2.4.7 Possible Groundwater Resources

Groundwater commonly occurs in unconsolidated sediments which has a capacity to keep water in itself. In the case of the study area, the Quaternary formation is expected to form a good aquifer. It has a wide distribution as shown in Figure 2.4.7. The Tertiary formation is made up of compact clay and is not expected to form good aquifers.

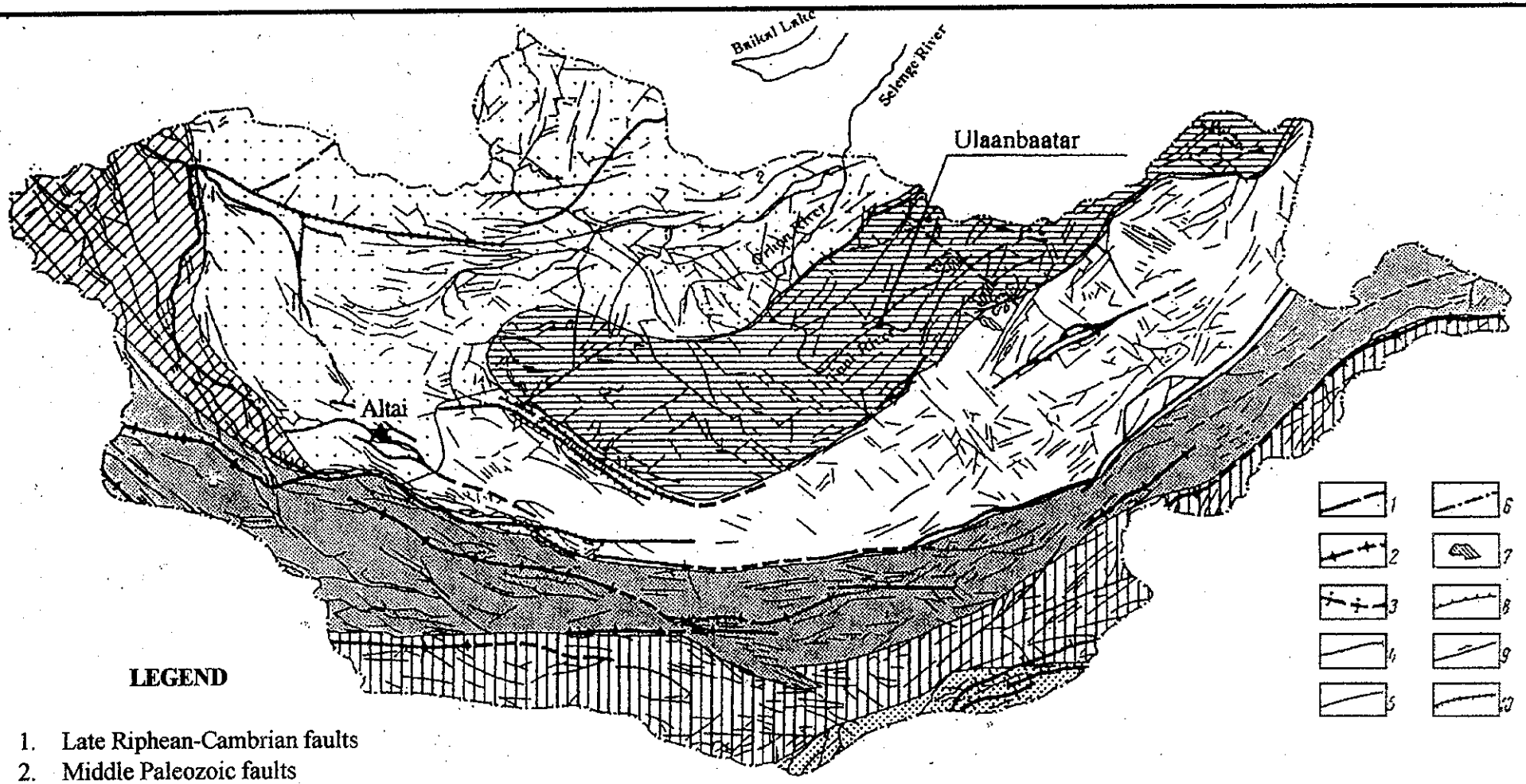
Most lineaments may correspond with faults and fractured zones. Faults and fractured zones may form either pervious or impervious zones which control groundwater flow in the ground. If some of these zones are large enough to hold water, they will be called fissure aquifer and can be used as water source. From this point of view, possible groundwater sources of fissure aquifer are expected in the following locations shown in Figure 2.4.5.

