey layer or an aquifer of salt water should continue.

5) Conclusion

The villages, which were evaluated at the high possibility of the groundwater development in each Township, were shown in Table 3.2.1.4.

Since it was assumed that two villages shall be selected in each Township as the site of test well to be constructed during this study, the village evaluated at the rank B were extracted in the Townships, whose possibility of groundwater development was evaluated at the lower rank.

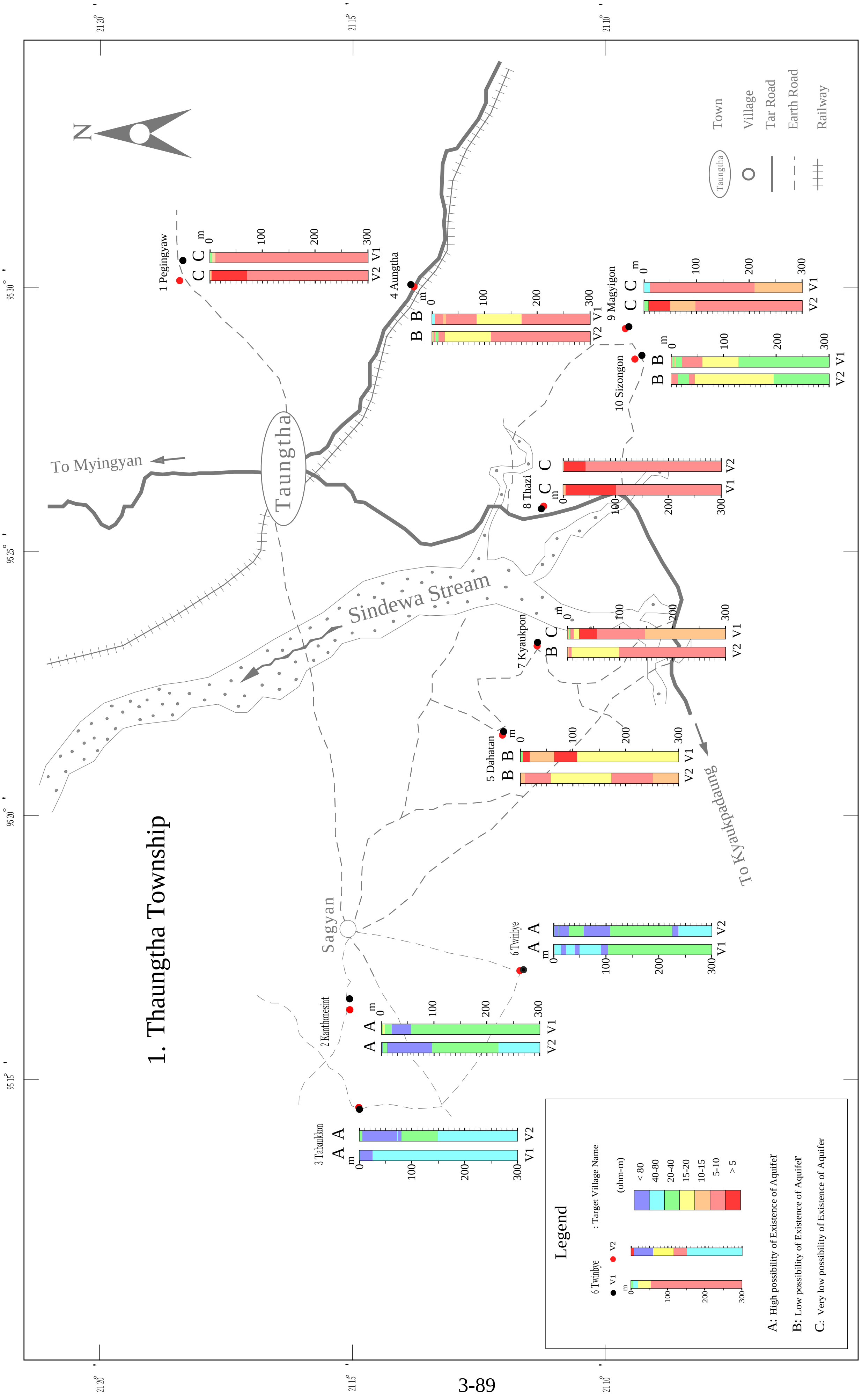


Fig. 3.2.1.4 Result of Vertical Electrical Sounding in Thaungtha T/S

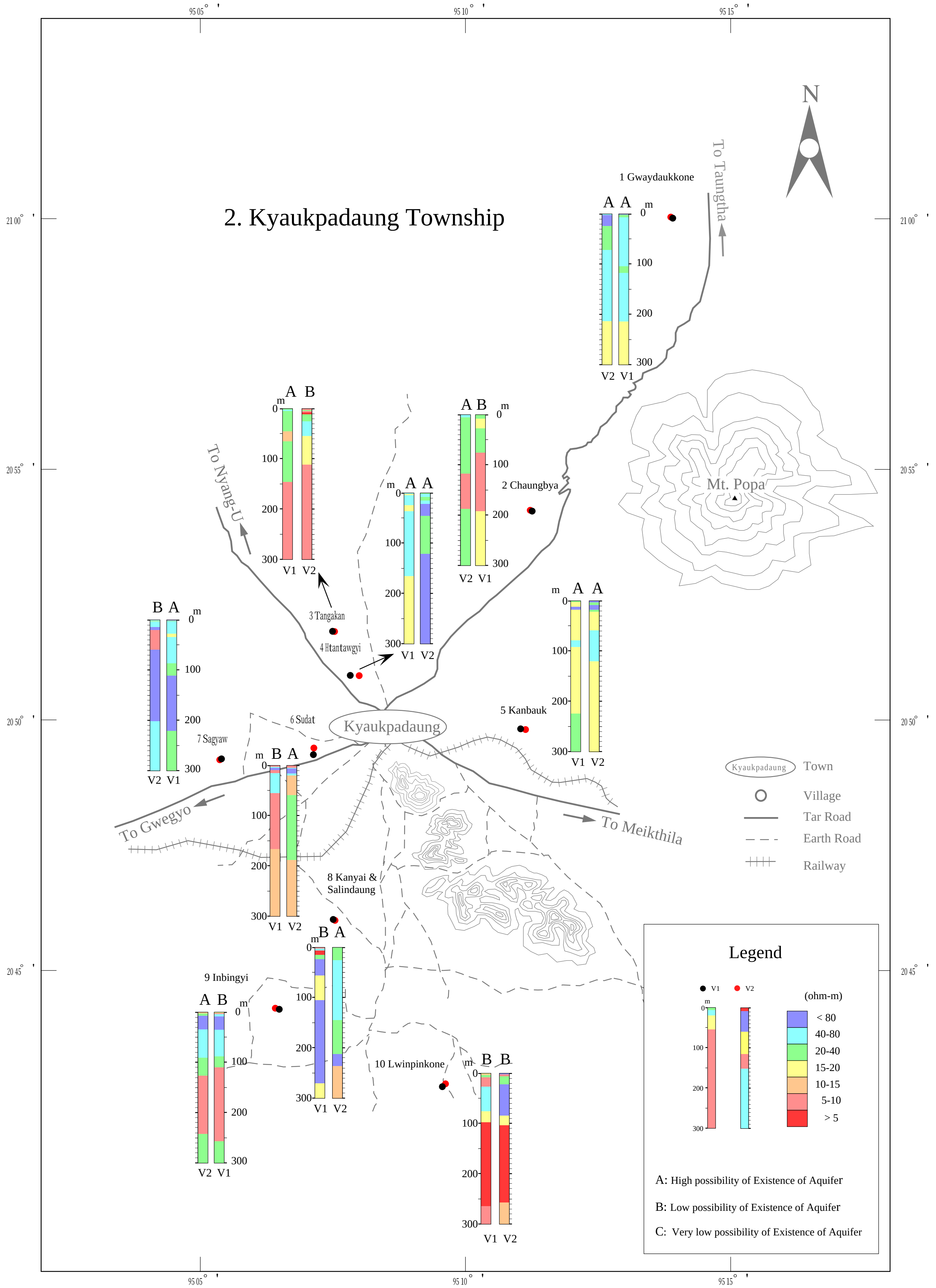


Fig. 3.2.1.5 Result of Vertical Electrical Sounding in Kyaukpadaung T/S

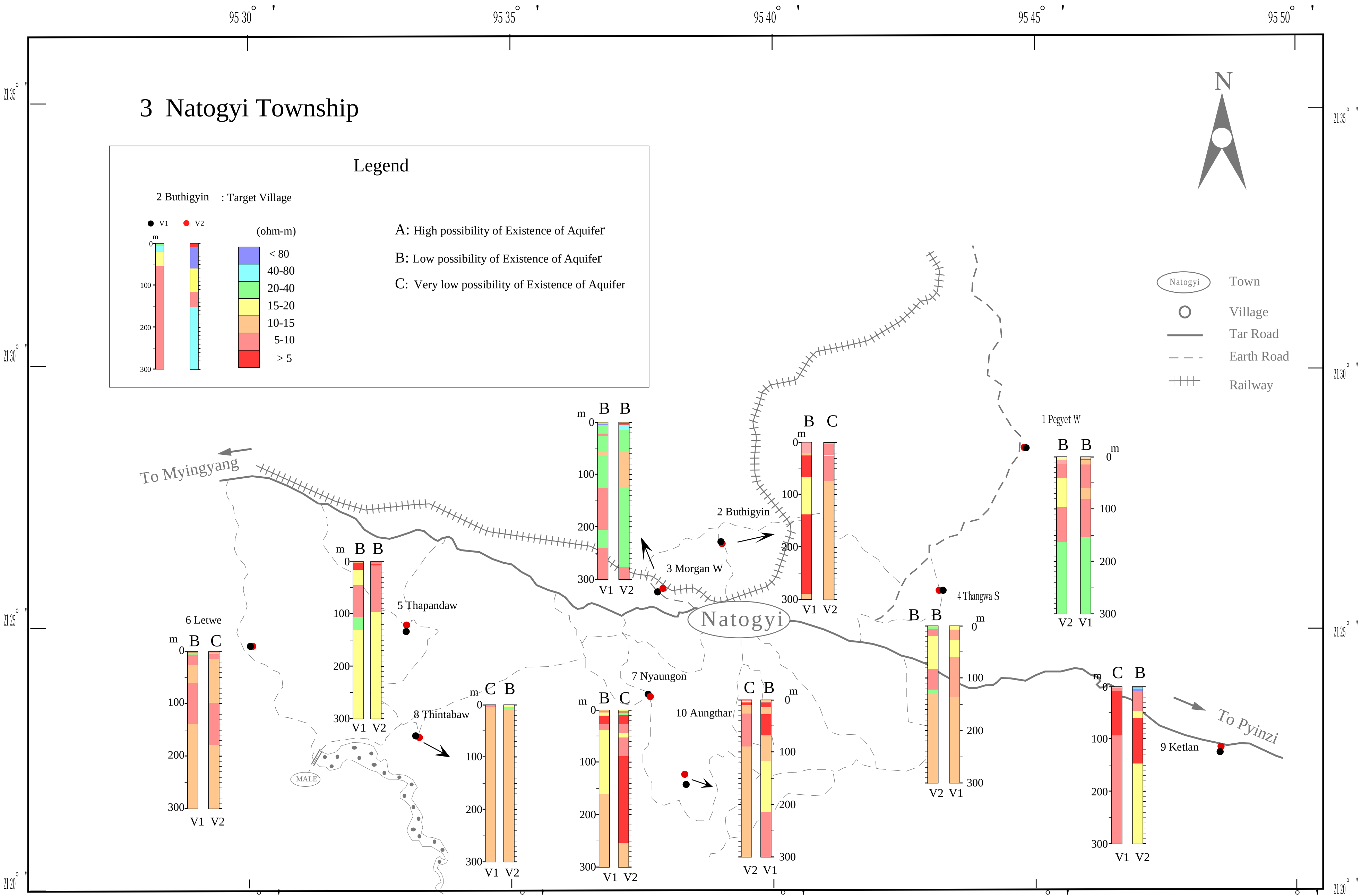


Fig.3.2.1.6 Result of Vertical Electrical Sounding in Natogyi T/S

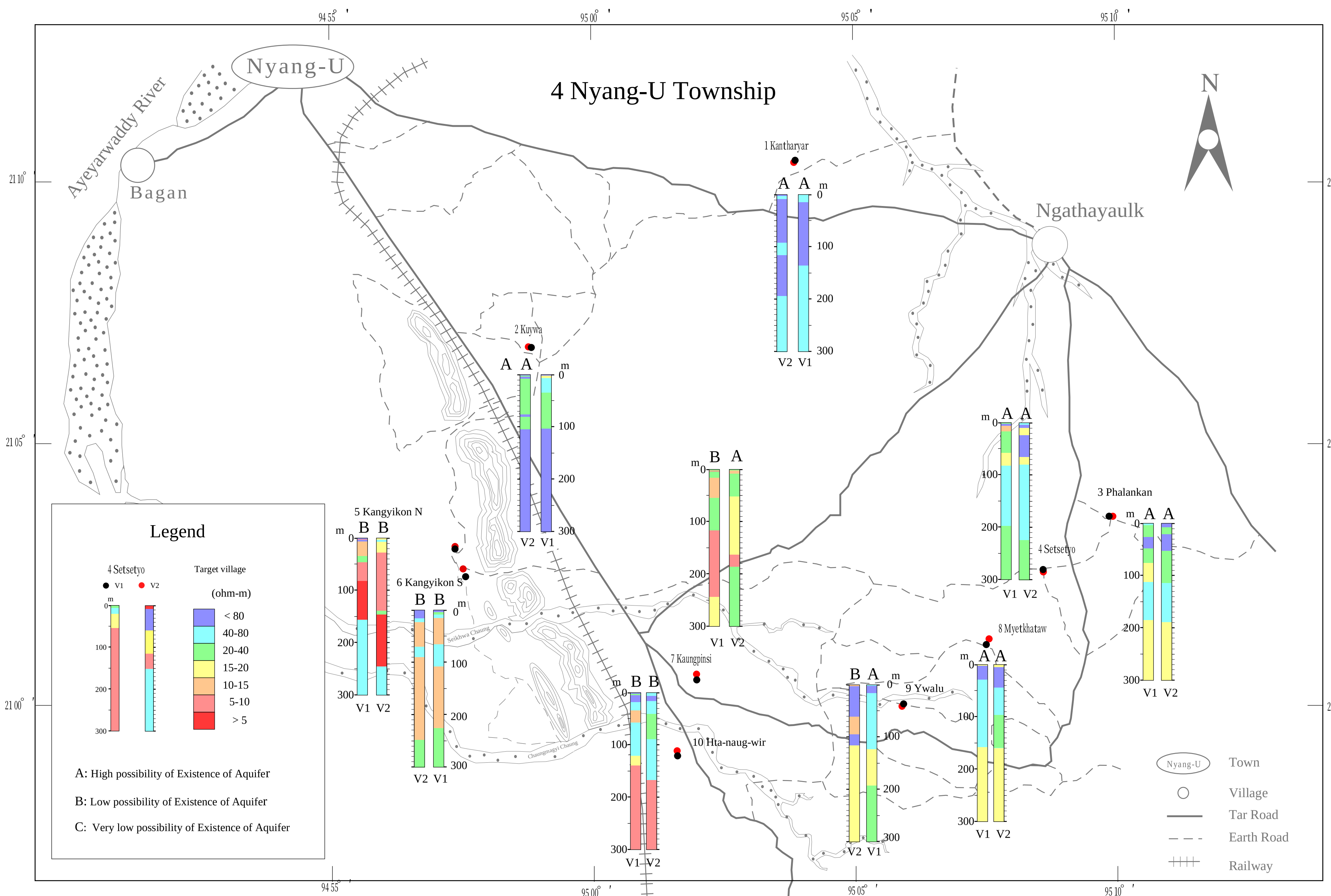


Fig.3.2.1.7 Result of Vertical Electrical Sounding in Nyang-U T/S

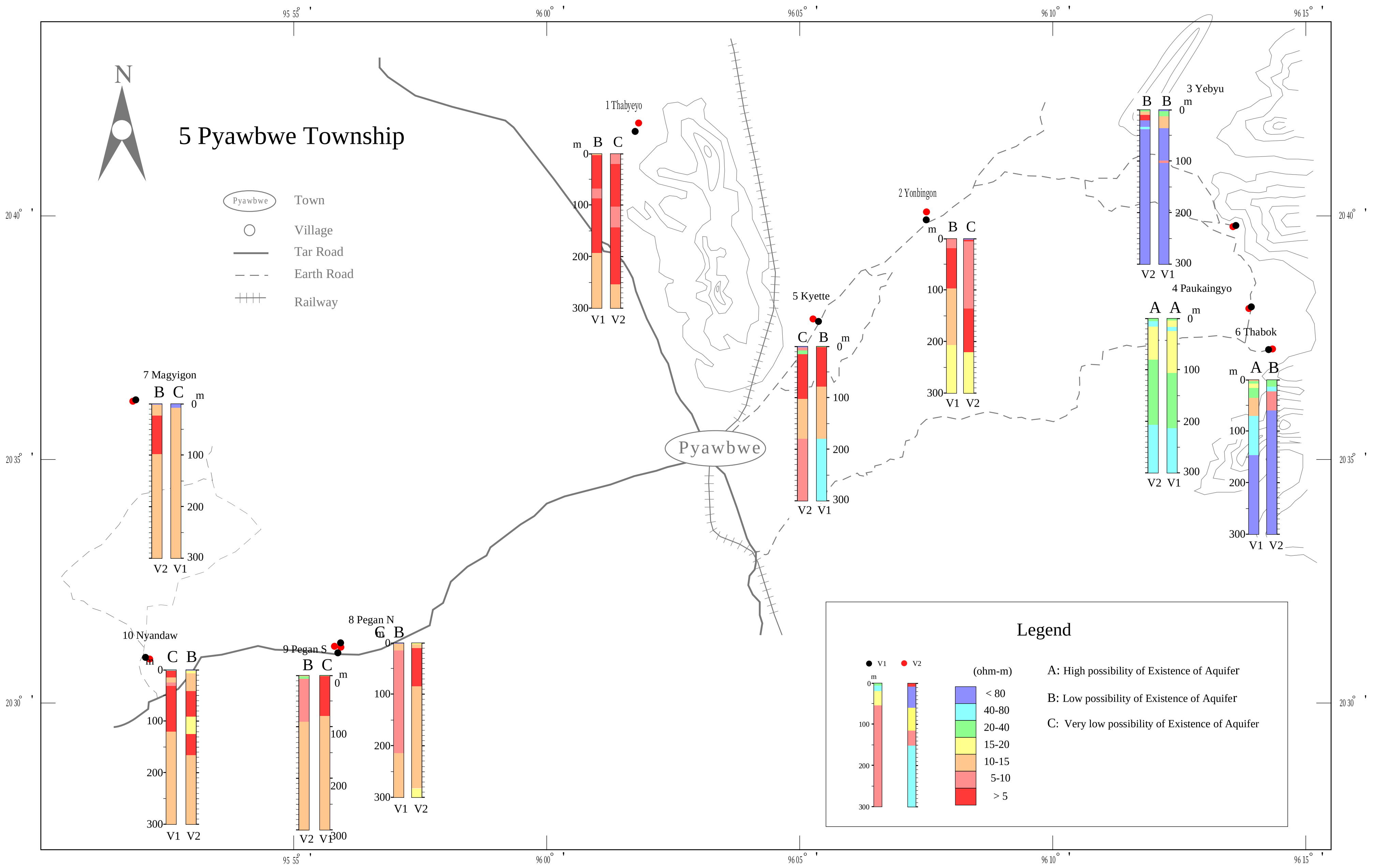


Fig. 3.2.1.8 Result of Vertical Electrical Sounding in Pyawbwe T/S

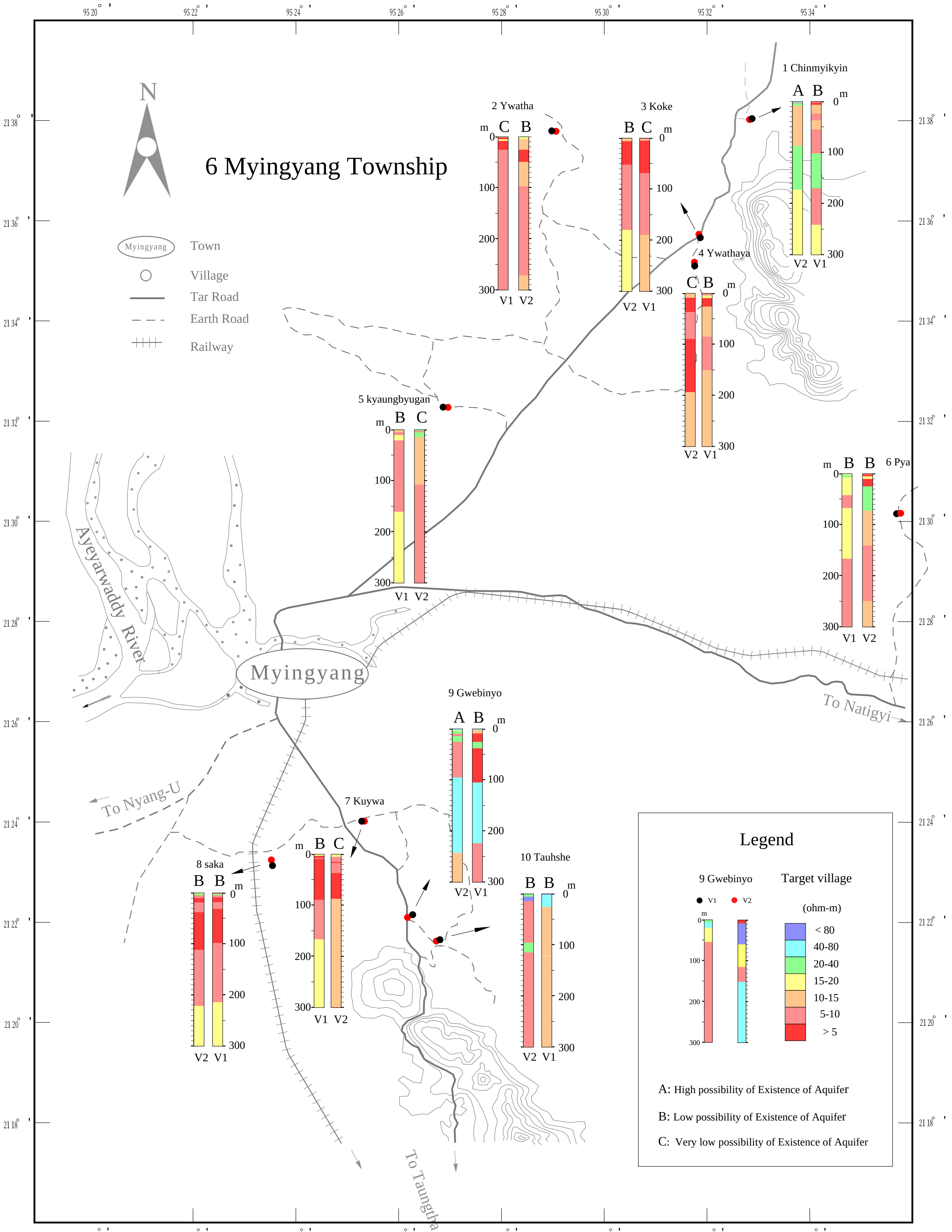


Fig. 3.2.1.9 Result of Vertical Electrical Sounding in Myingyang T/S

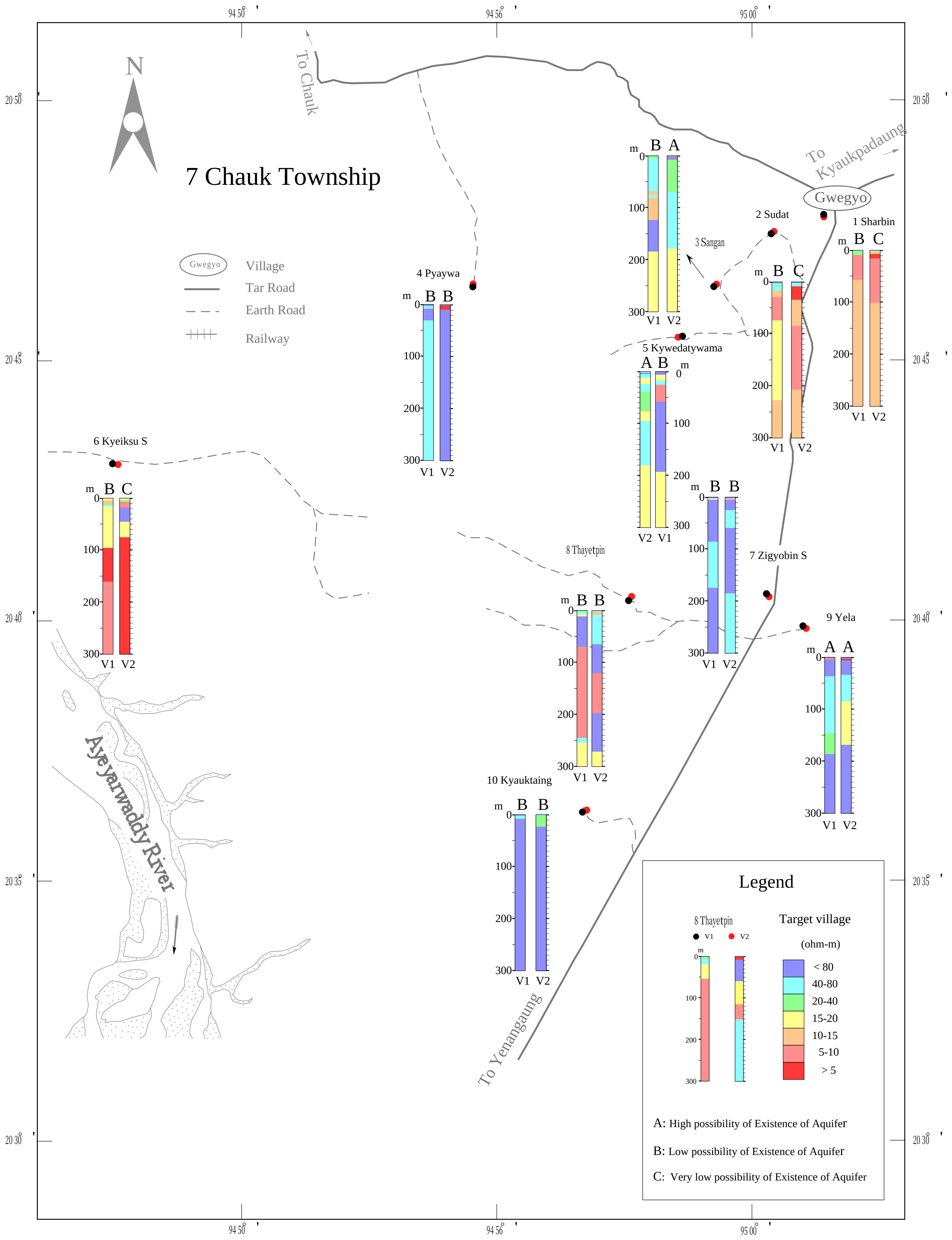


Fig.3.2.1.10 Result of Vertical Electrical Sounding in Chauk T/S

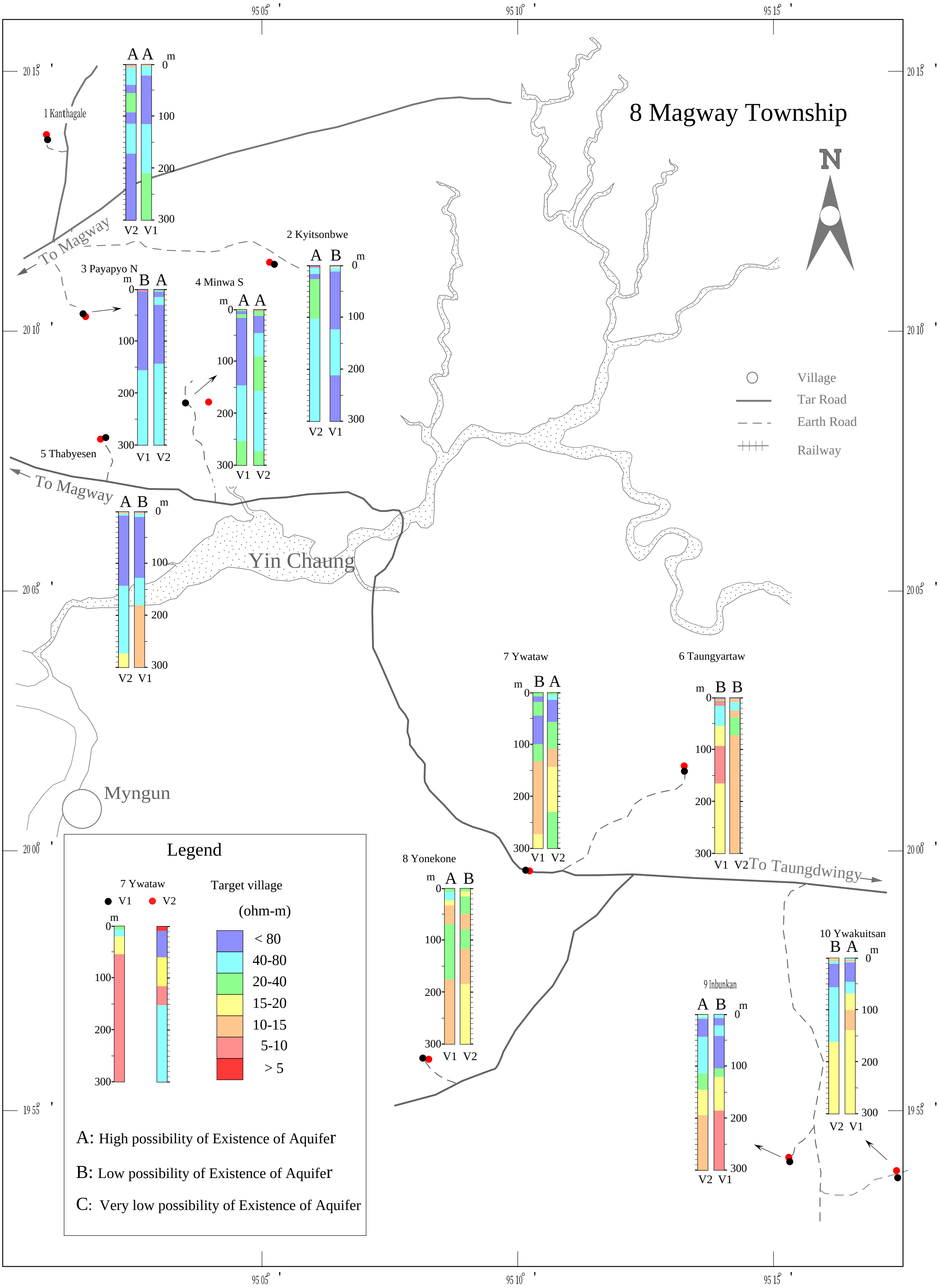


Fig. 3.2.1.11 Result of Vertical Electrical Sounding in Magway T/S

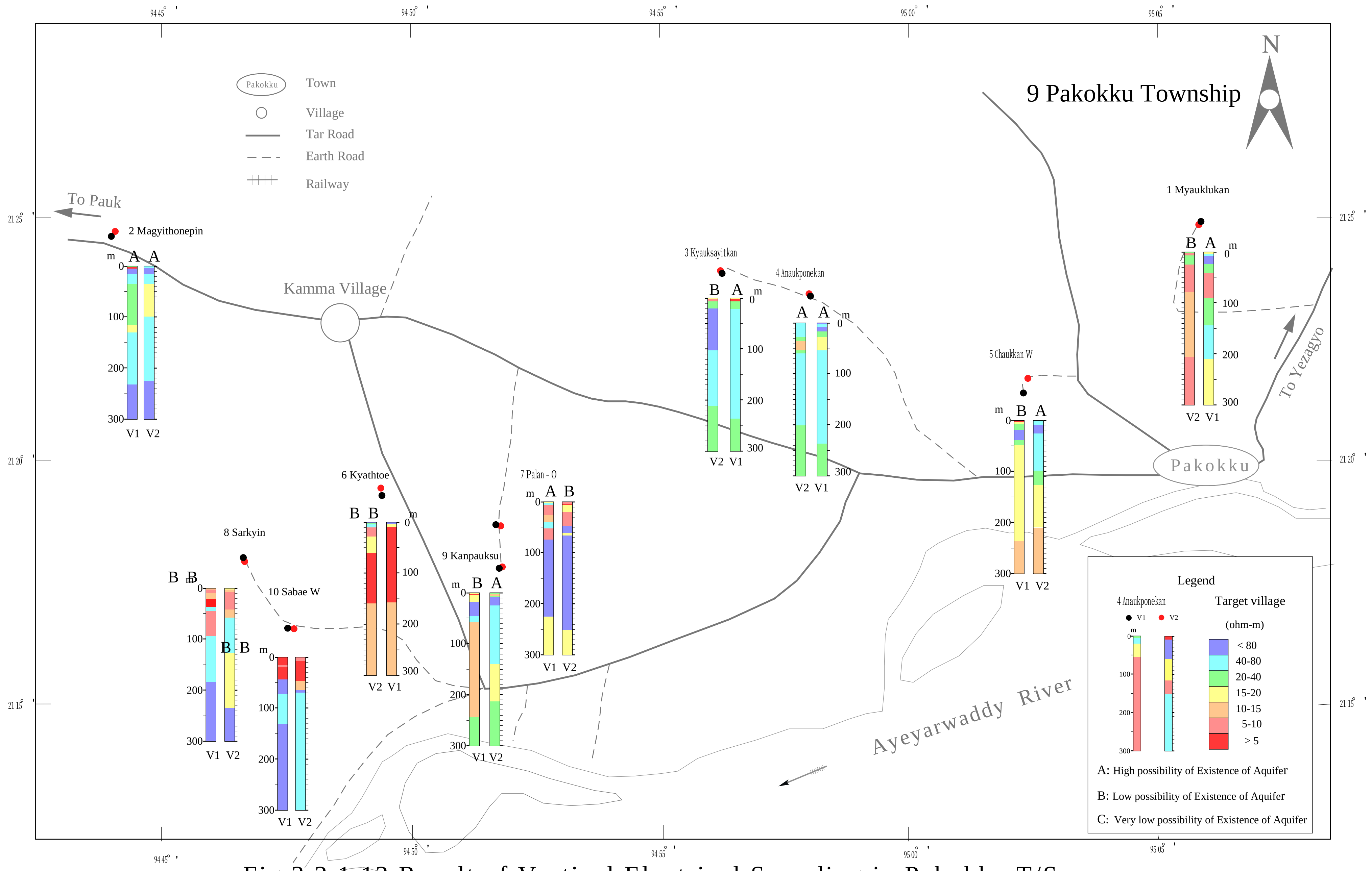


Fig.3.2.1.12 Result of Vertical Electrical Sounding in Pakokku T/S

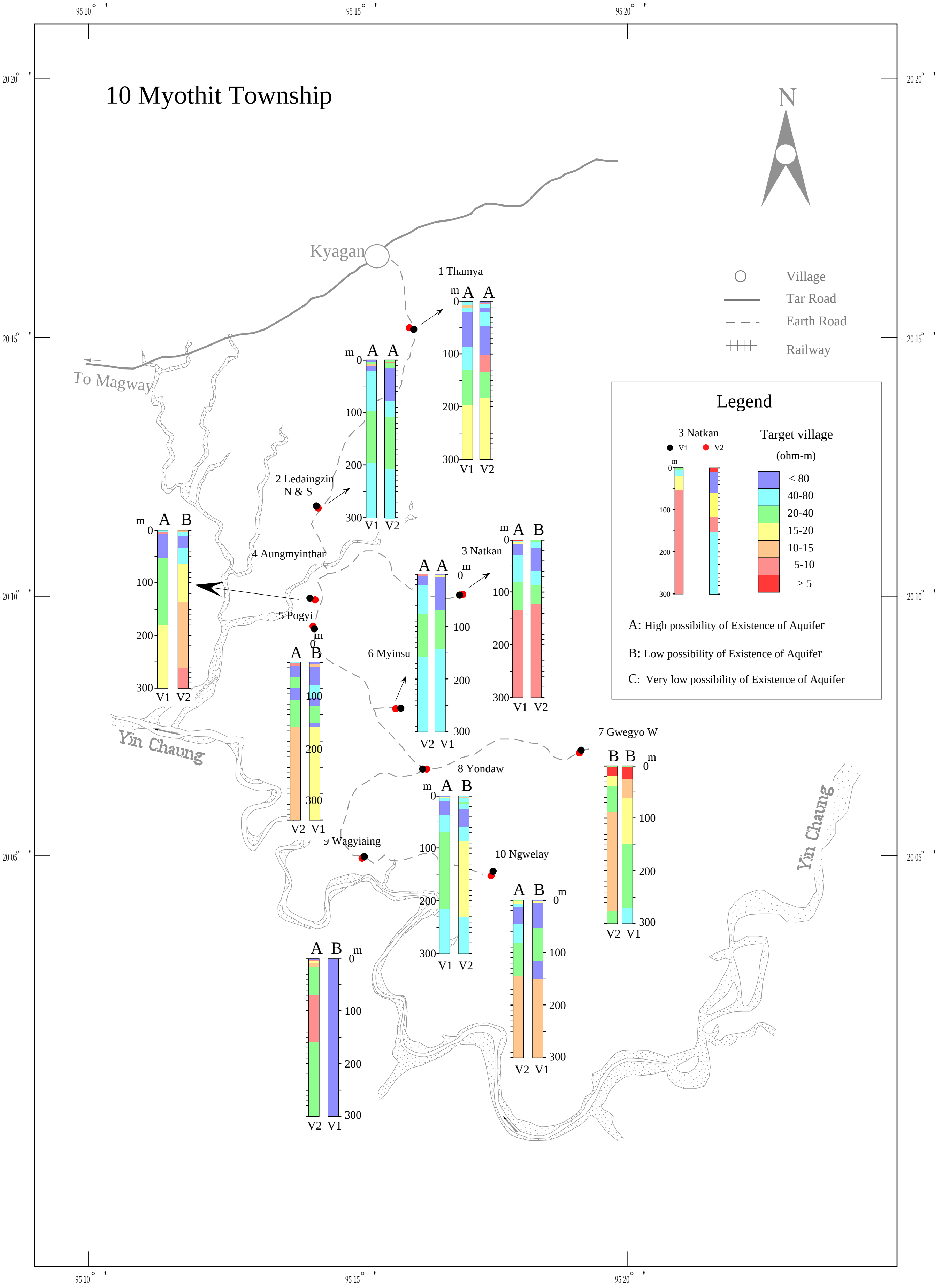


Fig.3.2.1.13 Result of Vertical Electrical Sounding in Myothit T/S

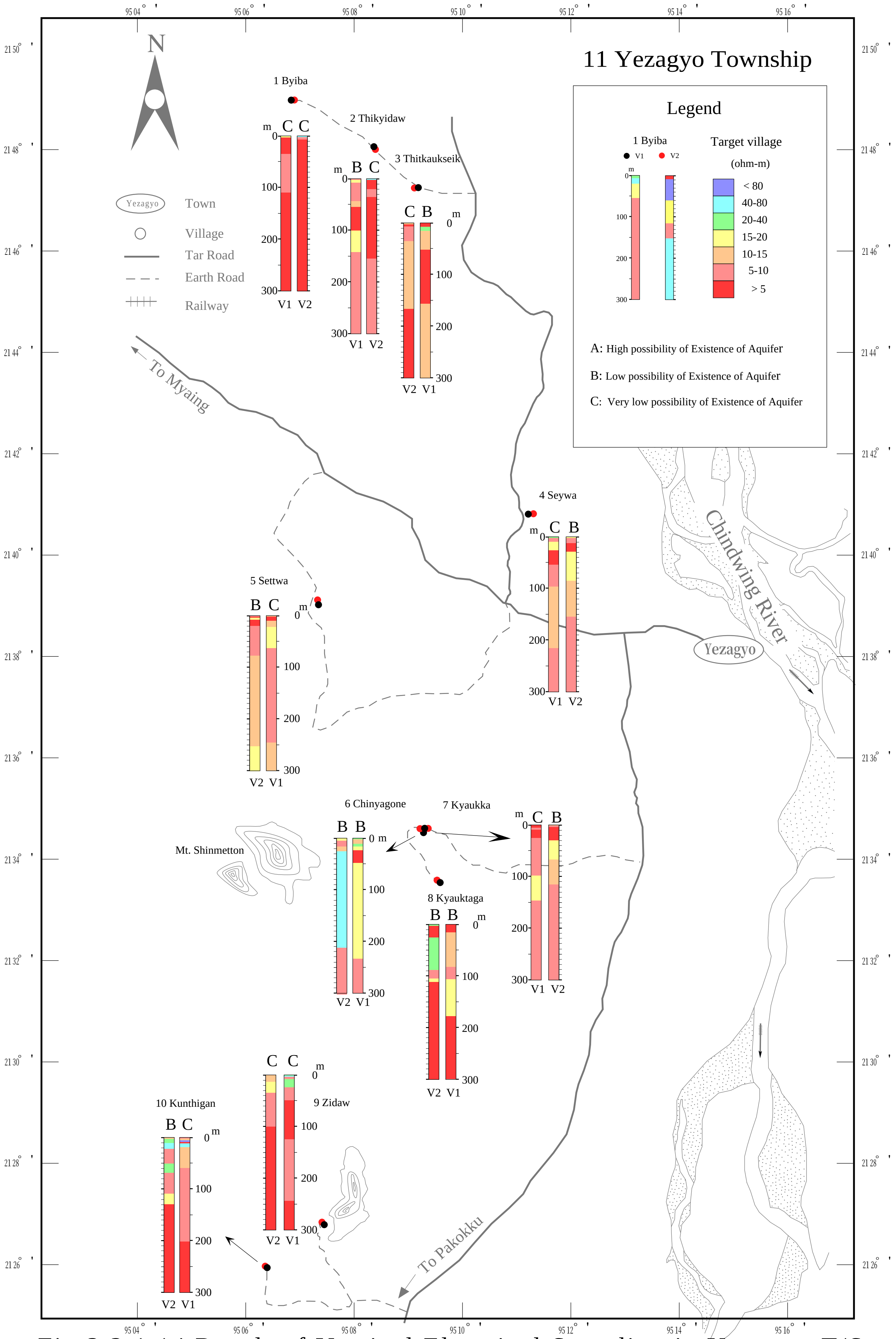
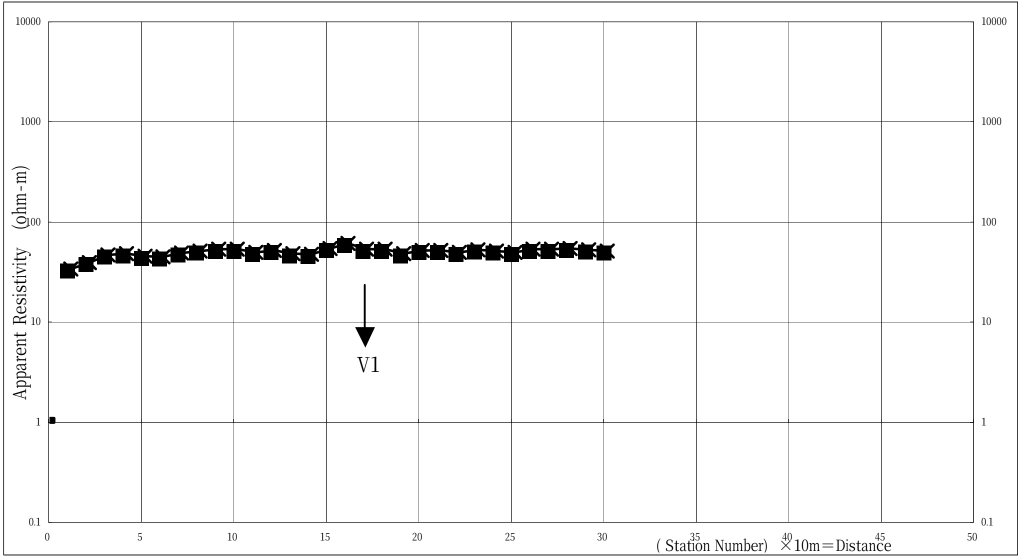