Table 2.4.1 Topographic Classification of the Study Area

Topographic Unit	Mountain I	Mountain II	Hilly Area	Undulated Area	Flat Plain Area
Altitude (m A.S.L)	>2500 m	2300-2500 m 2100-2250 m (N of Altai) 2050-2150 m (E of Altai)	1950-2050 m (NE of Altai)	2050-2300 m (Sukhiin Hooloi) 2150-2300 m (Harzat Area) 2150-2400 m (Olon Nuur Area)	1950-2150 m along river course (Sukhiin Hooloi) 2000-2150 m (SE of Altai) 2150-2220 m (Olon Nuur Area)
Slope Gradient (degree)	Steep (10-20°)	Moderately Steep (3-10°)	Gentle (1-3°)	Very Gentle (1-3°)	Almost Horizontal (0-1°)
Distribution	Khan Tayshiryn mountain range	Khan Tayshiryn mountain range, Sertengyn mountain range & around Undur Tsakhiram	Around Tsahir Tolgoy	Sukhin Hooloi area, Harzat area & Olon Nuur area	Around river course at Sukhin Hooloi -Ulaan Gaugazadgay Hooloi-Khanginaagyn Hooloi, Esun Bulagyn Shal-Olon Nuur
River System	Straight small course with sporadic current	Almost straight small course with sporadic current	Slightly irregular small course ordinarily without water	Underflow groundwater, but current water during heavy rain	Heavily meandering river course with current of sometimes salty water
Geology	Metamorphic & Granitic Rocks	Metamorphic & Granitic Rocks	Metamorphic & Granitic Rocks & dikes. Locally weathered as monadnocks	Alluvial deposits of good permeability such like fan and talus.	Fine sandy and/or clayey sediments
Hydrological System	Recharge Area Major precipitation area	Recharge Area	Partly Recharge Area	Discharge Area	Poor Drainage Area With Concentration of Salt Minerals
Hydrogeological Characteristics	Little possibility of development	Possibility of fissure aquifer along the regional faults	Possibility of fissure aquifer	Actual groundwater production area	Not feasible for exploitation because of bad water quality

Table 2.4.2 Geological Components

ERA & PERIOD		SYMBOL	SYSTEM	LITHOLOGICAL COMPONENT	REMARKS
CENOZOIC	Quaternary	QIV	Upper Quaternary Recent River Deposite	Sand, Sandy Loam, Loam, Clay, Gravel	*Unhomogeneous alluvial sediments distributed along river courses and their surroundings.
		QII-III	Middle & Upper Quaternary Fan & Talus Deposits	Gravel, Sandy gravel, Clay, Sand	*Unhomogeneous sediments distributed in piedmont, undulatede area, flat pla *Large distrubution in the study area. *Hydrogeologically the most important formation.
	Tertiary	N2at	Neogene System	Redstone with sandy and clayey layers	*Small scale distribution along Zadgay Khooloi.
PALEOZOIC	Devonian	D1-2	Lower & Middle Devonian Series	Sandstone, Conglomerate	*Small scale distribution at north end of the Study Area *Almost horizontal formation.
	Cambrian Lower & Middle	E 1-2	Tsagaan Olom Series	Limestone, Dolomitic Limestones, Shale, Marble	*Zonal distribution at south end of the Study Area *Gently deformated.
Proterozoic		Vht	Vendian Series Khan Tayshiryn Series	Green Rock and Greenschist of Basic Rock Origen	*Linear sporadic distribution affected by regional faults in the southwestern mountain area.
		R1-3gb	Upper-Lower Riphean Series	Serpentinite, Peridotite, Dunite, Diabase, Diorite, Green Rock, Greenschist	*Zonal distribution along Khan Tayshiryn mountain range & regional faults *Friable basic and/or ultrabasic rocks
		PR1	Gobi Altai & Ulaantolgoy Series	Banded Gneiss, Quarzite, Leucocratic Granodiorite & Tonalite, Aplite, Biotite Schist	*The basement of the study area. Large distribution in the northern area of Altai city
		PR1am		Banded Amphybolite with gneiss, granite alternated in small scale	*One unit of PR1, Strongly deformated.
Proterozoic		γR2-3	Intrusive Rock of Riphean Series	Granite, Granodiorite, Tonalite, Diorite, Gabbro, Amphybolite, Marble	*Stock type intrusive. More acidic granitic rock is the product of later granitic activity.
Unknown			Dike Rocks	Dolerite, Diabase, Porphyrite, Aplite, Pegmatite	*Width varies from some meters to scores of meters. *Gently folded, Large distribution in the NE sector of the study area



LEGEND

1. Late Riphean-Cambrian faults
2. Middle Paleozoic faults
3. Late Paleozoic faults
4. Regional faults
5. Other faults
6. Faults accompanied by stems of Mesozoic intrusions
7. Mesozoic granitoids within "intrusive rocks"
8. Thrust faults
9. Lateral faults
10. Faults accompanied by recent seismic activity

I Mongolian Altai Folded Zone
II North Mongolian Folded Zone
III Mongol Pre-baigalian Folded Zone
IV Central Mongolian Folded Zone
V. South Mongolian Folded Zone
VI. South Gobian Folded Zone
VII. Inner Mongolian Folded Zone