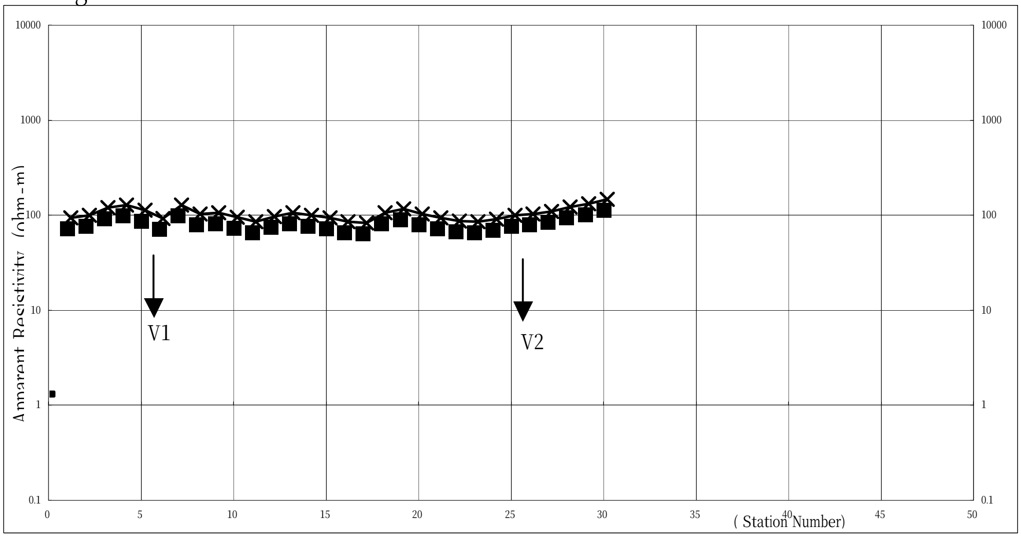
Fig.3.2.1.14 Result of Vertical Electrical Sounding in Yezagyo T/S

No.2 village

1.Taungtha T/S



No.3 village



No.6 village

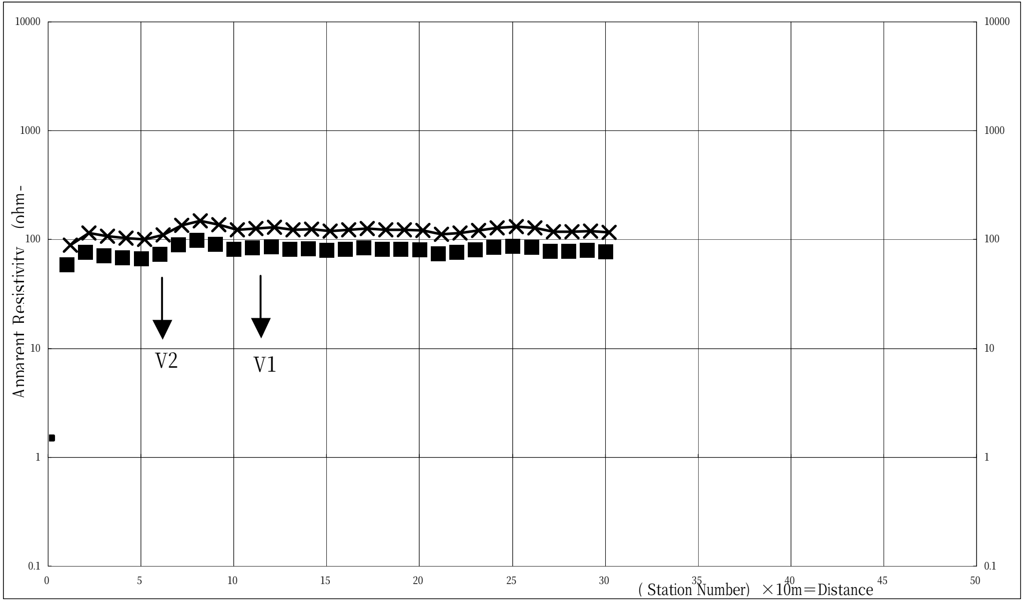
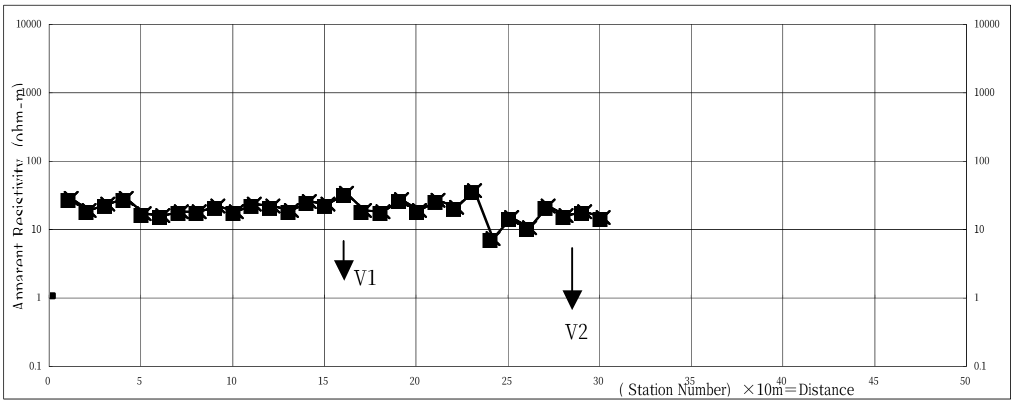
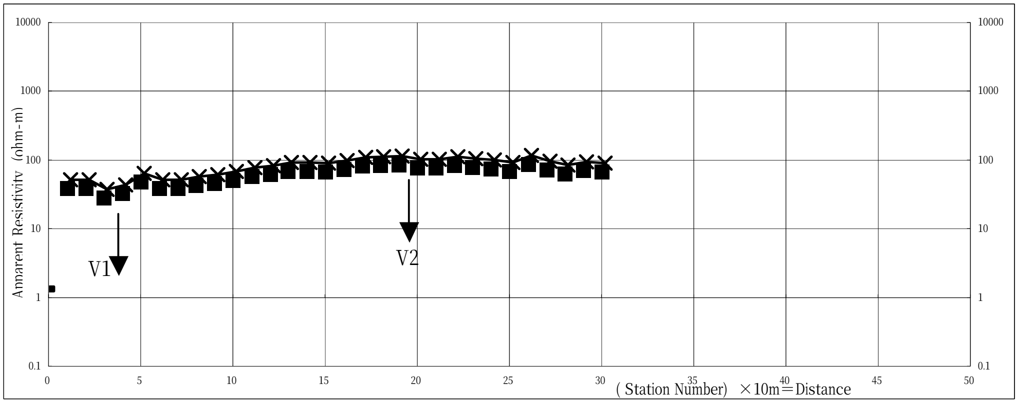


Fig. 3.2.2.15 Result of Horizontal Electrical Profiling in Taungtha T/S

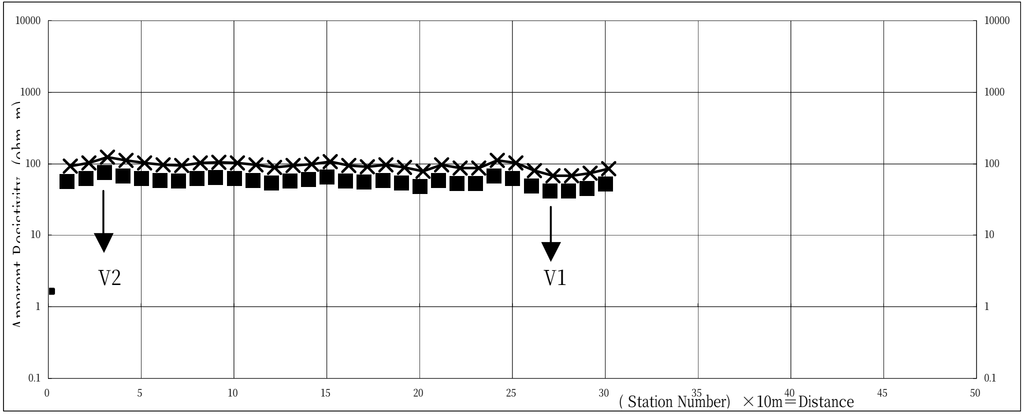
No.3 village 2. Kyaukpadaung T/S



No.4 village



No.6 village



N0.7 village

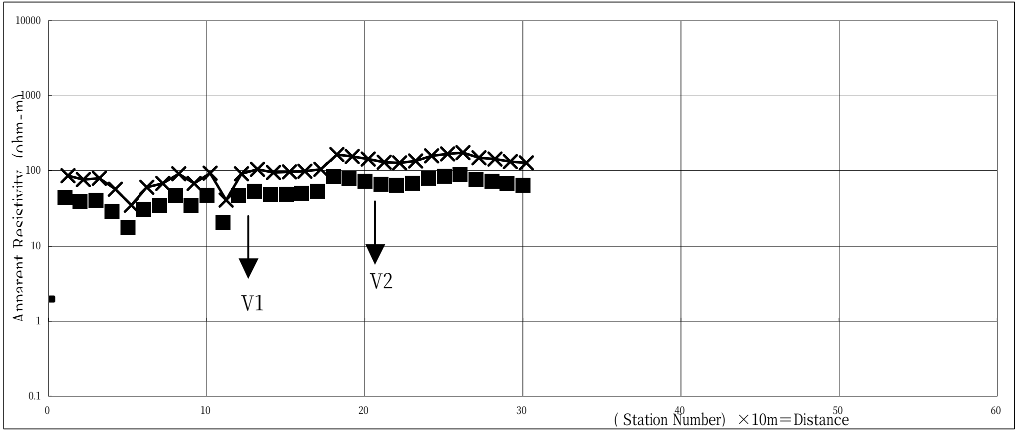
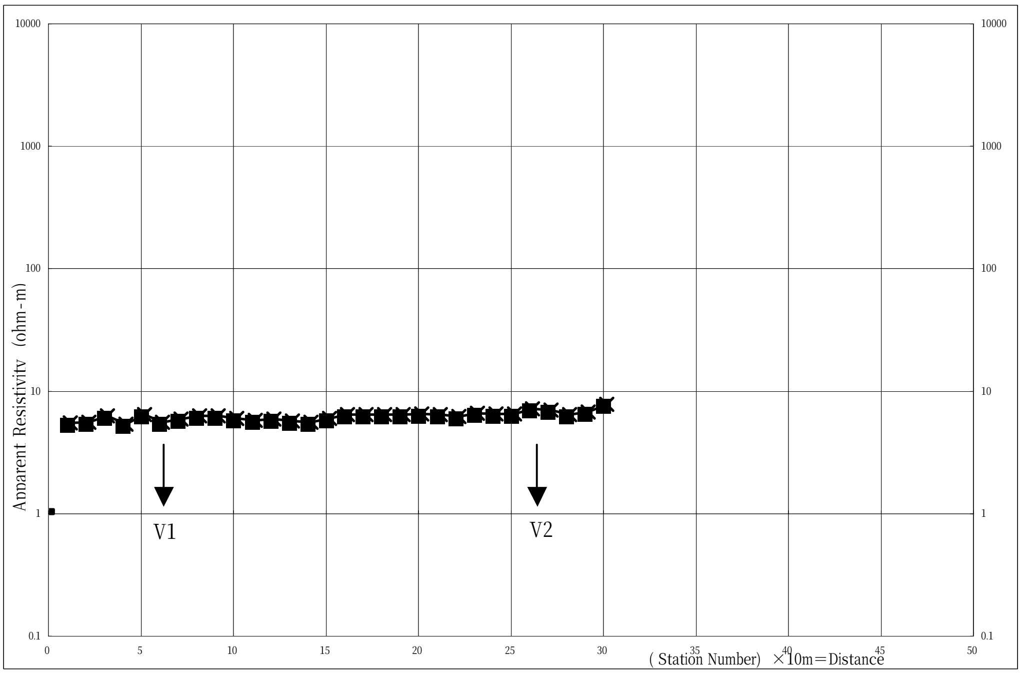


Fig. 3.2.1.16 Result of Horizontal Electrical Profiling in Kyaukpadaung T/S

No.3 village



No.4 village

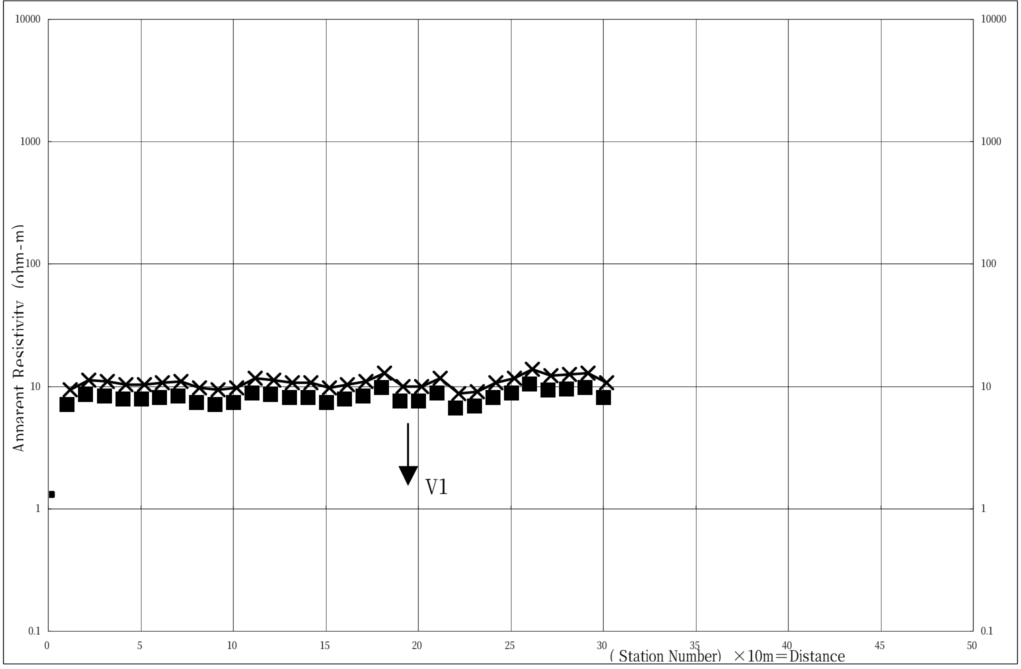
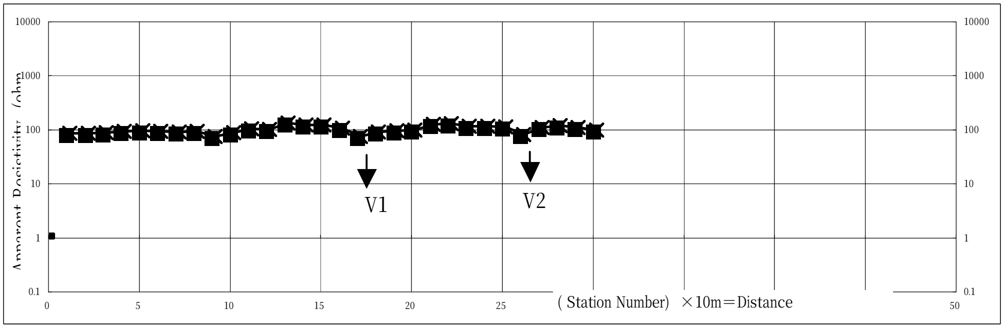
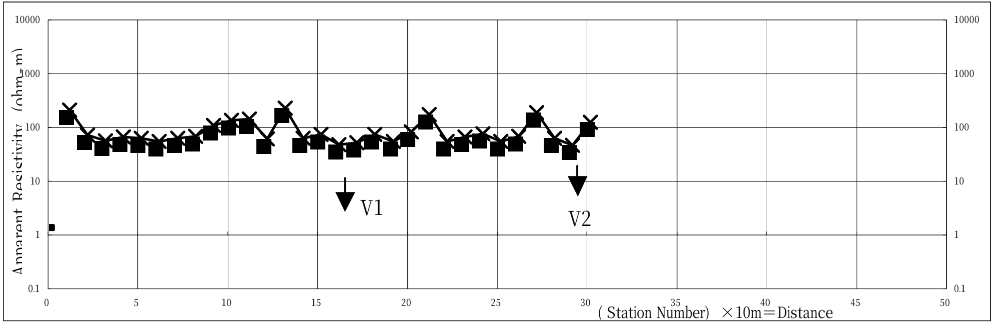


Fig. 3.2.1.17 Result of Horizontal Electrical Profiling in Natogyi T/S

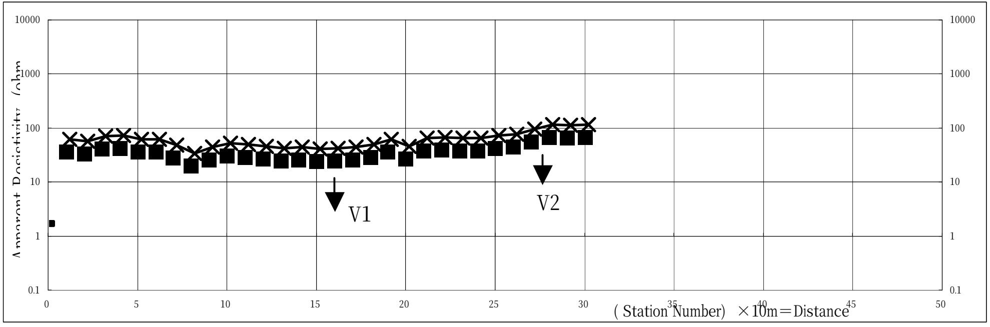
No.1 village 4. NyangU T/S



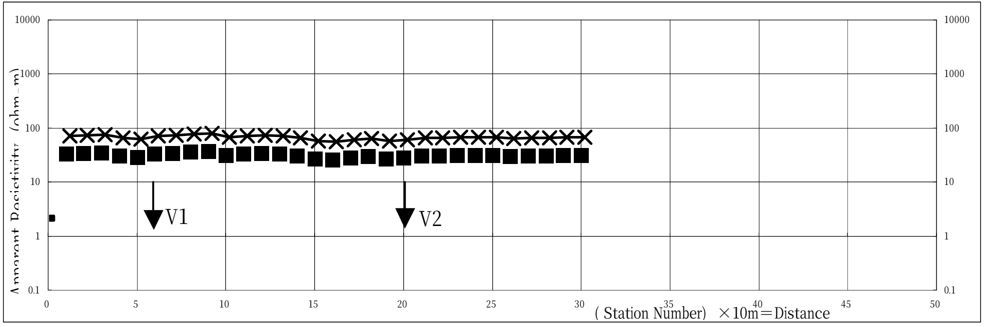
No.2 village



No.4 village



No.7 village



No.8 village

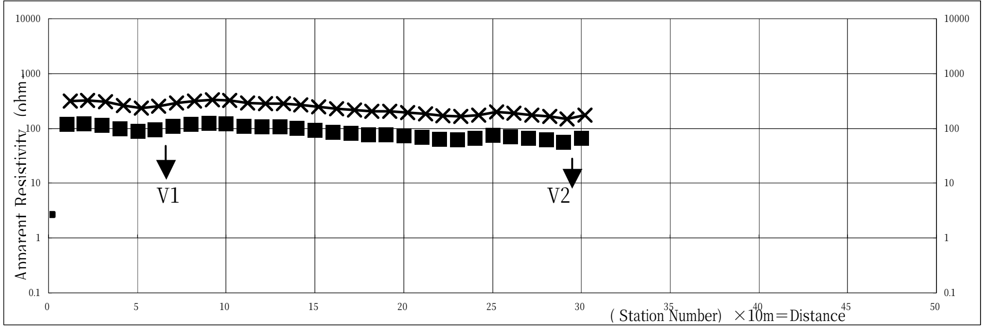
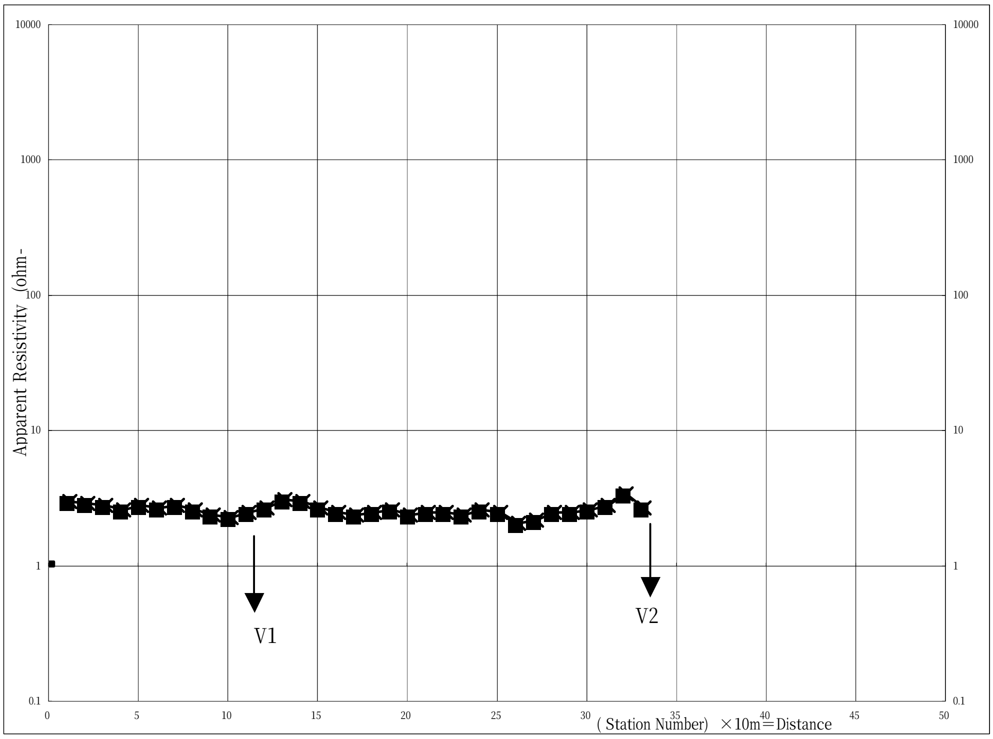


Fig. 3.2.1.18 Result of Horizontal Electrical Profiling in NyangU T/S

No.1 village 5. Pyawbue T/S



No.2 village

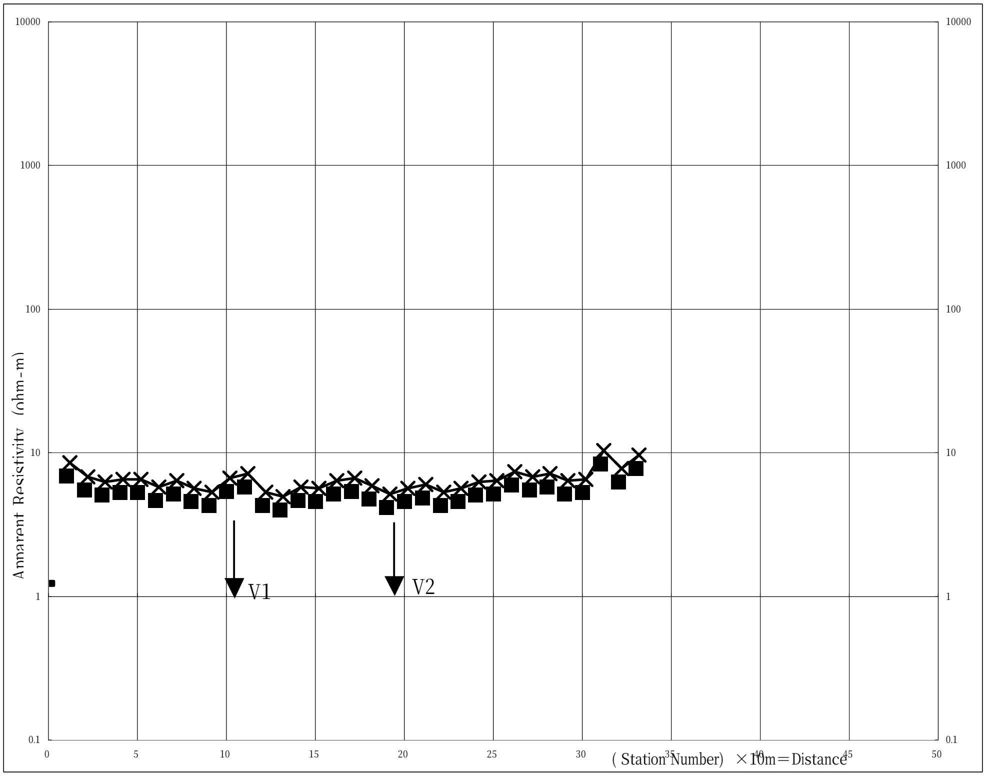
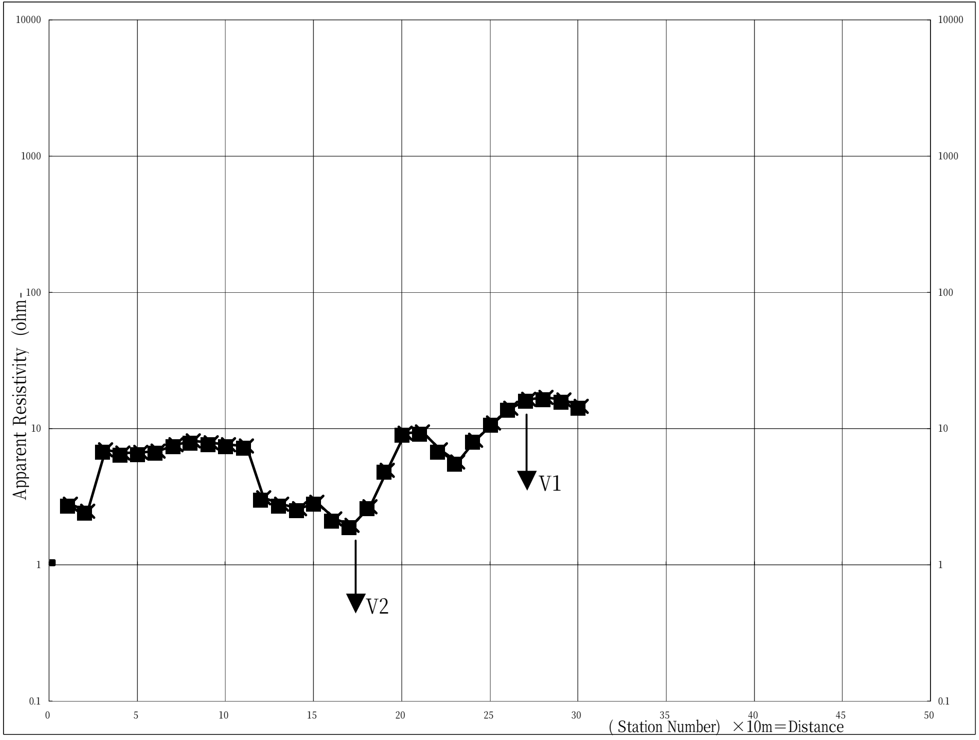


Fig. 3.2.1.19 Result of Horizontal Electrical Profiling in Pyawbwe T/S

No.1 village

6. Myingyang T/S



No.2 village

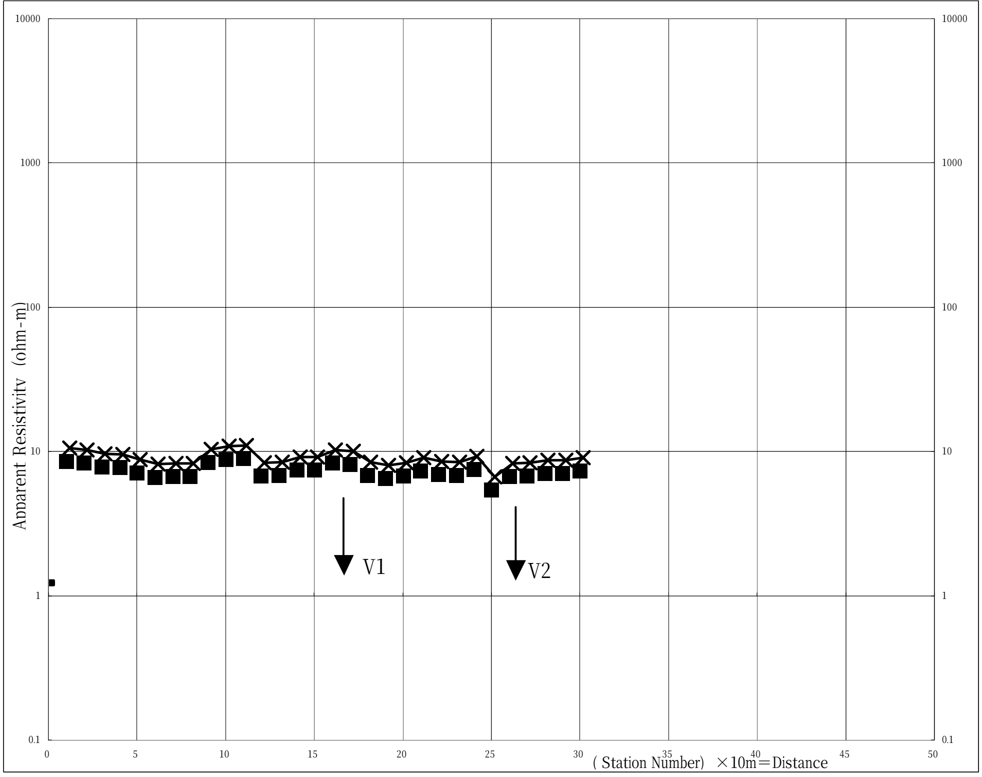
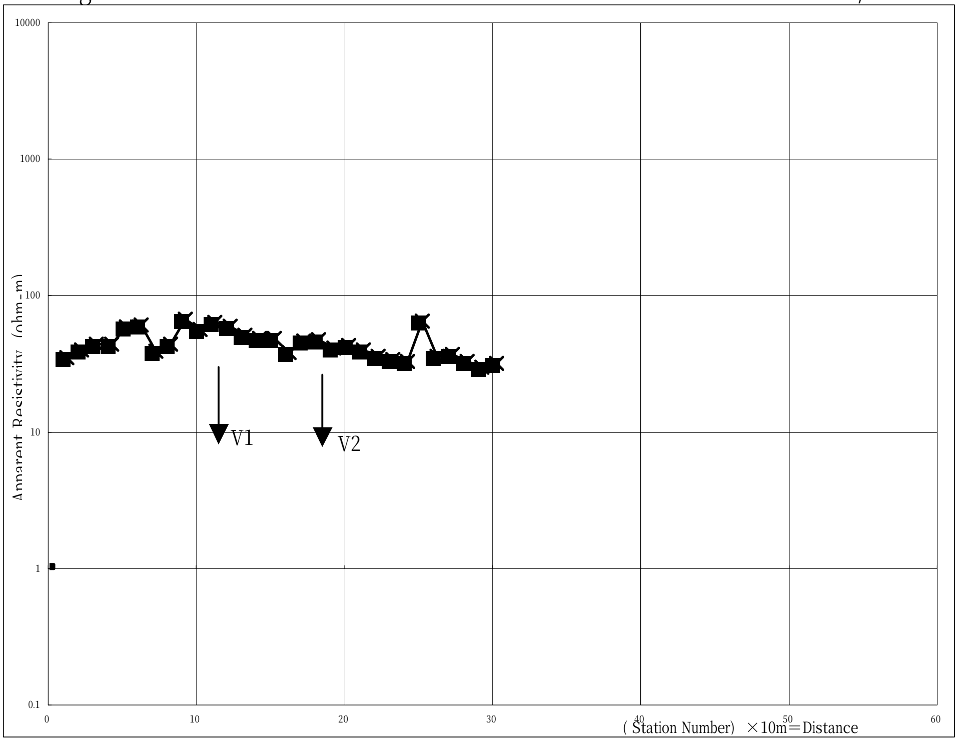


Fig. 3.2.1.20 Result of Horizontal Electrical Profiling in Myingyang T/S

No.3 village 7. Chauk T/S



No.8 village

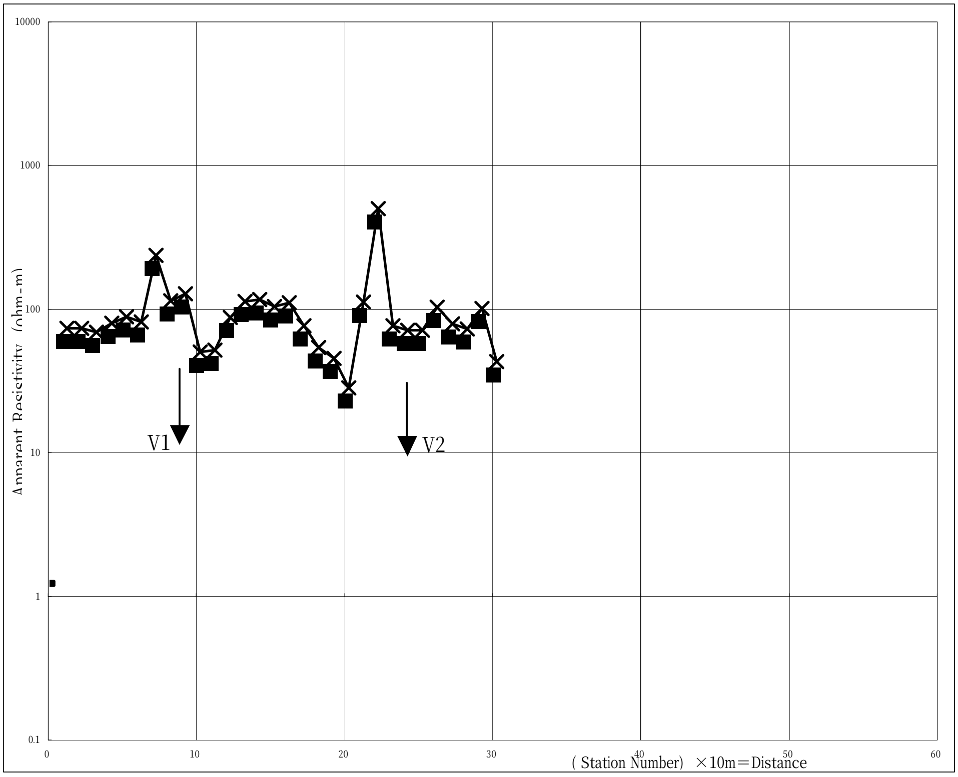
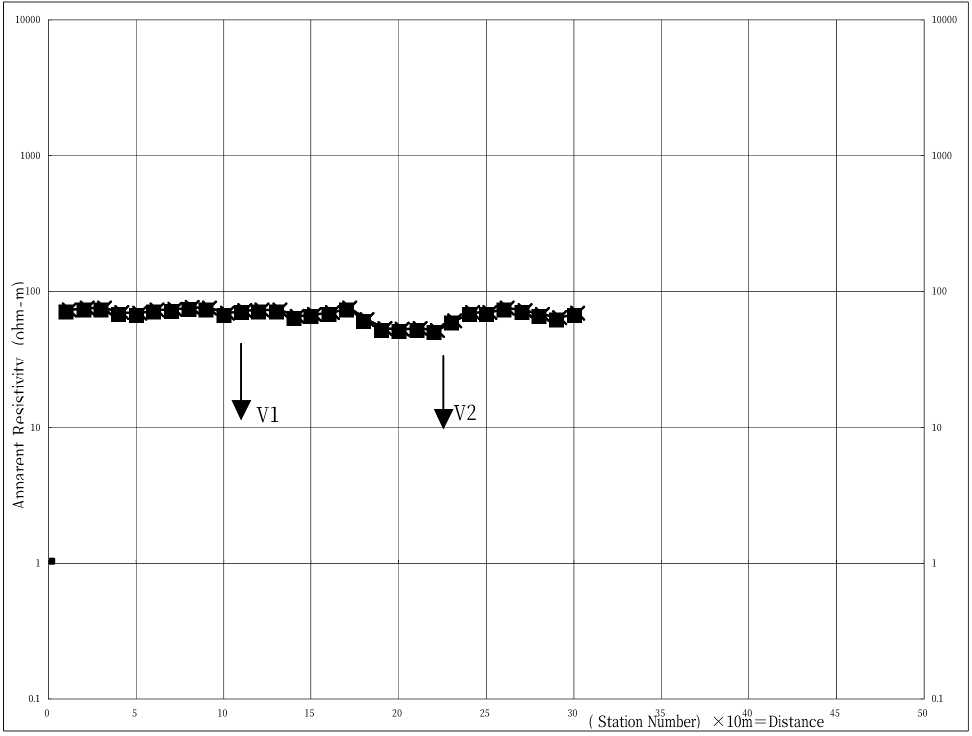


Fig. 3.2.1.21 Result of Horizontal Electrical Profiling in Chauk T/S

No.1 village

8. Magway T/S



No.9 village

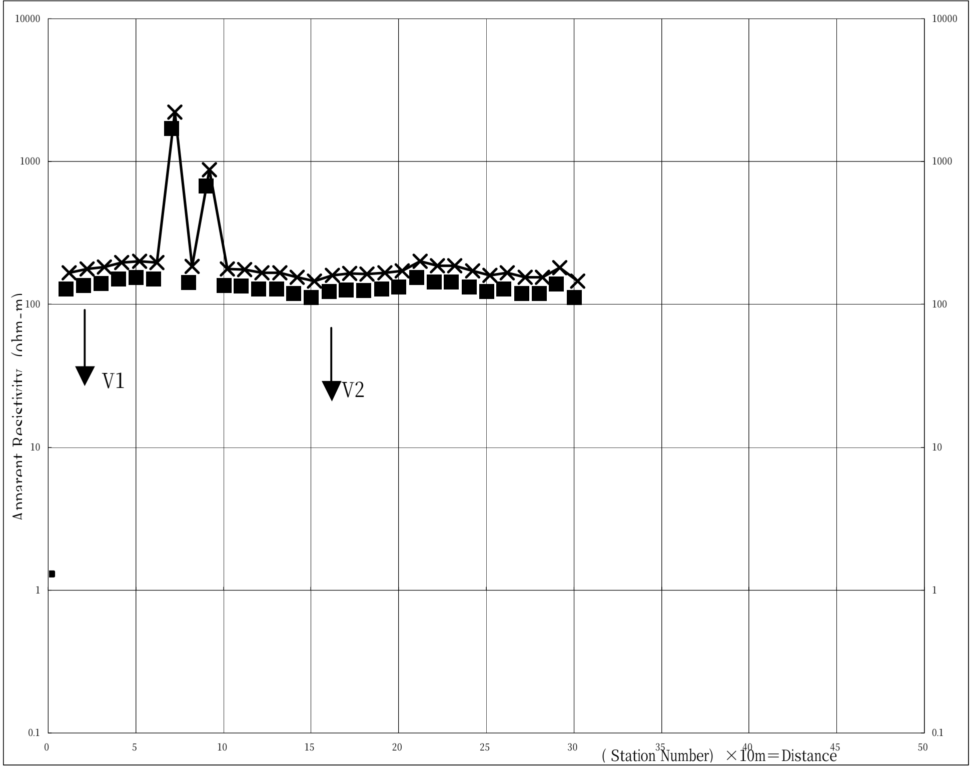
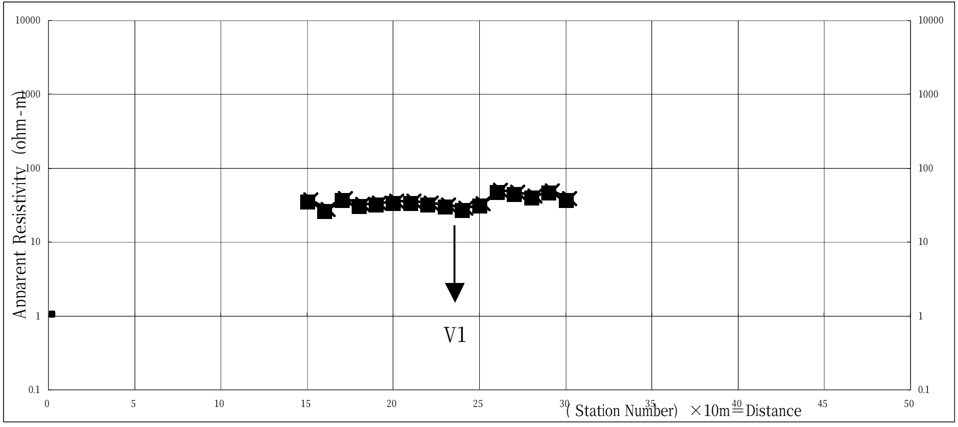


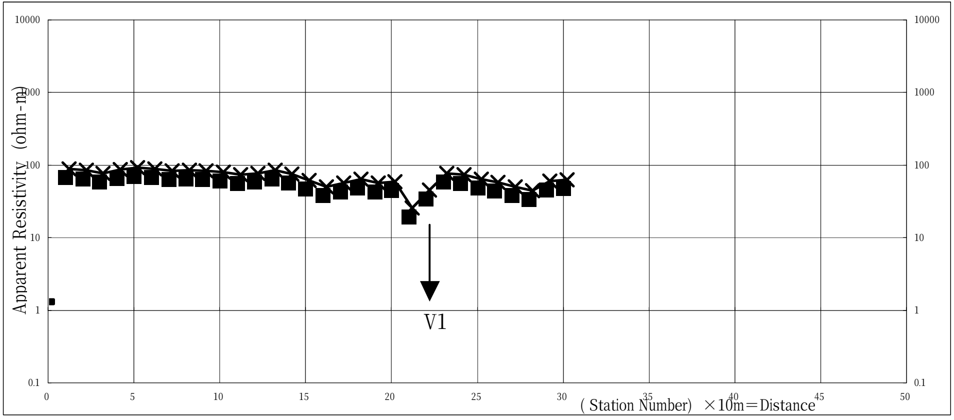
Fig. 3.2.1.22 Result of Horizontal Electrical Profiling in Magway T/S

No.3 village

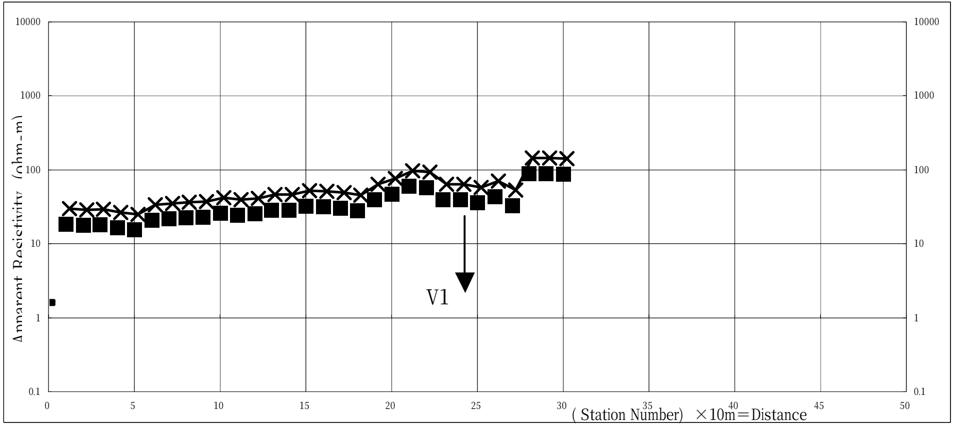
9. Pakokku T/S



No.4 village



No.5 village



No.7 village

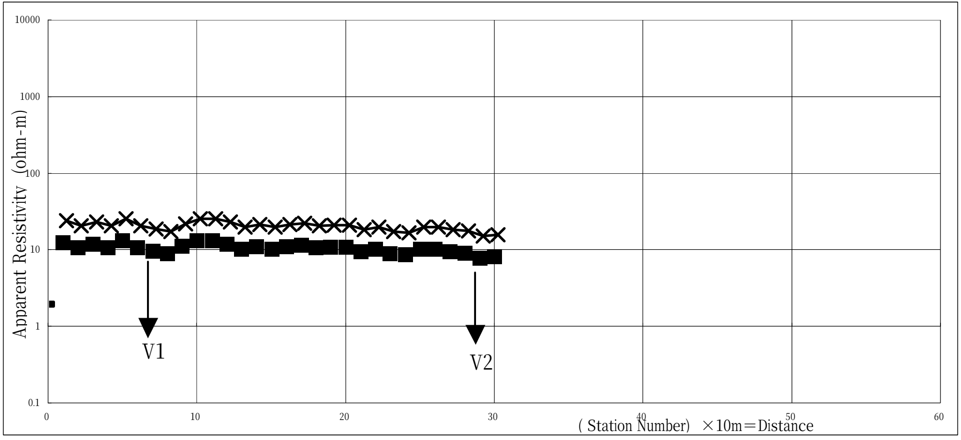
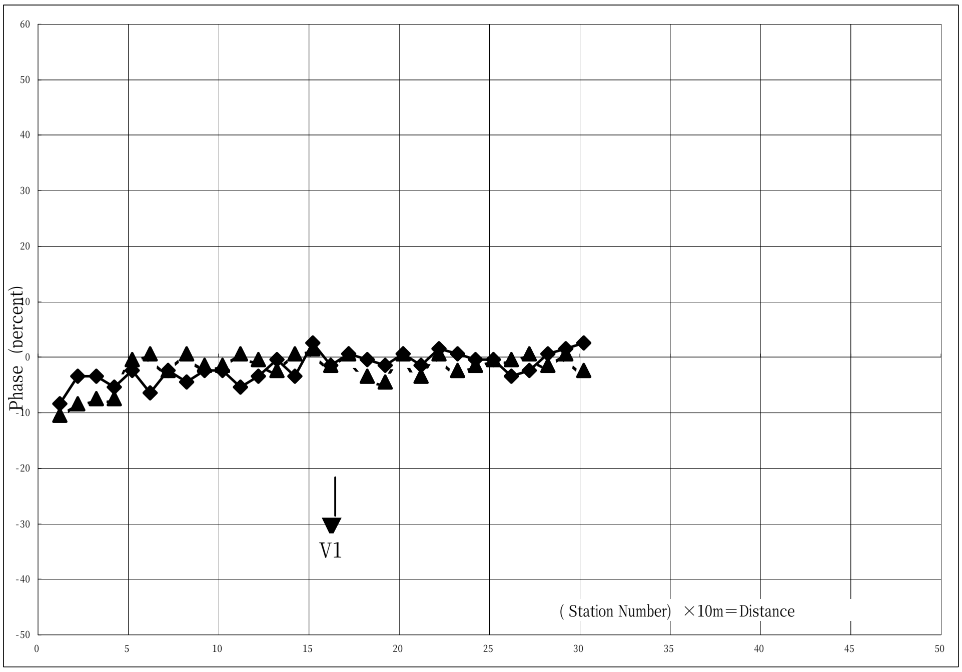