Figure 2.4.1 Geological Structure of Mongolia

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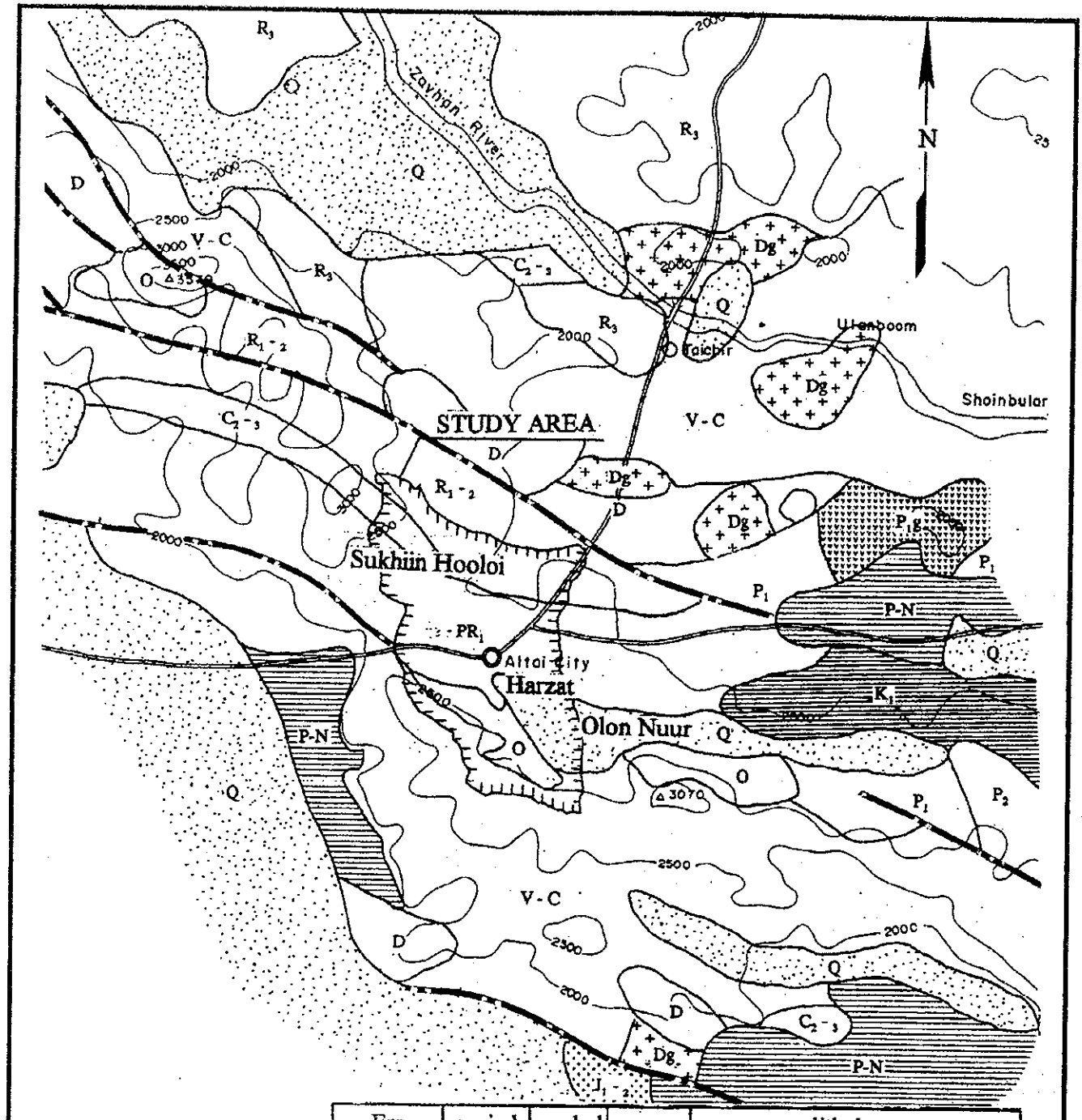

Era	period	symbol		lithology
Cenozoic	Quaternar	Q		clay, sand, gravel
	Tertiary	P-N		siltstone, sandstone, conglomerate
Mesozoic	Cretaceou	K 1		siltstone, sandstone, conglomerate, shale
	Jurassic	J 1,2		sandstone, conglomerate, rhyoritic porphyry
Paleozoic	Permian	P 1,2		siltstone, sandstone, conglomerate
	Devonian	D		sandstone, siltstone, rhyolitic porphyry
	Unknown	O		gabbro
	Cambrian	C 2,3		slate, phylite, metasandstone, siltstone
Proterozoic		V-C		diabase, limestone, sandstone, phylite, shale
		R 3		gneiss, schist, amphibolite
		R 1,2		gneiss, schist, amphibolite
		PR 1		gneiss, schist, amphibolite
Intrusive rocks	Permian			granite, adamerite
	Devonian			granite, granodiorite, adamerite