Fig. 3.2.1.23 Result of Horizontal Electrical Profiling in Pakokku T/S

10. Myothit T/S

VLF ———— IN Phase
- - - - - - OUT of Phase

No.4 village VLF Electromagnetic Profiling



No.6 village Horizontal Electrical Profiling

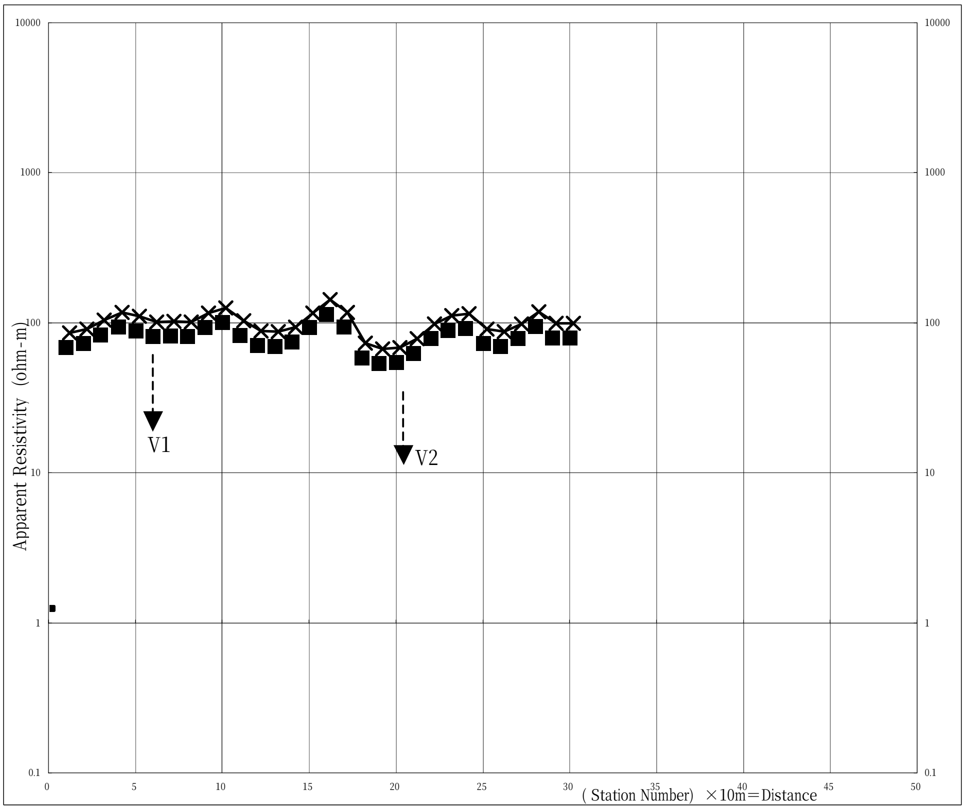
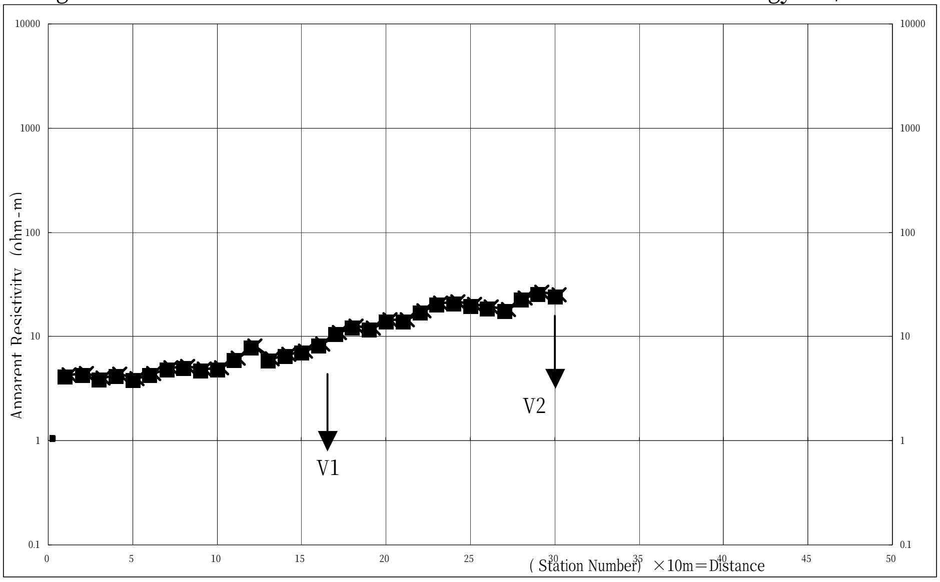


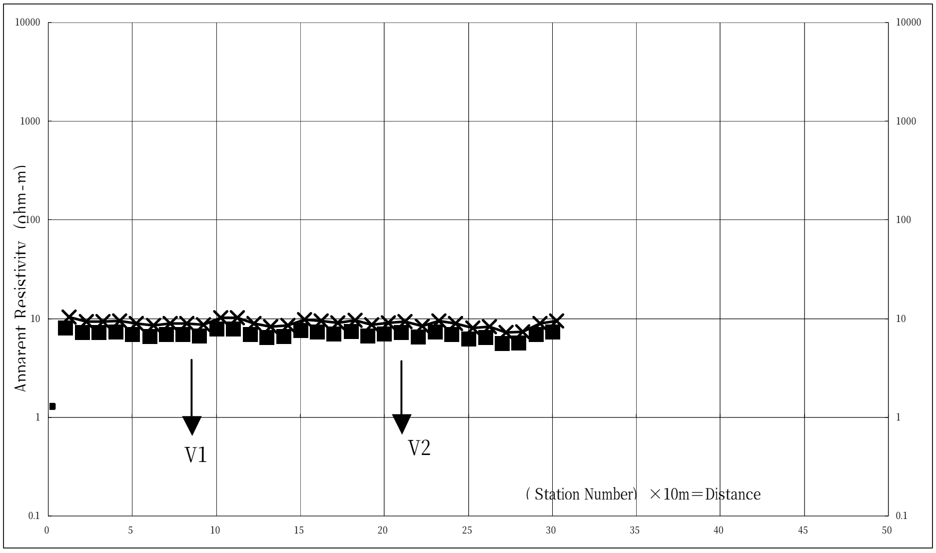
Fig. 3.2.1.24 Result of Horizontal Electrical Profiling in Myothit T/S

No.2 village

11. Yezagyo T/S



No.3 village



No.4 village

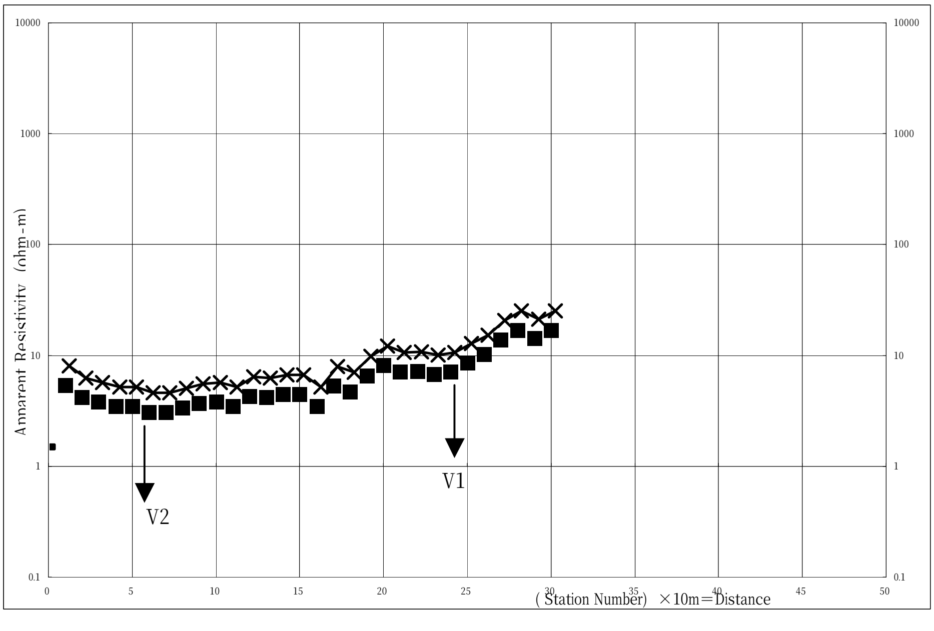


Fig. 3.2.1.25 Result of Horizontal Electrical Profiling in Yezagyo T/S

Table 3.2.1.3 Geophysical survey result (1/4)

T/S	Code			Village		Latitude		Longitude		Elevation	Result	Estimsted Aquifer			
				Tract	Name	°	’	°	’	(m)		D (m)	(Ωm)	D (m)	(Ωm)
Taungtha T/S	C1	1	V1	Magyipinte	Pegingyaw	21	18.508	95	30.508	183	C	2-6	11	Low resistyvity Saline water	
		1	V2				18.554		30.143	180	C	>68	10		
		2	**V1**	**Zagyan**	**Kanthonesint**	21	15.340	95	16.534	204	A	19-56	21	>56	21
		2	**V2**				15.350		16.814	202	A	1-10	25	>95	25
		3	**V1**	**Zagyan**	**Tabaukkon**	21	15.151	95	14.454	231	A	25-142	72	>142	45
		3	**V2**				15.178		14.573	228	A	81-148	30	>148	73
		4	V1	Aungtha	Aungtha	21	14.186	95	30.051	223	B	83-170	17		
		4	V2				14.105		30.104	218	B	25-111	16		
		5	V1	Thaputsu	Dahatan	21	12.401	95	21.624	165	B	17-63	14.5	>107	18
		5	V2				12.440		21.540	158	B	57-171	18		
		6	**V1**	**Chaukgwa**	**Twinbye**	21	12.048	95	17.075	178	A	48-82	57	>103	37
		6	**V2**				12.117		17.074	244	A	29-57	42	107-224	38
		7	V1	Thaputsu	Kyaukpon	21	11.794	95	23.224	154	B	11-22	15	>148	14
		7	V2				11.792		23.069	167	C	8-99	16		
		8	V1	Simigan	Thazi	21	11.727	95	25.815	155	C	Very low resistyvity Salinewater			
		8	V2				11.658		25.826	130	C				
		9	V1	Panpaung	Magyigon	21	10.034	95	29.228	207	C	>210	13	Low resistyvity	
		9	V2				10.103		29.225	215	C	49-98	13	Saline water	
		10	V1	Magincho	Sizongon	21	9.808	95	28.710	199	B	9-20	30	>60, 128	16, 29
		10	V2				9.906		28.661	191	B	12-32	30	>95, 194	14, 23

Kyawkpadaung T/S	C2	1	V1	Gwaydau-kkone	Gwaydau-kkone	21	0.537	95	13.411	75	A	All layer	15-59	(104-117	29)
		1	V2				0.545		13.379	76	A	All layer	19-56	(23-71	28)
		2	V1	Popa	Chaungbya	20	54.721	95	10.623	176	B	28-74	22-37	>193	18
		2	V2				54.727		10.600	378	A	3-117	21-35	>189	35
		3	**V1**	**Tangakan**	**Tangakan**	20	52.329	95	6.619	422	A	3-43	25	65-145	24
		3	**V2**				52.321		6.692	414	B	11-24	21	55-112	19
		4	**V1**		**Htantaw-gyi**	20	51.542	95	7.079	413	A	All layer	15-50		
		4	**V2**				51.526		7.191	413	A	0-22	32-51	47-120	24
		5	V1	Kanbauk	Kanbauk	20	50.401	95	10.408	379	A	>18m All layer 19-49Ωm			
		5	V2				50.347		10.492	346	A	>17m All layer 16-47Ωm			
		6	**V1**	**Simdaikan**	**Sudat**	20	49.868	95	6.280	384	B	14-54	78	>166	13
		6	**V2**				50.004		6.286	395	A	15-19	43	59-188	32
		7	**V1**	**Simdaikan**	**Sagyaw**	20	49.780	95	4.511	377	A	All layer	16-130		
		7	**V2**				49.771		4.513	361	B	2-12	43	>201	60
		8	V1	Sonywa	Kanyai & Salindau	20	46.590	95	6.631	318	B	55-104	16	>270	16
		8	V2				46.575		6.703	336	A	1-24	30	143-212	30
		9	V1	Twinphyu	Inbingyi	20	44.782	95	5.762	290	A	35-88	51	88-111	32
		9	V2				44.809		5.682	288	B	34-91	66	91-126	25
		10	V1	Kyauksayitkan	Lwinpinkone	20	43.268	95	8.835	275	B	26-76	50	76-99	20
		10	V2				43.265		8.900	277	B	4-22	24	83-102	20

Natogyi T/S	C3	**1**	**V1**	**Pegyet**	**Pegyet-W**	21	28.710	95	45.161	241	B	60-80	14	>151	22
		1	**V2**				28.722		45.133	241	B	41-98	15	>164	22
		2	V1	Thaminbe	Buthigyin	21	27.038	95	39.008	241	B	20-24	14	67-138	17
		2	V2				26.974		39.036	240	C	23-24	16		
		3	V1	Mogan	Mogan W	21	26.049	95	37.811	208	B	5-56	22-26	63-125	23
		3	V2				26.123		37.908	197	B	13-57	21	122-276	27
		4	**V1**	**Thangwa**	**Thangwa**	21	26.038	95	43.252	205	B	0-6	19	27-60	17
		4	**V2**				26.038		43.171	246	B	1-5	32	20-83	16
		5	V1	Gwegon	Thapandaw	21	22.428	95	32.000	220	B	16-47	16	108-130	30
		5	V2				25.274		33.955	220	B	>96	17		
		6	V1	Letwe	Letwe	21	25.001	95	30.308	170	B	23-60	14		
		6	V2				25.005		30.642	176	B	14-99	15		
		7	V1	Nyaungon	Nyaungon	21	24.063	95	37.580	210	B	39-160	16		
		7	V2				24.046		37.631	219	C	45-52	16		
		8	V1	Pyayachaung	Thintabaw	21	23.304	95	33.176	189	C	>5	11	Low resistyvity	
		8	V2				23.282		33.263	193	B	>28	13	Saline water	
		9	V1	Ketlan	Ketlan	21	23.030	95	48.552	203	C	Low resistivity		Saline water	
		9	V2				23.115		48.568	210	B	47-60	19		
		10	V1	Yongon	Aungthar	21	22.577	95	38.307	248	B	117-213	17		
		10	V2				22.392		38.356	218	C	10-26	12	Saline water	

Table 3.2.1.3 Geophysical survey result (2/4)

T/S	Code			Village		Latitude		Longitude		Elevation	Result	Estimsted Aquifer			
				Tract	Name	°	’	°	’	(m)		D (m)	(Ωm)	D (m)	(Ωm)
Nyang-U T/S	C4	**1**	**V1**	**Kantharyar**	**Kantharyar**	21	10.409	95	3.921	205	A	>136	47		
		1	**V2**				10.363		3.887	215	A	92-116	42	>194	51
		2	**V1**	**Kuywa**	**Kuywa**	21	6.821	94	58.888	224	A	34-102	25		
		2	**V2**				6.828		58.814	231	A	8-77	40	80-105	20
		3	V1	Phalankan	Phalankan	21	4.078	95	9.268	383	A	All layer	18-105	(>184	18)
		3	V2				4.076		9.328	381	A	All layer	18-120	(>189	18)
		4	**V1**	**Setsetyo**	**Setsetyo**	21	2.946	95	8.029	426	A	>17 All layer		(>198	32)
		4	**V2**				2.917		8.049	430	A	>8 All layer		(>170	34)
		5	V1	Letwae	Kangyikon N	21	2.978	94	57.412	210	B	32-47	31	>157	63
		5	V2				3.022		57.417	219	A	6-27	39	>245	46
		6	V1	Letwae	Kangyikon S	21	2.462	94	57.619	232	B	65-107	48	>226	28
		6	V2				2.604		57.583	240	B	70-89	45	>248	28
		7	**V1**	**Taungzin**	**Kaungpinsi**	21	1.151	95	1.329	330	B	53-115	26	>245	19
		7	**V2**				1.233		1.323	321	A	7-50	26-30	50-165	17
		8	**V1**	**Setsetyo**	**Myetkha-taw**	21	1.230	95	7.590	487	A	29-154	58	>157	17
		8	**V2**				1.340		7.641	488	A	All layer	18-81	(97-159	29)
		9	V1		Ywalu	20	59.766	95	5.762	445	A	80-123	46	>193	32
		9	V2				59.726		5.731	434	B	>116	15		
		10	V1	Zedae	Htanaungwin	20	59.071	95	1.673	349	B	58-121	43	121-141	17
		10	V2				59.125		1.668	335	B	41-89	21	89-167	53

Pyawbwe T/S	C5	**1**	**V1**	**Thabyeyo**	**Thabyeyo**	20	41.555	96	1.870	187	B	>193	13	low resistyvity Salinewater	
		1	**V2**				41.727		1.942	244	C	>256	11		
		2	**V1**	**Osanwa**	**Yonbingon**	20	39.837	96	7.532	169	B	>208	16		
		2	**V2**				39.998		7.530	176	C	>221	17		
		3	V1	Faungtan	Yebyu	20	39.737	96	13.620	227	B	100-105	10	Igneous rock area?	
		3	V2				39.716		13.577	244	B	20-38	170		
		4	V1	Faungtan	Paukain-gyo	20	38.150	96	13.824	224	A	All layer	16-49	(80-207	21)
		4	V2				38.124		13.787	213	A	All layer	17-60	(105-215	27)
		5	V1	Kyette	Kyette	20	37.874	96	5.434	184	B	77-189	14	>180	50
		5	V2				37.923		5.343	160	C	102-180	12	low resistyvity	
		6	V1	Kongtha	Thabok	20	37.757	96	14.157	165	A	16-34	35	70-148	71
		6	V2				37.234		14.219	165	B	>58	1190	Igeneous rock?	
		7	V1	Magyigon	Magyigon	20	36.347	95	52.179	274	C	7-137	13	Saline water?	
		7	V2				36.317		52.134	262	B	>98	14		
		8	V1	Sabaegon	Pegan N	20	31.624	95	56.148	301	C	>216	12		
		8	V2				31.536		56.156	244	B	135-281	15		
		9	V1	Sabaegon	Pegan S	20	31.447	95	56.111	251	C	>80	13		
		9	V2				31.566		56.077	263	B	>90	13		
		10	V1	Sabaegon	Nyandaw	20	31.345	95	52.367	287	C	>121	11		
		10	V2				31.329		52.446	294	B	90-124	20	>166	14

Myingyang T/S	C6	**1**	**V1**	**Pyawt**	**Chinmyi-kyin**	21	38.392	95	31.946	182	B	102-170	21	>241	15
		1	**V2**				38.381		31.891	180	A	88-173	34	>173	16
		2	**V1**	**Ywatha**	**Ywatha**	21	37.853	95	28.588	131	C	5-9	19	low resistivity	
		2	**V2**				37.845		28.664	138	B	2-23	10	49-97	12
		3	V1	Koke	koke	21	35.884	95	31.020	155	C	2-5	15	low resistivity	
		3	V2				35.940		30.993	154	B	>163	15		
		4	V1	Koke	Ywathaya	21	35.418	95	31.029	150	B	3-9	15	>150	14
		4	V2				35.491		31.016	152	B	2-7	14	>194	12
		5	V1	Taywinbo	Kyaungbyugan	21	32.225	95	26.417	92	B	10-21	15	>159	19
		5	V2				32.226		26.509	99	C	4-11	43	low resistivity	
		6	V1	Pya	Pya	21	30.351	95	35.247	186	B	6-42	17	68-166	18
		6	V2				30.361		35.325	185	B	4-10	18	23-71	25
		7	V1	Kuywa	Kuywa	21	24.312	95	24.775	109	B	>167	18		
		7	V2				24.309		24.824	116	C	Very low resistivity			
		8	V1	Saka	Saka	21	23.473	95	23.036	99	B	>214	16		
		8	V2				23.581		23.016	75	B	>221	16		
		9	V1	Gwebinyo	Gwebinyo	21	22.499	95	25.775	164	B	25-39	40	104-224	53
		9	V2				22.464		25.662	160	A	14-32	26	96-242	59
		10	V1	Gwebinyo	Taungshe	21	22.002	95	26.300	179	B	1-26	53	>26	12
		10	V2				21.984		26.230	183	B	3-14	88	97-116	30

Table 3.2.1.3 Geophysical survey result (3/4)

T/S	Code			Village		Latitude		Longitude		Elevation	Result	Estimsted Aquifer			
				Tract	Name	°	’	°	’	(m)		D (m)	(Ωm)	D (m)	(Ωm)
Chauk T/S	C7	1	V1	Gwegyo	Sharbin	20	47.803	95	1.051	307	B	1-9	27	>56	12
		1	V2				47.727		1.110	310	C	1-6	13	>101	12
		2	V1	Thittogan	Sudat	20	47.450	95	0.111	76	B	4-15	23-51	72-229	20
		2	V2				47.492		0.160	75	C	2-8	43-70	33-83	14
		3	**V1**	**Thittogan**	**Sangan**	20	46.432	94	58.805	280	B	4-68	48	>185	17
		3	**V2**				46.479		58.813	278	A	7-70	27	70-178	50
		4	V1	Thalonthwe	Pyaywa	20	46.318	94	54.168	191	B	2-8	52	>30	57
		4	V2				46.370		54.183	192	B	65-71	92	>153	100
		5	V1	Kywedat	Kywedatywama	20	45.732	94	58.310	253	B	6-16	16	>193	16
		5	V2				45.639		58.253	248	A	39-77	26	>180	16
		6	V1	Suyitkan	Kyeiksu S	20	42.943	94	47.464	198	B	12-15	15	37-95	17
		6	V2				42.935		47.556	176	C	3-6	30	46-74	16
		7	V1	Swebaukkan	Zigyobin S	20	40.525	94	59.810	417	B	85-173	80	183-266	88
		7	V2				40.508		59.964	403	B	24-59	61	>184	58
		8	**V1**	**Wetthesan**	**Thayetpin**	20	40.345	94	57.364	370	B	6-11	20	>253	17
		8	**V2**				40.451		57.401	414	B	7-63	46	>272	17
		9	V1	Swebaukkan	Yela	20	39.934	95	0.510	373	A	36-146	77	146-188	38
		9	V2				39.910		0.571	372	A	33-84	75	84-168	18
		10	V1	Thanbo	Kyauktaing	20	36.304	94	56.472	304	B	>7	370	high resistivity	
		10	V2				36.337		56.564	287	B	0.4-21	29		
Magway T/S	C8	**1**	**V1**	**Kanthagyi**	**Kanthagale**	20	13.697	95	0.797	187	A	115-210	74	>210	29
		1	**V2**				13.794		0.671	185	A	56-92	34	114-172	46
		2	V1	Kyitsonbwe	Kyitsonbwe	20	11.291	95	5.162	234	B	121-211	45		
		2	V2				11.323		5.062	236	A	102-255	43		
		3	V1	Payapyo	Payapyo N	20	10.325	95	1.470	193	B	>156	50		
		3	V2				10.281		1.548	200	A	14-29	73	>142	61
		4	V1	Thabyesen	Minwa S	20	9.118	95	3.458	197	A	147-253	59	>253	33
		4	V2				9.130		3.911	197	A	90-156	24	156-272	64
		5	V1	Thabyesen	Thabyesen N	20	7.961	95	1.924	159	B	127-181	41	>181	14.8
		5	V2				7.931		1.817	117	A	141-272	45	>271	19
		6	V1	Leya	Taungyartaw	20	1.435	95	13.550	141	B	17-55	47	55-92	16
		6	V2				1.622		13.058	144	B	37-72	34	>72	14
		7	V1	Papaesan	Ywataw	19	59.589	95	10.160	200	B	18-43	27	100-131	27
		7	V2				59.586		10.216	179	A	55-108	30	142-230	19
		8	V1	Kunon	Yonekone	19	55.998	95	8.022	128	A	21-32	17	69-176	27
		8	V2				55.963		8.129	122	B	15-50	25	79-115	25
		9	**V1**	**Alebo**	**Inbinkan**	19	54.007	95	15.079	193	A	104-120	39	120-187	16
		9	**V2**				54.086		15.066	197	B	113-145	40	145-194	18
		10	V1	Alebo	Ywakuit-san	19	53.809	95	17.368	202	A	46-69	45	69-100	18
		10	V2				53.841		17.356	195	B	57-161	60	>161	19
Pakokku T/S	C9	1	V1	Padaing-chone	Myauklu-kan	21	24.794	95	5.909	115	A	24-41	36	91-142	31
		1	V2				24.721		5.860	129	B	6-18	23	99-205	12
		2	V1	Magyitho-nepin	Magyitho-nepin		24.615	94	44.563	258	A	35-113	38	113-130	17
		2	V2				24.548		44.458	257	A	33-100	16	100-225	57
		3	V1	**Kyathto**	Kyauksayit-kan		23.819		56.583	175	A	21-236	61	>236	32
		3	V2				23.839		56.575	181	B	102-212	66	>212	31
		4	**V1**		**Anaukpone-kan**		23.292		58.212	156	A	54-237	67	>237	25
		4	**V2**				23.330	94	58.233	151	A	54-60	31	60-200	68
		5	V1		Chaukkan -W		21.432	95	2.437	120	B	38-49	22	49-237	19
		5	V2				21.701		2.522	117	A	24-98	58	98-126	31
		6	V1	Kyathto	Kyathtoe		19.433	94	49.889	131	B	3-8	17	>157	12
		6	V2				19.580		49.880	129	B	29-60	16	>160	12
		7	**V1**	**Palan-O**	**Palan-O**		18.896		52.116	111	A	40-51	43	74-226	98
		7	**V2**				18.888		52.192	115	B	49-61	79	66-250	93
		8	V1	Sabae	Sarkyin		18.186		47.188	134	B	37-45	57	93-184	62
		8	V2				18.113		47.191	134	B	58-125	55	126-235	15
		9	V1	Palan-O	Kanpauksu		18.005		52.202	111	B	47-58	41	58-242	12
		9	V2				18.027		52.358	114	A	24-138	56	138-212	18
		10	V1	Sabae	Sabae W		16.884		48.088	122	B	72-130	55		
		10	V2			21	16.873	94	48.166	113	B	70-195	41		

Table 3.2.1.3 Geophysical survey result (4/4)

T/S	Code			Village		Latitude		Longitude		Elevation	Result	Estimsted Aquifer			
				Tract	Name	°	’	°	’	(m)		D (m)	(Ωm)	D (m)	(Ωm)
Myothit T/S	C10	1	V1	Ledaing-zin	Thamya	20	15.271	95	15.656	225	A	129-199	30	>199	18
		1	V2				15.301		15.560	233	A	133-183	27	>183	17
		2	V1	Ledaing-zin	Ledaing-zin N&S	20	11.928	95	13.783	161	A	98-197	33	>197	45
		2	V2				11.912		13.819	160	A	108-207	31	>207	46
		3	V1	Yebye	Natkan	20	10.216	95	16.495	163	A	80-132	25		
		3	V2				10.237		16.496	163	B	88-122	34		
		4	**V1**	**Ledaing-zin**	**Aung-myinthar**	20	10.216	95	13.496	163	A	54-179	23		
		4	**V2**				10.036		13.903	163	B	32-63	56	63-133	19
		5	V1	Ledaing-zin	Pogyi	20	9.579	95	13.740	161	A	83-115	20	>122	18
		5	V2				9.631		13.721	166	B	72-123	21		
		6	**V1**	**Yondaw**	**Myinsu**	20	8.063	95	15.379	191	A	69-141	23	>141	73
		6	**V2**				8.056		15.290	186	A	76-158	30	>158	60
		7	V1	Gwegyo	Gwegyo - W	20	7.276	95	19.793	137	B	149-270	23		
		7	V2				7.236		18.790	137	B	40-88	35		
		8	V1	Yondaw	Yondaw	20	6.924	95	15.806	149	A	70-217	22		
		8	V2				6.923		15.861	165	B	59-86	65	86-231	16
		9	V1	Wagyiaing	Wagyiaing	20	5.246	95	14.685	117	B	>4	>4000		
		9	V2				5.219		14.661	117	A	14-70	30	>159	21
		10	V1	Wagyiaing	Ngwelay	20	4.958	95	17.130	137	B	52-117	21	>151	14
		10	V2				4.881		17.091	142	A	46-81	69	81-146	26

Yezagyo T/S	C1	1	V1	Pyiba	Byiba	21	49.009	95	6.145	99	C	Very low resistyvity Salinewater			
		1	V2				49.003		6.232	100	C				
		2	**V1**	**Thitkyi-daw**	**Thitkyi-daw**		48.106		7.753	109	B	43-53	14	100-141	16
		2	**V2**				48.035		7.792	105	B	1-26	38		
		3	**V1**	**Wetk-daw**	**Thitkau-kseik**		47.331		8.595	89	B	6-15	20	15-52	14.7
		3	**V2**				47.322		8.524	92	C	36-168	11		
		4	**V1**	**Zedaw**	**Seywa**		40.954		10.706	96	B	9-24	15	95-215	13
		4	**V2**				41.108		10.822	95	C	28-85	18	85-152	12
		5	V1	Salingon	Sattwa		39.259		6.759	124	C	22-62	17		
		5	V2				39.371		6.736	123	B	78-252	13	>252	19.5
		6	V1	Kyaukka	Chinya-gone		34.823		8.725	145	B	10-17	37	49-234	19
		6	V2				34.931		8.667	143	B	51-212	74		
		7	V1	Kyaukka	kyaukka		34.921		8.725	142	C	99-147	16		
		7	V2				34.920		8.779	142	B	39-66	15.5		
		8	V1	Kyaukka	Kyauk-taga		33.899		9.038	109	B	107-176	15.1		
		8	V2				33.956		8.997	104	B	25-88	22	105-112	19.8
		9	V1	Tange-daw	Zidaw		28.054		6.953	134	C	8-22	35		
		9	V2				28.076		6.923	126	C	12-35	15.6		
		10	V1	Tange-daw	Kunthi-gan		26.452		5.709	168	C	19-59	11		
		10	V2			21	26.473	95	5.704	148	B	51-68	30	109-129	19.6

Tab. 3.2.1.4 Evaluation of the Geophysical Survey Result and Accessibility to the Well Site

Township	No.	Village	Rank evaluated	Remark
1 Taungtha	**2**	Kanthonesint	A, A	Difficult accessibility
	3	Tabaukkon	A, A	
	6	Twinbye	A, A	
2 Kyawkpadaung	1	Gwaydauk-kone	A, A	
	4	Htantaw-gyi	A, A	
	5	Kanbauk	A, A	
3 Natogyi	1	Pegyet W	B, B	
	3	Mogan W	B, B	Pegu Group area
4 Nyang-U	1	Kanthar-yar	A, A	
	2	Kuywa	A, A	
	3	Phalankan	A, A	
	4	Setsetyo	A, A	
	8	Myetkha-taw	A, A	
5 Pyawbwe	4	Paukaingyo	A, A	Difficult accessibility
	6	Thabok	A, B	Difficult accessibility
6 Myingyang	1	Chinmyi-kyin	A, B	Pegu Group area
	6	Pya	B, B	
	9	Gwebinyo	A, B	Pegu Group area
7 Chauk	3	Sangan	A, B	
	5	Kywedatywama	A, B	
	9	Yela	A, A	
8 Magway	1	Kanthagale	A, A	
	4	Minwa S	A, A	
9 Pakokku	2	Magyitonepin	A, A	
	4	Anaukponekan	A, A	
10 Myothit	1	Thamya	A, A	
	2	Ledaingzin N & S	A, A	
	6	Myinsu	A, A	
11 Yesagyo	4	Seywa	B, C	
	6	Chinyagone	B, B	Pegu Group area
	8	Kyauktaga	B, B	Pegu Group area

3.2.2 Test Well Construction

(1) Site Selection

Procedure of site selection for the test wells has been described already in "2.3.2 Selection of 22 Tube Well Construction Site"

Twenty-two tube wells (two wells per Township) with total drilling depth of 4,640 m were planned as presented on Table 3.2.2.1.

(2) Drilling

Drilling work of the test wells, pumping tests, and water quality tests in laboratory were carried out at the sites selected through the procedure described above.

Drilling work were conducted by a newly procured drilling machine and the 3 (three) existing drilling machines, which have been provided by DDA and repaired in Phase I Study. The existing 3(three) machines had been also procured through a grant aid project of the Government of Japan in 1983. List of the drilling machines used in this Project is as follows,

No.	Model	Year	Remarks
1	TDR-300	1983	Existing
2	TDR-300	1983	Existing
3	TDR-300	1983	Existing
4	TOP-500	2001	Newly Procured

Immediately after drilling work completed, electrical logging, gamma logging and spontaneous potential logging were carried out in order to determine the suitable installation positions of screen.

List of the test wells is presented on Table 3.2.2.1. Standard casing program of the test well is shown in Fig.3.2.2.1 and geological log of every test well together with other logging data are shown in 3-F "Well Log" of Vol. III, Supporting Report.

Finally, 23 tube wells with total depth of 4,945 m were drilled.

At Aungthar in Natogyi Township, two shallow tube wells were drilled to check comparatively shallow aquifer (depth of 60 to 70 m) and at Thayetpin in Chauk Township, a very deep tube well (depth of 412 m) was drilled to check deep aquifer.

Table 3.2.2.1 List of Test Wells in The Central Dry Zone

NO	Division	Township	Village Tract	Village	Drilling Depth (m)		Ground Elevation (m)1)	Road Repairing	Machine Type	Static Water Level (m)	Depth of Casing Bottom (m)	Screen Depth Top - Bottom (Total Length) (m)	Pumping Test		Water Quality
					Planned	Actual							Sc2)	T3)	
1	Mandalay	(1) Taungtha	Zagyan	Kanthonesint	200	200	203	○	TDR-300A	130.60	199.00	154.97 - 193.45 (38.48)	4.0+	—	High iron content
2			Zagyan	Tabaukkon	200	200	230		TDR-300A	149.00	198.00	152.50 - 194.50 (42.00)	0.4	8.59 x 10-5	High iron content
3		(2) Kyauk- padaung	Gwaydaukkone	Gwaydaukkone	200	205	376	○	TDR-300B	159.00	202.50	105.19 - 180.30 (47.36)	2.7	5.66 x 10-5	High iron content
4			Simdaikaun	Sudat	200	194	390		TDR-300B	121.00	193.00	136.50 - 188.50 (30.00)	1.6	1.73 x 10-4	High TDS and iron content
5		(3) Nathogi	Pegyet	Pegyet W	250	300	241		TOP-500	24.00	300.00	230.50 - 294.50 (47.50)	0.4	1.89 x 10-4	High iron content
6-1			Yongon	Aungthar-1	70	72	233		TDR-300C	15.00	70.00	35.22 - 64.50 (23.78)	0.01	1.06 x 10-5	High TDS and iron content
6-2			Yongon	Aungthar-2	60	60	233		TDR-300C	21.00	62.23	27.45 - 56.68 (23.68)	0.01	9.32 x 10-6	High TDS, TH, Mg, Cl, SO4 and iron content
7		(4) Nyaung U	Letwar	Kangyikon(N)	300	310	215		TOP-500	—	—	—	—	—	
8			Zedae	Htanaungwin	150	168	342		TDR-300C	99.00	168.00	64.98 - 156.90 (47.52)	0.4	7.14 x 10-4	High Ca, iron and TH content
9		(5) Pyawbwe	Thabyeyo	Thabyeyo	200	201	216	○	TDR-300B	24.00	199.00	137.8 - 193.45 (44.55)	0.005	—	High iron content
10			Osanwe	Yonbingon	200	201	173	○	TDR-300B	Artesian	199.50	134.90 - 194.00 (53.50)	4.4+	—	Chemically potable
11		(6) Myingyan	Koke	Koke	200	204	155		TDR-300C	14.00	199.00	51.58 - 187.90 (47.52)	0.2	1.33 x 10-4	High TDS and iron content
12			Saka	Saka	250	303	87		TOP-500	46.00	303.00	250.32 - 297.45 (41.58)	1.3	1.76 x 10-3	High TDS, TH and iron content
13	Magway	(7) Chauk	Thittogan	Sangan	250	302	279	○	TOP-500	180.00	300.00	223.00 - 294.50 (48.00)	1.5	2.39 x 10-4	High iron content
14			Wetthesan	Thayetpin	300	412	392	○	TOP-500	166.00	412.00	365.00 —406.50 (36.00)	0.2	6.75 x 10-5	
15		(8) Magway	Kanthagyi	Kanthagale	200	201	186		TDR-300A	107.00	200.00	130.67 - 194.45 (47.13)	5.3	1.05 x 10-3	Chemically potable
16			Kyitsonbwe	Kyitsonbwe	200	200	235		TDR-300A	163.00	200.00	88.84 - 188.90 (44.61)	0.5	1.99 x 10-4	Slightly high iron content
17		(9) Pakokku	Magyithonepin	Magyithonepin	210	201	258		TDR-300B	194.00	200.00	132.25 - 194.45 (45.55)	0.04	—	
18			Kyathto	Anaukponekan	200	201	169		TOP-500	96.00	200.00	133.25 - 194.45 (44.10)	0.3	6.23 x 10-5	High iron content
19		(10) Myothit	Ledaingzin	Thamyu	200	204	229	○	TDR-300C	122.00	203.00	141.80 - 197.50 (44.64)	1.1	3.53 x 10-4	Slightly high iron content
20			Ledaingzin	Ledaingzin N& S	200	204	161		TDR-300C	69.60	203.00	119.60 - 197.45 (44.79)	2.6	2.24 x 10-4	High iron content
21		(11) Yesagyo	Thitkyidaw	Thitkyidaw	200	201	107	○	TDR-300C	15.70	200.00	122.15 - 188.90 (44.55)	2.0	2.49 x 10-4	High TDS and iron content
22			Zedaw	Seywa	200	201	96		TDR-300A	25.10	200.00	112.15 - 194.45 (54.58)	40.4	—	Slightly high TDS and high iron content
				Total	4,640	4,945									

1):by GPS 2)Sc:Specific Capacity (lit/sec/m) at the continuous test 3)T:Transmissivity (m^2/sec)

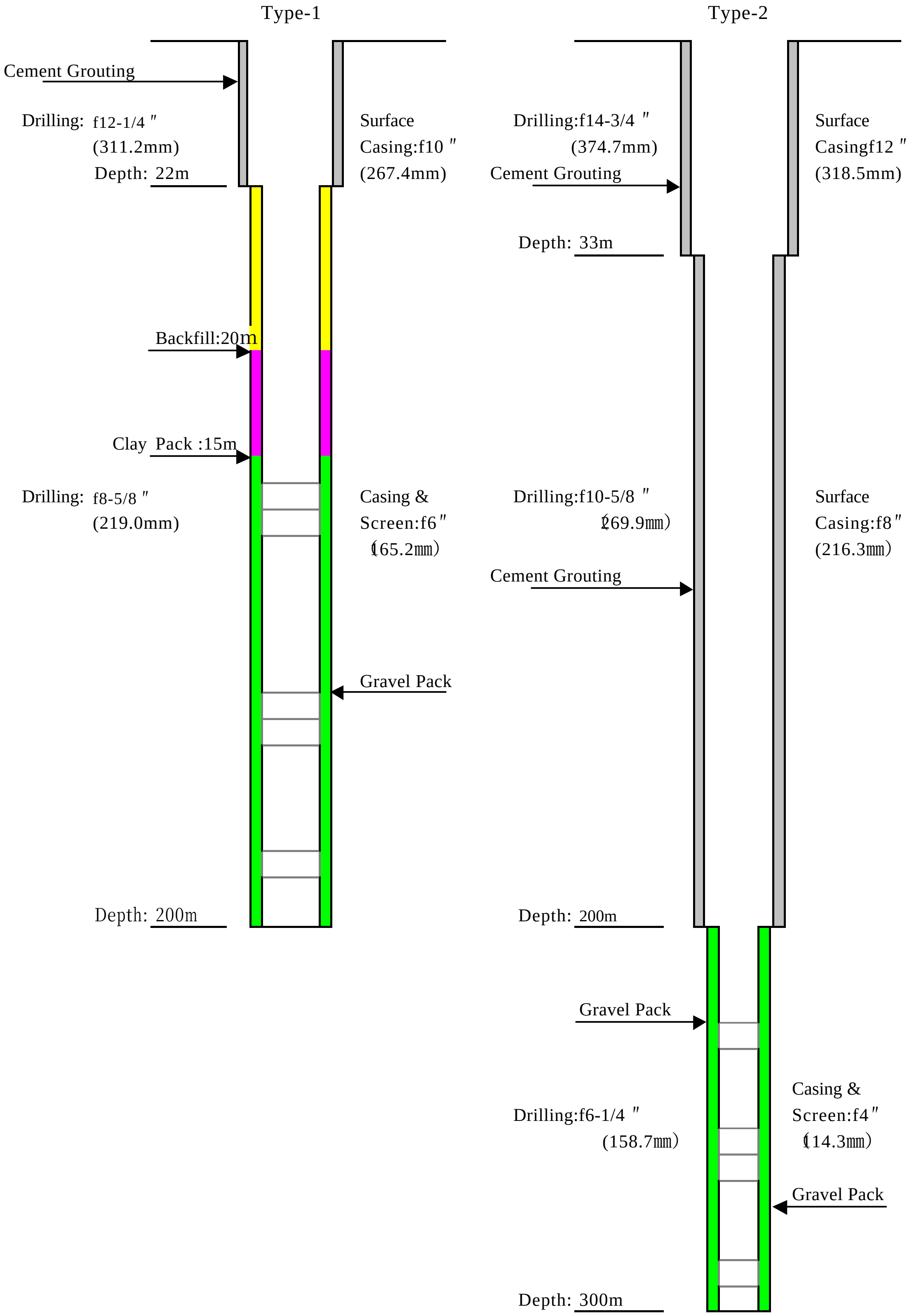


Fig. 3.2.2.1 Standard Design of the Test Well

At Kangyinkon(N) in Nyaung U Township, casings had been installed until 200 m deep, however, for the deeper until 310m deep, bottom of the well, casings and screens have not been installed because the aquifer could not be confirmed.

At Sangan in Chauk, the loss of circulation drilling mud had occurred at around the depth of 106 m and 158 m and the cement grouting was carried out to protect the loss of circulation mud. At the depth of 192 m, drill bit and stabilizer were jammed by the collapsed earth and sand from the cement grouting places described above. As it was very hard to recover the jammed drill bit and stabilizer, another new well was drilled at near the original place.

The progress of the drilling of the test wells is shown in Fig. 3.2.2.2.

(3) Pumping Test

Pumping tests were carried out at the drilled test wells except for some wells. Only continuous pumping test was carried out because of the prepared pump capacity.

Results of the pumping tests are presented on Table 3.2.2.2. Calculations of hydrogeological constant (Transmissivity) by Theis method and pumping test sheets were presented in 3-G "Pumping Test Sheet" of Vol. III, Supporting Report.

At Kangyinkon (N) in Nyaung U Township, pumping test could not be performed due to no water. At Kanthonesient in Taugthar Township, Yonbingon in Pyawbwe and Seywa in Yesagyo, calculations of hydrogeological constant were impossible due to no or too little drawdown with full capacity of the prepared pump. At Thabyeyo in Pyawbwe Township and Magyithonepin in Pakkoku, continuous pumping test could not be performed due to too much draw-down or too low (deep) water level.