Figure 2.4.2 Geological Map of Altai City and Surrounding Area

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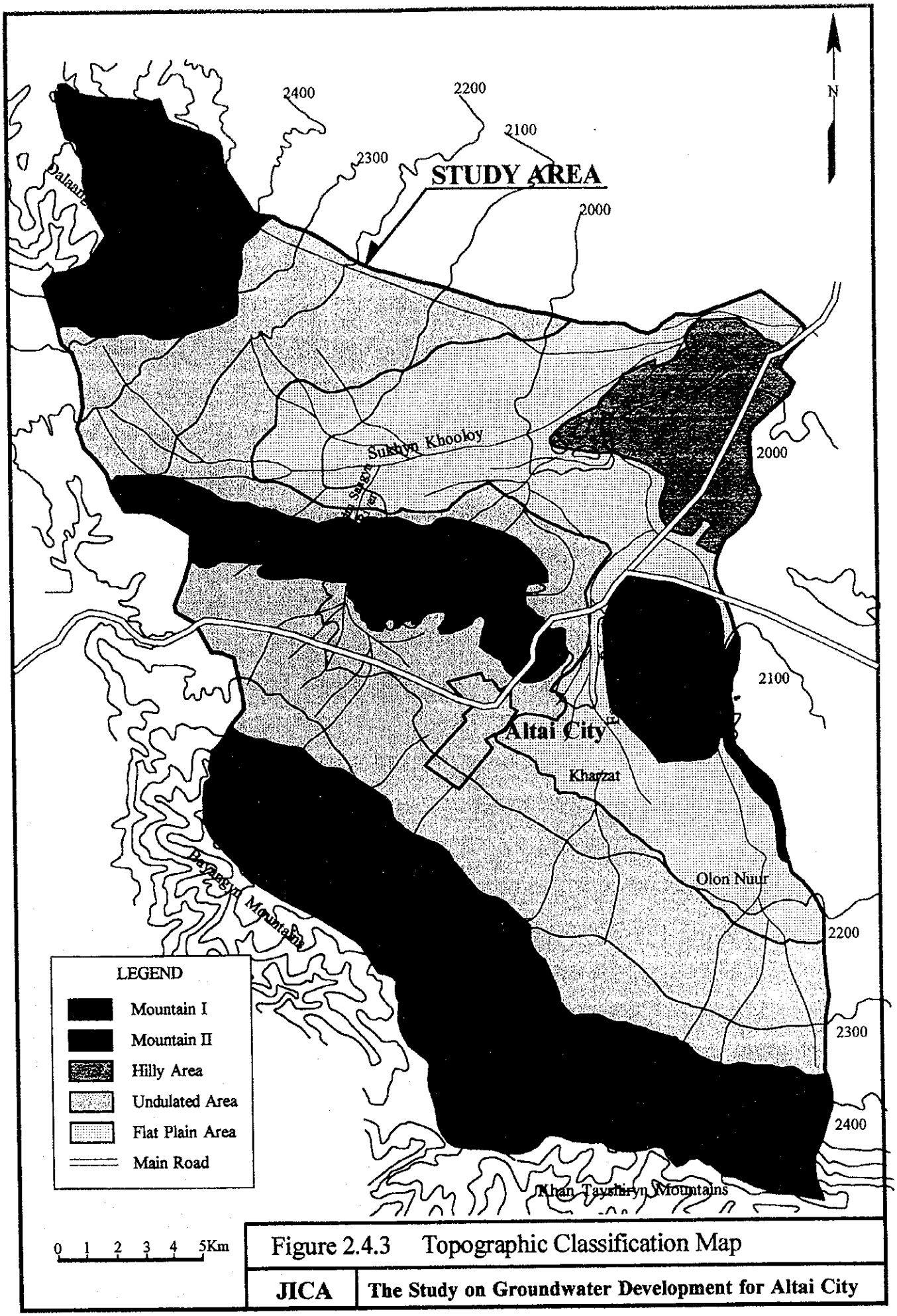