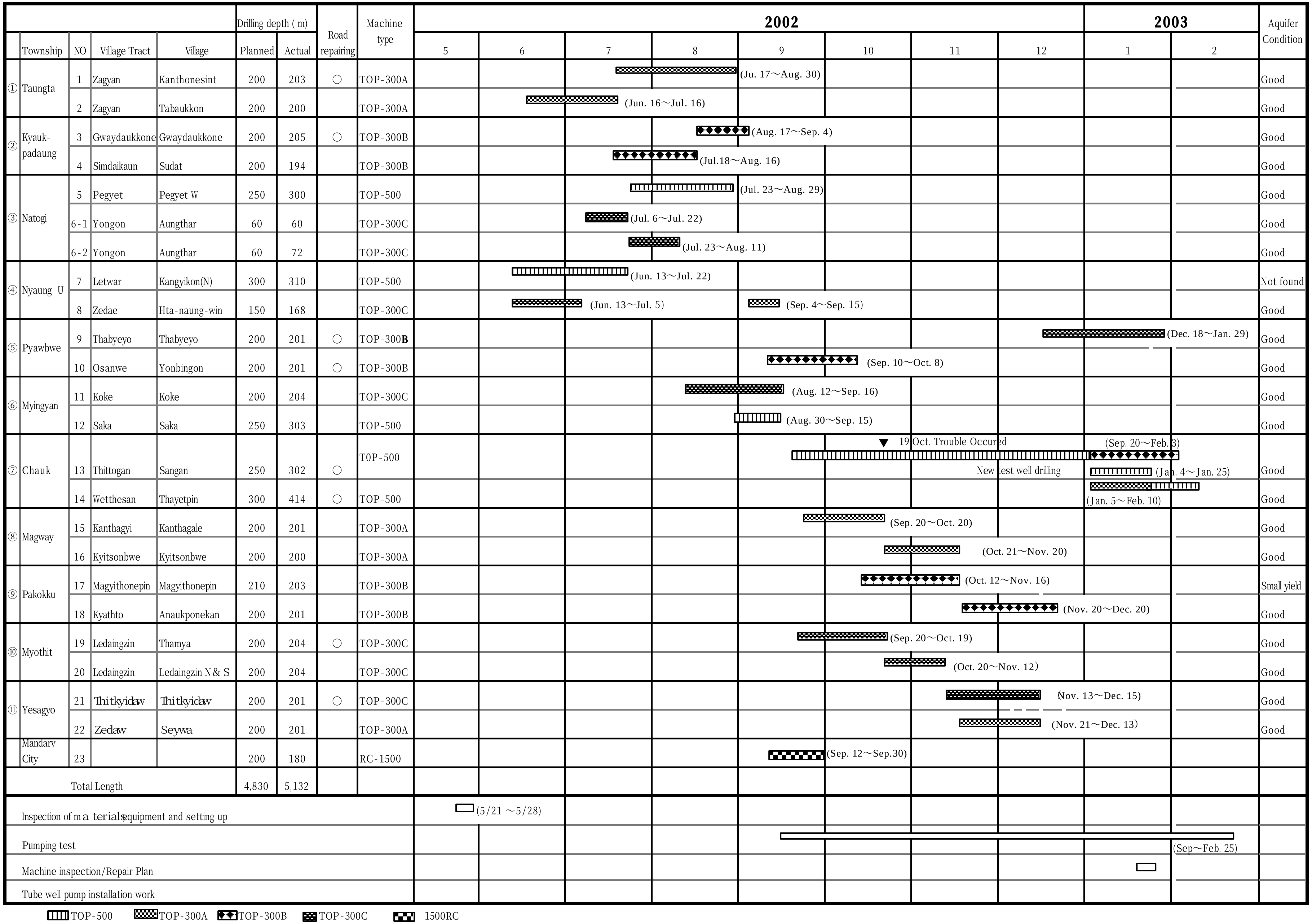
(4) Water Quality Test

Water samples were collected at the final stage of the continuous pumping tests and water quality tests in laboratory were performed to the same samples.

Proposed National Drinking Water Quality Standards of Myanmar is presented in Table 3.2.2.3. Results of the water quality tests are shown in Table 3.2.2.4(1-2/2) and Table3.2.2.5.

At almost all test well sites, groundwater shows high TDS and/or high iron (Fe) like the monitoring wells. Furthermore, groundwater of the all test wells are plotted in the area (**III**) of the trilinear diagram (see "3.2.1 Hydrogeological Characteristics) as shown in Fig.3.2.2.3.

Fig. 3.2.2.2 Progress of Drilling Work in The Central Dry Zone



Township	NO	Village Tract	Village	Drilling depth (m) Planned	Drilling depth (m) Actual	Road repairing	Machine type	Aquifer Condition
① Taungta	1	Zagyan	Kanthonesint	200	203	○	TOP-300A	Good
	2	Zagyan	Tabaukkon	200	200		TOP-300A	Good
② Kyauk-padaung	3	Gwaydaukkone	Gwaydaukkone	200	205	○	TOP-300B	Good
	4	Simdaikaun	Sudat	200	194		TOP-300B	Good
③ Natogi	5	Pegyet	Pegyet W	250	300		TOP-500	Good
	6-1	Yongon	Aungthar	60	60		TOP-300C	Good
	6-2	Yongon	Aungthar	60	72		TOP-300C	Good
④ Nyaung U	7	Letwar	Kangyikon(N)	300	310		TOP-500	Not found
	8	Zedae	Hta-naung-win	150	168		TOP-300C	Good
⑤ Pyawbwe	9	Thabyeyo	Thabyeyo	200	201	○	TOP-300**B**	Good
	10	Osanwe	Yonbingon	200	201	○	TOP-300B	Good
⑥ Myingyan	11	Koke	Koke	200	204		TOP-300C	Good
	12	Saka	Saka	250	303		TOP-500	Good
⑦ Chauk	13	Thittogan	Sangan	250	302	○	T0P-500	Good
	14	Wetthesan	Thayetpin	300	414	○	TOP-500	Good
⑧ Magway	15	Kanthagyi	Kanthagale	200	201		TOP-300A	Good
	16	Kyitsonbwe	Kyitsonbwe	200	200		TOP-300A	Good
⑨ Pakokku	17	Magyithonepin	Magyithonepin	210	203		TOP-300B	Small yield
	18	Kyathto	Anaukponekan	200	201		TOP-300B	Good
⑩ Myothit	19	Ledaingzin	Thamya	200	204	○	TOP-300C	Good
	20	Ledaingzin	Ledaingzin N& S	200	204		TOP-300C	Good
⑪ Yesagyo	21	Thitkyidaw	Thitkyidaw	200	201	○	TOP-300C	Good
	22	Zedaw	Seywa	200	201		TOP-300A	Good
Mandary City	23			200	180		RC-1500	
Total Length				4,830	5,132			
Inspection of materials equipment and setting up								
Pumping test								
Machine inspection/Repair Plan								
Tube well pump installation work								

Table 3.2.2.2 Results of Pumping Tests of Test Wells

No	Division	Township	Village Tract	Village	Drilling Depth (m)		Pumping Rate(l/min)	Static Water Level (m)	Dynamic Water Level(m)	Drawdown (m)	Specific Capacity (l/sec/m)	Transmissivity (m2/sec)	Temper-ature(℃)	PH	Remarks
					Planned	Actual									
1	Mandalay	(1) Taungtha	Zagyan	Kanthonesint	200	200	240	130.60	130.6	0.00	4.0+	—	34.6	7.85	No drawdown (pump capacity)
2			Zagyan	Tabaukkon	200	200	171.4	149.00	157	8.00	0.4	8.59 x 10-5	36	7.5	
3		(2) Kyauk-padaung	Gwaydaukkone	Gwaydaukkone	200	205	160	159.00	160	1.00	2.7	5.66 x 10-5	25	6.7	
4			Simdaikaun	Sudat	200	194	183	121.00	123	2.00	1.6	1.73 x 10-4	35.2	7.34	
5		(3) Natogyi	Pegyet	Pegyet W	250	300	571	24.00	46	22.00	0.4	1.89 x 10-4	36.8	7.01	
6-1			Yongon	Aungthar-1	70	72	24	15.00	56	41.00	0.01	1.06 x 10-5	29.7	8.42	
6-2			Yongon	Aungthar-2	60	60	20	21.00	50	29.00	0.01	9.32 x 10-6	26.2	7.6	
7		(4) Nyaung U	Letwar	Kangyikon(N)	300	310	—	—	—	—	—	—	—	—	No water
8			Zedae	Htanaungwin	150	168	240	99.00	110	11.00	0.4	7.14 x 10-4	32.8	7.22	
9		(5) Pyawbwe	Thabyeyo	Thabyeyo	200	201	15	24.00	72	48.00	0.005	—	—	—	No continuous test (too much drawdown)
10			Osanwe	Yonbingon	200	201	262	Artesian	Artesian	0.00	4.4+	—	28	7.55	No drawdown (pump capacity)
11		(6) Myingyan	Koke	Koke	200	204	400	14.00	56	42.00	0.2	1.33 x 10-4	30	7.95	
12			Saka	Saka	250	303	620	46.00	54	8.00	1.3	1.76 x 10-3	25	7.11	
13	Magway	(7) Chauk	Thittogan	Sangan	250	302	90	180.00	181	1.00	1.5	2.39 x 10-4	30	7.7	
14			Wetthesan	Thayetpin	300	412	106	166.00	176.50	10.50	0.2	6.75 x 10-5	30	7.15	
15		(8) Magway	Kanthagyi	Kanthagale	200	201	270	107.00	107.85	0.85	5.3	1.05 x 10-3	29.3	7.78	
16			Kyitsonbwe	Kyitsonbwe	200	200	48.7	163.00	164.8	1.80	0.5	1.99 x 10-4	30.2	9.02	
17		(9) Pakokku	Magyithonepin	Magyithonepin	210	201	5	194.00	196	2.00	0.04	—	—	—	No continuous test (too low (deep) water level)
18			Kyathto	Anaukponekan	200	201	270	96.00	110.02	14.02	0.3	6.23 x 10-5	26	7.6	
19		(10) Myothit	Ledaingzin	Thamyu	200	204	135	122.00	124	2.00	1.1	3.53 x 10-4	29.6	7.98	
20			Ledaingzin	Ledaingzin N& S	200	204	450	69.60	72.5	2.90	2.6	2.24 x 10-4	30.4	7.65	
21		(11) Yesagyo	Thitkyidaw	Thitkyidaw	200	201	799.9	15.70	22.4	6.70	2.0	2.49 x 10-4	28	7.8	
22			Zedaw	Seywa	200	201	727.2	25.10	25.4	0.30	40.4	—	39.3	8.15	Too little drawdown (pump capacity)
				Total	4,640	4,945									

Table3.2.2.3 Proposed National Drinking Water Quality Standards (NDWQS)

Microbiology

Type of Water and Source	Faecal Coliforms	Coliform Organisms (no./100ml)	Remarks
Treated Piped Water	0	0	
Untreated Piped Water	0	0	
Water Distribution Systen	0	0	
Unpiped Water Supplies	0	10	
Bottled Drinking Water	0	0	
Emergency Water Supplie	0	3	Chlorinated Supplies

Inorganic Substances

Constituents		Remarks
Arsenic(As)*	0.05 mg/l	*Tests for these substances will not be included in routine examination, except on special request In lieu of sufficient national rcords available at present, proposed standards for these parameters are adopted from the WHO-Guidelines for drinking water,1894. These values will be subject to revision whenever found necessary
Cadmium(Cd)*	0.005 mg/l	
Chromium(Cr)*	0.05 mg/l	
Cyanide(CN)*	0.05 mg/l	
Flouride(Fl)*	1.5 mg/l	
Lead(Pb)*	0.05 mg/l	
Mercury(Hg)*	0.001 mg/l	
Nitrate(as N)	10.0 mg/l	
Nitrite(as N)	0.5 mg/l	
Selenium(Se)*	0.01 mg/l	

Aesthentic Quality

Constituents		Remarks
Aluminium(Al)	0.2 mg/l	*Test for this substance will not be performed for routine test except on special request
Chloride(Cl)	200-600 mg/l	
Colour(TCU)	5.50 Pt-Co	
Copper(Cu)*	1.0 mg/l	
Hardness(as CaCO3)	500 mg/l	
Iron(Fe)	0.5-1.5 mg/l	
Manganese(Mn)	0.3 mg/l	
pH	6.5-9.2	
Sodium(Na)	200 mg/l	
Sulphate(SO4)	400 mg/l	
Taste & Odour	inoffensive mg/l	
TDS	1000 mg/l	
Turbidity(NTU)	20 mg/l	
Zinc(Zn)	5-15 mg/l	
Calcium(Ca)	75-200 mg/l	
Magnesium(Mg)	30-150 mg/l	
EC	1500 µS/cm	

Source; "Water Resources, Water Quality Standard and Groundwater Management in Myanmar"
Water Resources Utilization Department MOA & I

Table3.2.2.4.(1/2) Results of Water Quality Test of the Test Wells in the Central Dry Zone (WRUD)

Division	Township	No	Village Name	Sample No	Sampled Date	Analycis Date	Na $^+$	Ca $^{2+}$	Mg $^{2+}$	K$^+$	Fe $^{2+}$	Cl $^-$	SO$_4$ $^{2-}$	HCO$_3$ $^-$	CO$_3$$^{2-}$	Remarks	Appea-rance	Col-our	Smell	Sedin-ments	TDS	EC	pH	TH*	TA*
Madalay	Taungtha	1	Kanthonesint			27-12-02	68	120.25	35.88	5.26	2.00	135	207.64	106	ND	High Iron content	Clear		Nil		730		7.66	450	106
		2	Tabaukkon			27-12-02	59	85.77	38.32	6.57	2.00	194	84.96	74	ND	High Iron content	Clear		Nil		650		7.72	332	74
	Kyaukpadaung	1	Gwedaukkon			14-10-02	56	96.99	16.32	6.25	2.00	74	98.96	100	ND	High Iron content	Clear		Nil		455		6.67	3.10	100
		2	Sudat			06-12-02	123	131.46	28.20	13.15	2.00	231	224.60	250	ND	High Total Dissolved Solids and High Iron content	Clear		Nil		1650		7.66	446	250
	Natogyi	1	Pegyet W			28-10-02	86	73.42	22.20	4.41	3.00	193	166.60	64	ND	High Iron content	Clear		Nil		710		7.67	276	64
		2	Aungthar 1			12-12-02	185	133.86	291.72	9.86	6.00	891	875.16	152	ND	High Total Dissolved Solids, Total Hardness, Magnesium, Iron, Chlorride and Sulphate content	Turbid		Nil		3900		6.66	1550	152
		3	Aungthar 2			27-12-02	167	145.89	28.68	10.26	5.00	323	186.04	216	ND	High Total Dissolved Solids and High Iron content	Slightly Turbid		Nil		2600		6.76	484	216
	Nyaung U	1	Kangyikon (N)																						
		2	Htanaungwin			14-10-02	63	216.43	13.68	7.50	3.50	239	141.04	84	ND	High Iron, Calcium and Total Hardness content	Clear		Nil		770		6.76	598	84
	Pyawbwe	1	Thabyeyo			13-02-03	91	44.08	11.52	12.50	3.00	183	34.56	94	ND	High Iron content	Clear		Nil		790	1220	7.76	158	94
		2	Yonbingon			13-02-03	77	32.06	14.40	5.68	1.00	99	43.20	96	ND	Chemically Potable	Clear		Nil		480	750	6.66	140	96
	Myingyan	1	Koke			03-03-03	146	145.89	27.72	11.00	2.50	298	183.16	192	ND	High Tota Dissolved Solids and Iron content	Clear		Nil		1550	2400	6.77	480	192
		2	Saka			23-10-02	139	173.14	28.20	10.29	2.50	382	184.60	168	ND	High Total Dissolved Solids, Total Hardness and Iron	Clear		Nil		1980		7.76	550	168
Magway	Chauk	1	Sangan			20-03-03	51	133.86	22.44	5.88	2.50	297	67.32	84	ND	High Iron content	Clear		Nil		720	1120	6.76	428	84
		2	Thayetpin			2006/4/3	46	56.91	8.64	6.00	3.00	148	25.92	82	ND	High Iron content	Clear		Nil		585	900	6.76	178	82
	Magway	1	Kathagale			03-03-03	59	106.61	21.96	5.00	1.00	161	105.88	106	ND	Chemically Potable	Clear		Nil		585	900	6.66	358	106
		2	Kyitsonbwe			03-03-03	51	99.39	8.16	7.50	1.50	162	124.48	90	ND	Slightly High Iron content	Clear		Nil		545	-	6.67	282	90
	Pakkoku	1	Magyithonepin																						
		2	Anaukponekan			20-03-03	81	19.23	18.72	6.47	3.00	105	86.16	96	N.D	High Iron content	Clear		Nil		590	910	7.76	126	96
	Myothit	1	Thamya			20-03-03	36	72.94	22.56	4.12	1.55	48	67.68	82	ND	Slightly High Iron content	Clear		Nil		400	625	6.77	276	82
		2	Ledaingzin N			20-03-03	46	47.29	15.36	4.41	4.00	97	46.08	98	ND	High Iron content	Clear		Nil		380	585	6.76	182	98
	Yesagyo	1	Thikyidaw			10-02-03	191	56.91	39.36	10.22	2.00	518	118.08	126	ND	High Total Dissolved Solids and Iron content	Clear		Nil		2800	4400	6.77	306	126
		2	Seywa			13-02-03	122	50.50	10.56	5.68	2.50	188	81.68	186	ND	Slightly High Total Dissolved Solids and High Iron content	Clear		Nil		1100	1790	6.77	170	186
						Proposed NDWQS*	200	75-200	30-150	-	0.5-1.5	200-600	400	-	-						1000	1500	6.5-9.2	500	-

Note(*); Proposed NDWQS: Proposed National Drinking Warter Quality Standard Source:"Water Resources, Water Quality Standard and Groundwater Management in Myanmar, WRUD, MOA&I

TH: Total Hardness, TA: Tatal Alkalinity

Table 3.2.2.4 (2/2) Results of Water Quality Test of the Test Wells in the Central Dry Zone (MSTRD)

(mg/l)

Division	Township	No	Village Name	Sample No	Sampled Date	Analycis Date	Organisms		TS*	DS*	PH*	K	N (Ammonia)	CN	Zn	As	Cu	CO2	Pb	N (Nitrate)	Mn	BOD	COD	DO*	Sediment	Turbidity
							Coliform	E.Coli.																		
Mandalay	Taungtha	1	Kanthonesint				1	Nil	810.00	805.00	18.00	4.00	N.D	N.D	0.02	N.D	N.D	N.D	N.D	0.09	N.D		N.D	5.00	5.00	N.D
		2	Tabaukkon				Nil	Nil	578.00	578.00	24.00	0.30	N.D	N.D	0.20	N.D	N.D	N.D	N.D	0.02	N.D	-	1.84	5.80	N.D	N.D
	Kyaukpadaung	1	Gwedaukkon				Nil	Nil	569.00	569.00	4.00	N.D	N.D	N.D	2.20	N.D	N.D	Nil	N.D	0.15	N.D	1.40	N.D	6.20	N.D	N.D
		2	Sudat				Nil	Nil	2180.00	2180.00	15.00	0.70	N.D	N.D	0.50	N.D	N.D	N.D	N.D	0.09	0.50	-	5.50	4.00	N.D	N.D
	Natogyi	1	Pegyet W				Nil	Nil	800.00	800.00	4.00	0.50	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.002	N.D	-	3.60	6.60	N.D	N.D
		2	Aungthar 1				Nil	Nil	14456.00	13580.00	2364.00	5.40	N.D	N.D	3.00	N.D	N.D	N.D	N.D	0.002	3.00	-	7.36	6.80	876.00	80.00
		3	Aungthar 2				Nil	Nil	4085.00	3295.00	12.00	2.80	N.D	N.D	1.50	N.D	N.D	N.D	N.D	0.02	N.D	-	3.68	5.00	790.00	40.00
	Nyaung U	1	Kangyikon (N)																							
		2	Htanaungwin				Nil	Nil	1374.00	1346.00	324.00	N.D	N.D	N.D	0.30	N.D	N.D	Nil	N.D	N.D	0.10	1.20	N.D	6.00	28.00	N.D
	Pyawbwe	1	Thabyeyo				Nil	Nil	2569.00	2200.00	132.00	9.40	-	N.D	N.D	N.D	0.05	N.D	N.D	N.D	N.D	-	10.40	6.60	369.00	80.00
		2	Yonbingon				Nil	Nil	550.00	550.00	4.00	0.20	-	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	-	N.D	6.40	N.D	N.D
	Myingyan	1	Koke				Nil	Nil	942.00	937.00	40.00	1.10	-	N.D	N.D	N.D	N.D	N.D	N.D	0.16	N.D	-	4.06	6.00	5.00	N.D
		2	Saka				Nil	Nil	2857.00	2672.00	173.00	N.D	N.D	N.D	N.D	N.D	N.D	Nil	N.D	N.D	N.D	2.00	N.D	6.00	185.00	N.D
Magway	Chauk	1	Sangan				Nil	Nil	800.00	800.00	234.00	0.90	-	N.D	N.D	N.D	N.D	N.D	N.D	0.02	N.D	-	N.D	6.40	5.00	N.D
		2	Thayetpin				40	Nil	630.00	576.00	14.00	1.90	N.D	N.D	N.D	N.D	N.D	N	N.D	N.D	N.D	-	N.D	5.40	62.00	15.00
	Magway	1	Kathagale				Nil	Nil																		
		2	Kyitsonbwe				Nil	Nil	500.00	500.00	98.00	0.70	-	N.D	N.D	N.D	N.D	N.D	N.D	0.08	N.D	-	4.06	6.20	N.D	N.D
	Pakkoku	1	Magyithonepin																							
		2	Anaukponekan				Nil	Nil	778.00	625.00	60.00	1.30	-	N.D	1.50	N.D	N.D	N.D	N.D	0.02	N.D	-	N.D	5.00	153.00	10.00
	Myothit	1	Thamyu				Nil	Nil	475.00	475.00	31.00	0.20	-	N.D	0.20	N.D	N.D	N.D	N.D	0.03	0.01	-	N.D	5.80	N.D	N.D
		2	Ledaingzin N				Nil	Nil	400.00	400.00	22.00	0.20	-	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	-	N.D	6.20	3.50	N.D
	Yesagyo	1	Thikyidaw				Nil	Nil	3480.00	3475.00	16.00	2.20	-	N.D	N.D	N.D	N.D	N.D	N.D	0.01	N.D	-	N.D	6.20	5.00	N.D
		2	Seywa				Nil	Nil	1328.00	1325.00	19.00	0.40	-	N.D	0.10	N.D	N.D	N.D	N.D	0.002	N.D	-	4.16	6.60	3.50	N.D
						Proposed NDWQS	10*1	0*1	-	1000*2	500*3	-	0.5*4	0.05	5-15	0.05	1.0	-	0.05	10.0	0.3	-	-	-	-	-

Note(*); *1: Unpiped Water Supply, *2: as TDS, *3: as CaCO3, *4: Nitrite, TS: Total Solids, DS: Dissolved Solids, PH: Permanent Hardness, DO: Dissolved Oxygen

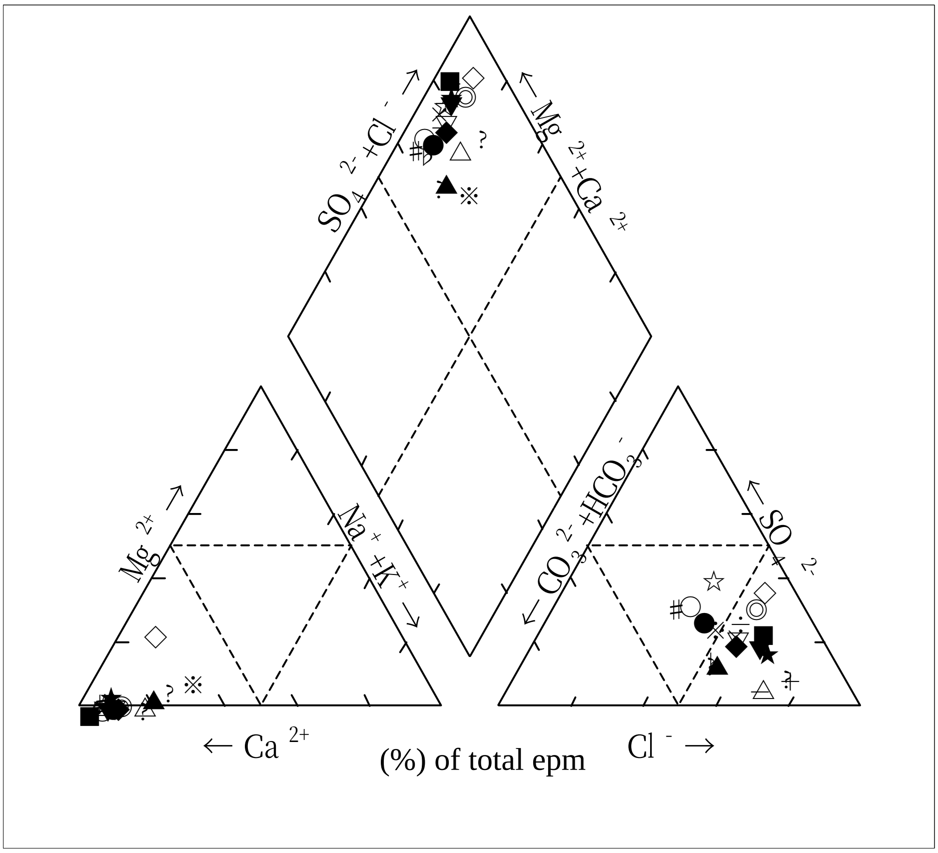
Table 3.2.2.5 Results of Water Quality Analysis of Test Wells (epm)

Division	Township	No	Village Name	Mg^{2+}		Ca^{2+}		Na^{+}		K^{+}		CO_3^{2-}		HCO_3^{-}		Cl^{-}		SO_4^{2-}	
				(mg/l)	(epm)	(mg/l)	(epm)	(mg/l)	(epm)	(mg/l)	(epm)	(mg/l)	(epm)	(mg/l)	(epm)	(mg/l)	(epm)	(mg/l)	(epm)
Madalay	Taungtha	1	Kanthonesint	35.88	2.95	120.25	54.10	68	2.96	5.26	0.13	0.00	0	106	1.74	135	3.81	207.64	4.32
		2	Tabaukkon	38.32	3.15	85.77	38.59	59	2.57	6.57	0.17	0.00	0	74	1.21	194	5.47	84.96	1.77
	Kyaukpadaung	1	Gwedaukkon	16.32	1.34	96.99	43.64	56	2.44	6.25	0.16	0.00	0	100	1.64	74	2.09	98.96	2.06
		2	Sudat	28.20	2.32	131.46	59.14	123	5.35	13.15	0.34	0.00	0	250	4.10	231	6.51	224.60	4.68
	Nathogyi	1	Pegyet W	22.20	1.83	73.42	33.03	86	3.74	4.41	0.11	0.00	0	64	1.05	193	5.44	166.60	3.47
		2	Aungthar 1	291.72	23.99	133.86	60.22	185	8.05	9.86	0.25	0.00	0	152	2.49	891	25.13	875.16	18.22
		3	Aungthar 2	28.68	2.36	145.89	65.64	167	7.26	10.26	0.26	0.00	0	216	3.54	323	9.11	186.04	3.87
	Nyaung U	1	Kangyikon (N)																
		2	Htanaungwin	13.68	1.13	216.43	97.37	63	2.74	7.50	0.19	0.00	0	84	1.38	239	6.74	141.04	2.94
	Pyawbwe	1	Thabyeyo	11.52	0.95	44.08	19.83	91	3.96	12.50	0.32	0.00	0	94	1.54	183	5.16	34.56	0.72
		2	Yonbingon	14.40	1.18	32.06	14.42	77	3.35	5.68	0.15	0.00	0	96	1.57	99	2.79	43.20	0.90
	Myingyan	1	Koke	27.72	2.28	145.89	65.64	146	6.35	11.00	0.28	0.00	0	192	3.15	298	8.40	183.16	3.81
		2	Saka	28.20	2.32	173.14	77.90	139	6.05	10.29	0.26	0.00	0	168	2.75	382	10.77	184.60	3.84
Magway	Chauk	1	Sangan	22.44	1.85	133.86	60.22	51	2.22	5.88	0.15	0.00	0	84	1.38	297	8.38	67.32	1.40
		2	Thayetpin	8.64	0.71	56.91	25.60	46	2.00	6.00	0.15	0.00	0	82	1.34	148	4.17	25.92	0.54
	Magway	1	Kathagale	21.96	1.81	106.61	47.96	59	2.57	5.00	0.13	0.00	0	106	1.74	161	4.54	105.88	2.20
		2	Kyitsonbwe	8.16	0.67	99.39	44.72	51	2.22	7.50	0.19	0.00	0	90	1.48	162	4.57	124.48	2.59
	Pakkoku	1	Magyithonepin																
		2	Anaukponekan	18.72	1.54	19.23	8.65	81	3.52	6.47	0.17	0.00	0	96	1.57	105	2.96	86.16	1.79
	Myothit	1	Thamya	22.56	1.86	72.94	32.82	36	1.57	4.12	0.11	0.00	0	82	1.34	48	1.35	67.68	1.41
		2	Ledaingzin N	15.36	1.26	47.29	21.28	46	2.00	4.41	0.11	0.00	0	98	1.61	97	2.74	46.08	0.96
	Yesagyo	1	Thikyidaw	39.36	3.24	56.91	25.60	191	8.31	10.22	0.26	0.00	0	126	2.07	518	14.61	118.08	2.46
		2	Seywa	10.56	0.87	50.50	22.72	122	5.31	5.68	0.15	0.00	0	186	3.05	188	5.30	81.68	1.70

Fig. 3.2.2.3 Trilinear Diagram of Test Wells

(epm)

Division	Township	No	Village Name	Mark	Mg^{2+}	Ca^{2+}	$Na^{+}+K^{+}$	$CO_3^{2-}+HCO_3$	Cl^{-}	SO_4^{2-}
Madalay	Taungtha	1	Kanthonesint	☆	2.95	54.10	3.09	1.74	3.81	4.32
		2	Tabaukkon	★	3.15	38.59	2.73	1.21	5.47	1.77
	Kyaukpadau	1	Gwedaukkon	○	1.34	43.64	2.60	1.64	2.09	2.06
		2	Sudat	●	2.32	59.14	5.69	4.10	6.51	4.68
	Nathogyi	1	Pegyet W	◎	1.83	33.03	3.85	1.05	5.44	3.47
		2	Aungthar 1	◇	23.99	60.22	8.30	2.49	25.13	18.22
		3	Aungthar 2	◆	2.36	65.64	7.53	3.54	9.11	3.87
	Nyaung U	1	Kangyikon (N)	□						
		2	Htanaungwin	■	1.13	97.37	2.93	1.38	6.74	2.94
	Pyawbwe	1	Thabyeyo	△	0.95	19.83	4.28	1.54	5.16	0.72
		2	Yonbingon	▲	1.18	14.42	3.49	1.57	2.79	0.90
	Myingyan	1	Koke	▽	2.28	65.64	6.63	3.15	8.40	3.81
		2	Saka	▼	2.32	77.90	6.31	2.75	10.77	3.84
Magway	Chauk	1	Sangan	+	1.85	60.22	2.37	1.38	8.38	1.40
		2	Thayetpin	—	0.71	25.60	2.15	1.34	4.17	0.54
	Magway	1	Kathagale	×	1.81	47.96	2.69	1.74	4.54	2.20
		2	Kyitsonbwe	÷	0.67	44.72	2.41	1.48	4.57	2.59
	Pakkoku	1	Magyithonepin	*						
		2	Anaukponekan	※	1.54	8.65	3.69	1.57	2.96	1.79
	Myothit	1	Thamya	♯	1.86	32.82	1.67	1.34	1.35	1.41
		2	Ledaingzin N	♭	1.26	21.28	2.11	1.61	2.74	0.96
	Yesagyo	1	Thikyidaw	?	3.24	25.60	8.57	2.07	14.61	2.46
		2	Seywa	?	0.87	22.72	5.45	3.05	5.30	1.70



This means that groundwater of the test wells, also have much quantity of dissolved solids and are affected strongly by the chemical composition or mineralogy of the host rocks during long residence time in the aquifer.

(5) Installation of Pumps in Test Wells

Pump installation work have been done for two months from May 2003 under supervision of an engineer of the Study Team. Since these test wells had been intended to use as production wells, JICA procured 21 sets of helical rotor pumps and delivered them to the Study Area. Two sets of airlift pumping system, which consists of an air compressor, an engine and pipes, were procured locally and provided for the two shallow wells at Aungthar village in Natogyi Township. Results of installation of pumps for the test wells is shown in Table 3.2.2.6. Among the 21 deep wells, three wells were not used as production wells due to the following reasons.

At Kangyikon N village, Nyaung-U Township, aquifer could not be confirmed up to 300 m deep in the ground. At Magyithonepin village, Pakokku Township, the test well had a yield of only 5 l/min, which was too little to use. At Thayetpin village, Chauk Township, a static water level was 315 m deep, which was beyond specified heads of the procured pumps. At Yonbingon village, Pyawbwe Township pump was not necessary because the well was an artesian well. Therefore four sets of well pumps were no need to be installed for the above three unsuccessful wells and an artesian well. The pump installation work including the progress, equipment used in each well, test operation and training to the villagers etc. is reported in 3-K of Vol. III, Supporting Report.

Consequently, 17 sets of well pumps were installed totally except the above three unsuccessful test wells and an artesian well. DDA has constructed a set of reservoir, pump house, and pipe between the pump and the reservoir for each tube well on its own responsibility. The specifications of uninstalled four well pumps are as follows,

Table 3.2.2.7 Specification for Well Pumps to be Stored in DDA's Warehouse

Head(m)	Discharge (gal/hr)	Well Diameter (mm)	Length of Riser Pipe (m)	No.	Engine （kW）
220	3,000	>120	220	1	15.5
170	1,500	>100	170	1	7.3
120	1,000	>120	120	1	3.0
100	1,000	>100	100	1	3.0

The two unsuccessful tube wells in Magyithonepin and Thayetpin villages will be used as monitoring wells to trace water level and water quality in future.

Table 3.2.2.6 Results of Installation of Pumps for Test Wells

			Population		Water Demand		Pumping Test Result Water Level			Pump to be installed				
	Village Tract	Village	Year 2001	Year 2010	Total Demand (gal/day)	Required Pump Rate (gal/hr)	Static Water Level	Dynamic Water Level	Discharge (gals/hr)	Discharge (gals/hr)	Head (m)	Installation Depth (GL-m)	Ground Tank proposed Capacity (gallon)	
Taungtha	Zagyan	Kanthonesint	1,332	1,564	23,460	2,932	-130.6	-130.6	3,165	3,000	220	-150	8,000	
	Zagyan	Tabaukkon	410	481	7,221	903	-149.0	-157. 0	2,255	1,800	200	-170	5,000	
Kyaukpadaung	Gwaydaukkone	Gwaydaukkone	1,560	1,832	27,476	3,434	-159.0	-160.0	2,110	2,000	170	-170	5,000	
	Simdaikan	Sudat	500	587	8,806	1,101	-121.0	-123.0	2,413	2,000	170	-180	5,000	
Natogyi	Pegyet	Pegyet W	1,261	1,481	22,209	2,776	-24.0	-46.0	7,530	5,000	170	-100	8,000	
	Yongon	Aungthar	902	1,059	15,886	1,986	-21.0	-50.0	264					Two sets of Air Copressor were supplied.
							-15.0	-56.0	343		-		2,000	
Nyaung U	Letwae	Kangyikon N	700	822	12,329	1,541			-	Not available due to unidentidication of aquifer.				
	Zedae	Htanaungwin	750	881	13,209	1,651	-99.0	-110.0	3,165	2,000	170	-130	5,000	
Pyawbwe	Thabyeyo	Thabyeyo	500	587	8,806	1,101	-24.0	-72.0	198	1,000	120	-130	3,000	
	Osanwa	Yonbingon	350	411	6,164	771			-	Artesian well				
Myingyan	Koke	koke	2,500	2,935	44,031	5,504	-14.0	-56.0	7,029	5,000	170	-100	15,000	
	Saka	Saka	1,001	1,175	17,630	2,204	-46.0	-54.0	8,176	3,000	220	-100	6,000	
Chauk	Thittogan	Sangan	700	822	12,329	1,541	-178.0	-181.0	1,055	1,500	270	-210	4,000	
	Wetthesan	Thayetpin	1,150	1,350	20,254	2,532	-315.0	-315.0	1,600	Installation of Pump was not available due to the deep groundwater level, which is beyond specified heads of the procured pumps.				
Magway	Kanthagyi	Kanthagale	1,146	1,346	20,184	2,523	-107.0	-108.0	3,560	2,000	170	-155	7,000	
	Kyitsonbwe	Kyitsonbwe	5,000	5,871	88,063	11,008	-163.0	-164.8	642	1,000	220	-175	3,000	
Pakokku	Magyithonepin	Magyithonepin	350	411	6,164	771	-194.0	-196.0	66	Not available due to very small yield.				
	Kyathto	Anaukponekan	950	1,115	16,732	2,091	-96.0	-110.0	3,560	2,000	170	-153	6,000	
Myothit	Ledaingzin	Thamya	2,500	2,935	44,031	5,504	-122.0	-124.1	1,780	2,000	170	-165	6,000	
	Ledaingzin	Ledaingzin N&S	3,000	3,523	52,838	6,605	-69.6	-72.5	5,934	3,000	170	-155	8,000	
Yesagyo	Thitkyidaw	Thitkyidaw	3,000	3,523	52,838	6,605	-15.7	-22.4	10,549	5,000	170	-100	12,000	
	Zedaw	Seywa	1,075	1,262	18,933	2,367	-25.1	-25.4	9,587	2,000	170	-100	6,000	

However, the one in Thayetpin village can be utilized as the production well if a pump with an enough capacity is procured. The above four sets of well pumps unused this time can be installed for the wells to be drilled in the "10 Year Project" in the Central Dry Zone in future.

(6) Geological features and difficulties in drilling works in the Central Dry Zone

According to result of the test boring, the geological formation of the Central Dry Zone in Myanmar is composed of three layers with sandy rock and shale rock of the Tertiary period as follows:

a) Surface layer, generally from 0m to 40m in depth, is sandstone and mudstone which are easy to collapse. However, this layer may continue up to depths of 60m to 70m at some places.
b) Second layer is composed of sandy rock and shale which themselves are soft and easier to collapse, further there are many opened cracks caused by faults. In drilling work it is supposed that drilling mud flows out into the cracks.
c) Third layer is also composed of sandy rock and shale, however this layer is more stable and a uniform layer than the second layer and composes an aquifer.

Therefore, groundwater exists as the fissure water in the cracks of the third layer.

1) Surface layer (from 0m to 70m in depth)

The surface layer is drilled by standard mud (Specific gravity: 1.16, viscosity rate: 50 seconds). During the drilling work, sandy rock does not collapse with mud circulation in the hole, if mud circulation is stopped at the time of bit exchange or casing insertion, it will become easy to collapse.

Moreover, it can easily lead to accidents of jamming at the time of raising rods or casings. With the present drilling equipment, the counter measures against collapse are raising the specific gravity and viscosity rate of mud to protect the wall or lowering a safety casing to the required depth to stop collapse forcibly.

When collapse does not stop at depths below the bottom of the inserted casing, a dredging is repeated by dense mud, or cementation is done to protect the hole. In this case, it is better to performed in 24 hours shift operation.

The object of cementation for this layer is to protect wall. Cementation is done using cement mortar and sand mixed in a proportion decided according to the condition of the collapse. For the cementation, generally, mortar is placed from bottom of hole by a pump; however, in this project the pump was not procured, and mortar had to be placed from mouth of hole.

Therefore, mortar got mixed with mud in the hole and formed to a gel. As a result, hardening of cement took time and waiting time increased. Moreover, since cement mortar adhered to intermediate wall, the necessary volume of mortar for cementation did not reach to the bottom. For this reason, cementation was repeated over several times. If there was another pump for cementation or power mud, the collapse and lost circulation could have been arrested more quickly.

2) Second layer of sandstone and shale layer (Lost circulation bed from 70m to 240m in depth)

There are two types of lost circulation, one is complete loss and another is partial loss. The complete lost circulation occurs at once flashing out from the crack. In Kanthonesint village of Taungtha Township, cuttings accumulated in a hole at 146m in depth and the stabilizer was jammed by cuttings remained inside of the hole. The opportune timing of raising the rod was lost; leading to an accident, and its retrieval took 2 days.

If the position of lost circulation bed was known by geophysical exploration, suitable measure could have been selected. At present stage, it cannot but has to depend on the skill of operator.

The number of occurrences of lost circulation depends on hole, however it was 2 or 3 times per hole minimum. In the Sangan village of Chauk Township, all of layers were lost circulation beds from surface to 200m in depth.

Lost circulation part of the hole was grouted with cement milk from the bottom of the hole through a 2 inch pipe to pour into the crack. If cementation is done by injecting the cement milk to the depth of lost circulation using a pump, it is effective. Moreover, when the lost circulation volume was more than 200l/min, leaves and sawdust were mixed to mud as a substitute for raising viscosity.

3) Third layer of sandstone and shale layer (Aquifers from 240m to 420m in depth)

After passed the second layer, it was a stable stratum of sandstone and shale, and since the aquifer was thin, it was very difficult to confirm the position of aquifer during digging.

To find the exact position of aquifer, well logging needs to be grasped. After confirmed the aquifers, water jetting and airlift were continuously performed for cleaning of the hole. And since it was inadequate, the ground water level had changed. When cleaning was not performed completely into the cracks and the cuttings or mud was not fully removed water paths closed and as a result change of water level took place inside the hole. When washing cracks for fissure water, the swapping method is necessary to eliminate cuttings and mud.

4) Lost Circulation Occurred in the Field

During the test well drilling in the field, lost circulations were occurred almost in the drilling sites. The main appearances of the lost circulation are described as follows;

i) In Kanthonesint village, sand strata lie from 0m to 65m in depth. For stopping the collapse, the safety casing was installed to 30m in depth. However, the casing could not enter deeper; therefore, counter measure was changed to cementation. The cementation carried out repeatedly and wall had been secured. Drilling between 0m to 65m took 23 days. In the meantime, cementation was carried out 12 times using 200 nos of 40kg bags of cement.

From 65m in depth, it enters the sandstone layer. Since it was very soft, digging was performed with the mud raising its concentration. But lost circulation happened near 127m in depth, all rods were lifted, and cementation was performed.

The scale of cracks and the maximum lost circulation volume from cracks could not be confirmed. Therefore, at first, cementation was tried by 1200kg of mortar cement mixed with 20kg salt. After allowing 24 hours for mortar hardening, the effect of the cementation was checked using a rod. Cement had flowed out from the cracks and it was judged that cementation was not effective. Then, cementation was carried out for a second time using 2400kg of mortar cement mixed with 40kg of salt. After confirming hardened surface of cementation near 123m in depth, the digging was resumed for cutting cement.

After passing through 127m, lost circulations happened 3 times at 130m, 162m and 174m. When lost circulation occurred, the rod was raised immediately to avoid its jamming. Also for each lost circulation, cementation was performed and digging was ended at 200m in depth.

Since cementation was continuously performed many times for stopping the lost circulation. There was apprehension where the hole could be used as a product well. However, from the result of well logging, the existence of aquifers was confirmed, and finally the amount of pumping of 280 l/min was secured.

ii) In the Saka village, from 0m to 46m in depth is sand strata. Here, safety casing was inserted to 20m and the rest was excavated by cementation method. To pass this layer, it took 16 days and cementations were performed 7 times and using 3720kg of cement.

iii) In a Gwaydaukkone village, cementation was carried out at 138m, 196m for lost circulation.

iv) In the Sudat village, the lost circulation happened at 139m, 165m and 176m in depth. For stopping the lost circulation, cementation and prevention material was used.

v) In the Sungan Village, for drilling from 20m to 198m in depth, cementation and using prevention material were repeated as the counter measure for lost circulation. As lost circulation bed was thick and lost circulation could not be stopped completely. However digging was continued under lost circulation. Then a stabilizer was blocked by collapse in the hole as the accident. It took four months to recovery rods except the bit and bit-sub.

In the point detached 20m from the first well, new well was drilled in 24 hours shift operation. The cementation was not adapted. As the counter measure against lost circulation, the clay which could be taken in near the drilling site was used for substitutive prevention material for lost circulation.

vi) In the Kanthagle village, lost circulations happened at 143m and 155m in depth, the lost circulation was stopped by prevention material.

vii) In the Kyitsonbwe village, lost circulations happened at 126m, 138m and 165m in depth, the lost circulation was stopped by cementation and prevention material.

viii) In the Anaukponekan village, lost circulation happened at 125m, 146m and 188m in depth, lost circulations was stopped by cementation.

ix) In the Laydaingzin village, lost circulation happened at 100.5m, 118m and 128m in depth, lost circulation was stopped by the prevention material.

x) In the Thabyeyo village, lost circulation happened at 144m and 168m in depth, it was stopped by cementation.