Figure 2.4.3 Topographic Classification Map

JICA	The Study on Groundwater Development for Altai City

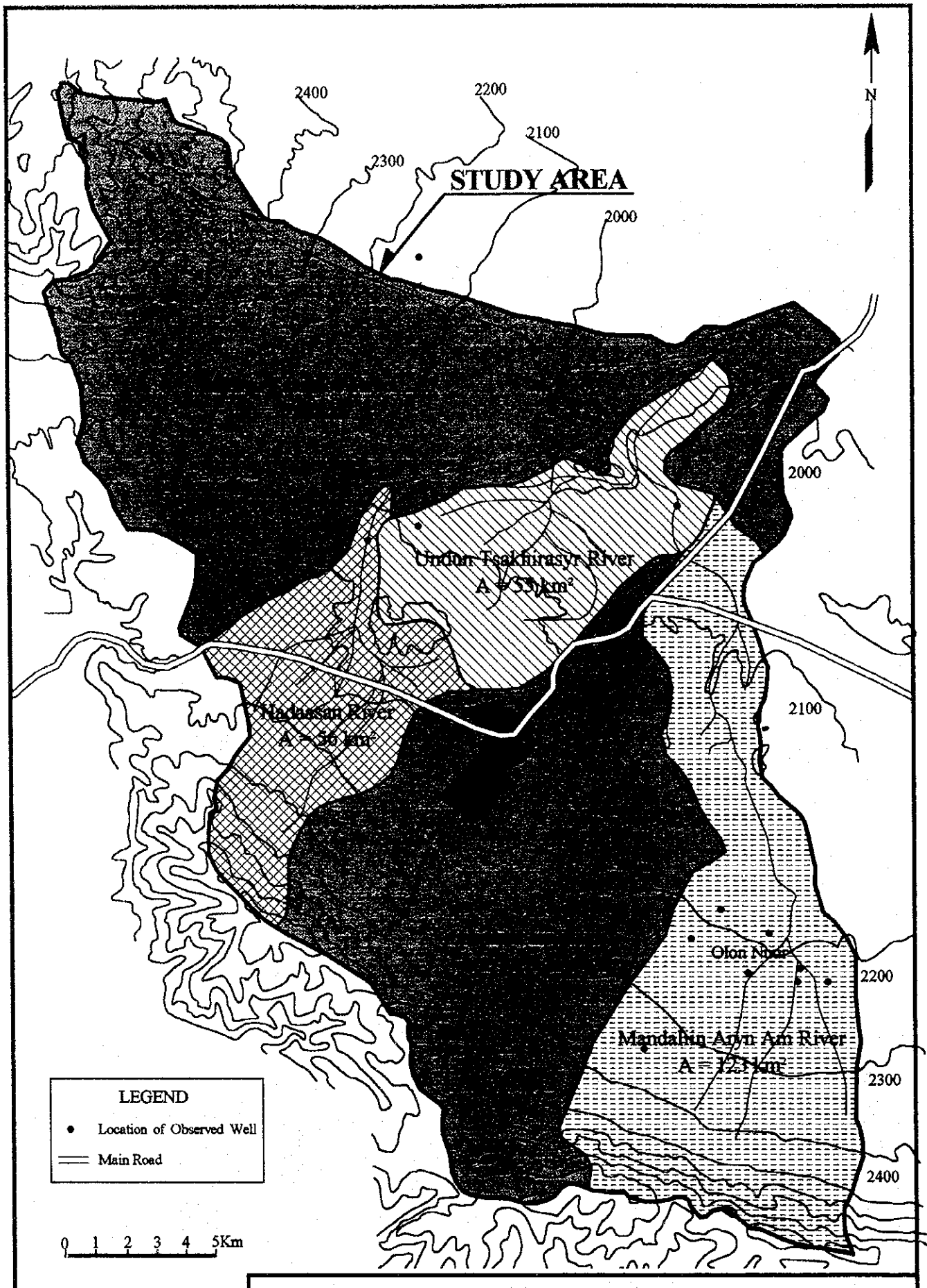

Figure 2.4.4 Division of Catchment Area

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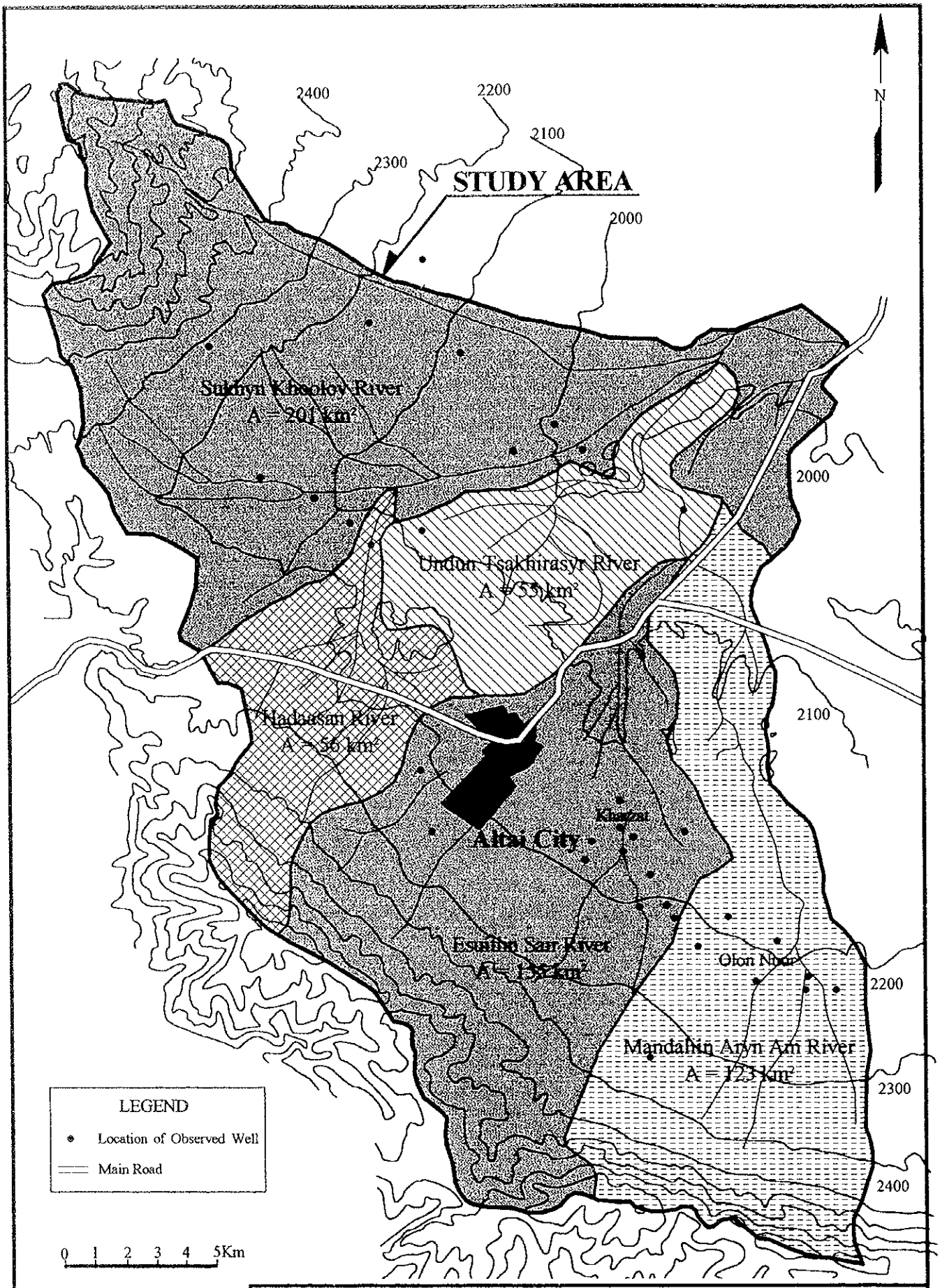

Figure 2.4.4 Division of Catchment Area

JICA	The Study on Groundwater Development for Altai City

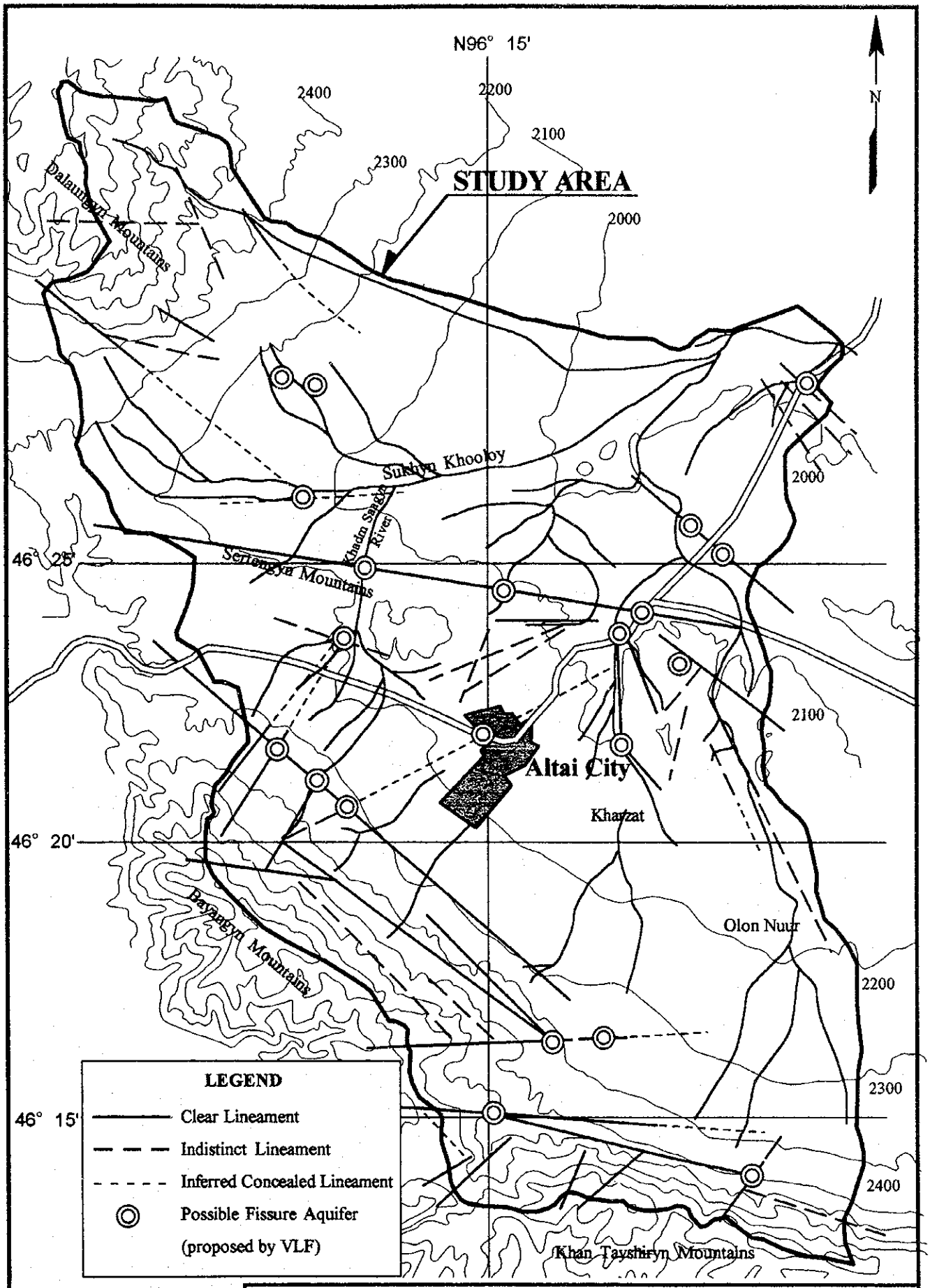

Figure 2.4.5 Lineament, Possible Fissure Aquifers

JICA	The Study on Groundwater Development for Altai City

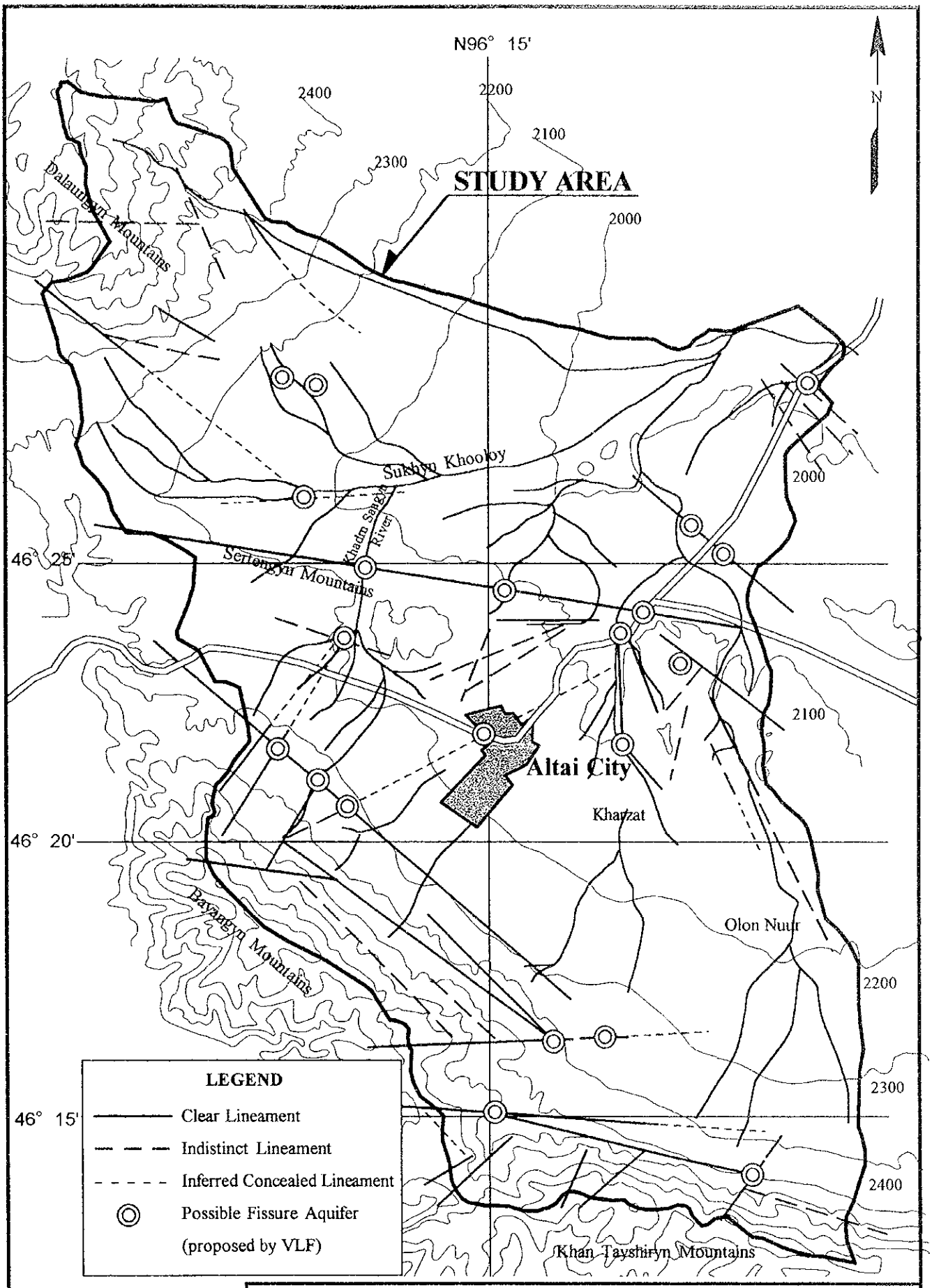

Figure 2.4.5 Lineament, Possible Fissure Aquifers

JICA	The Study on Groundwater Development for Altai City

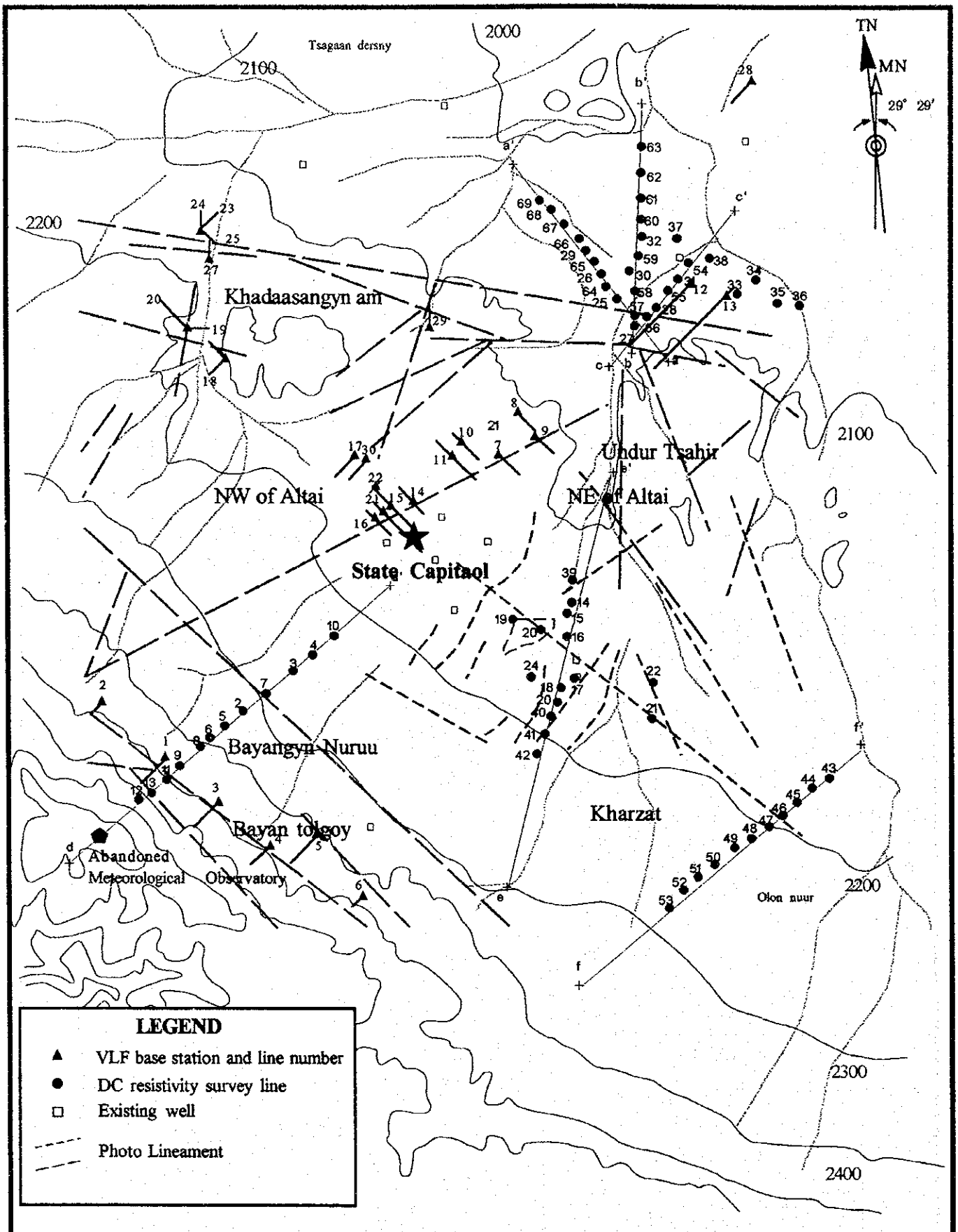

Figure 2.4.6 Lines and Stations for Geophysical Survey

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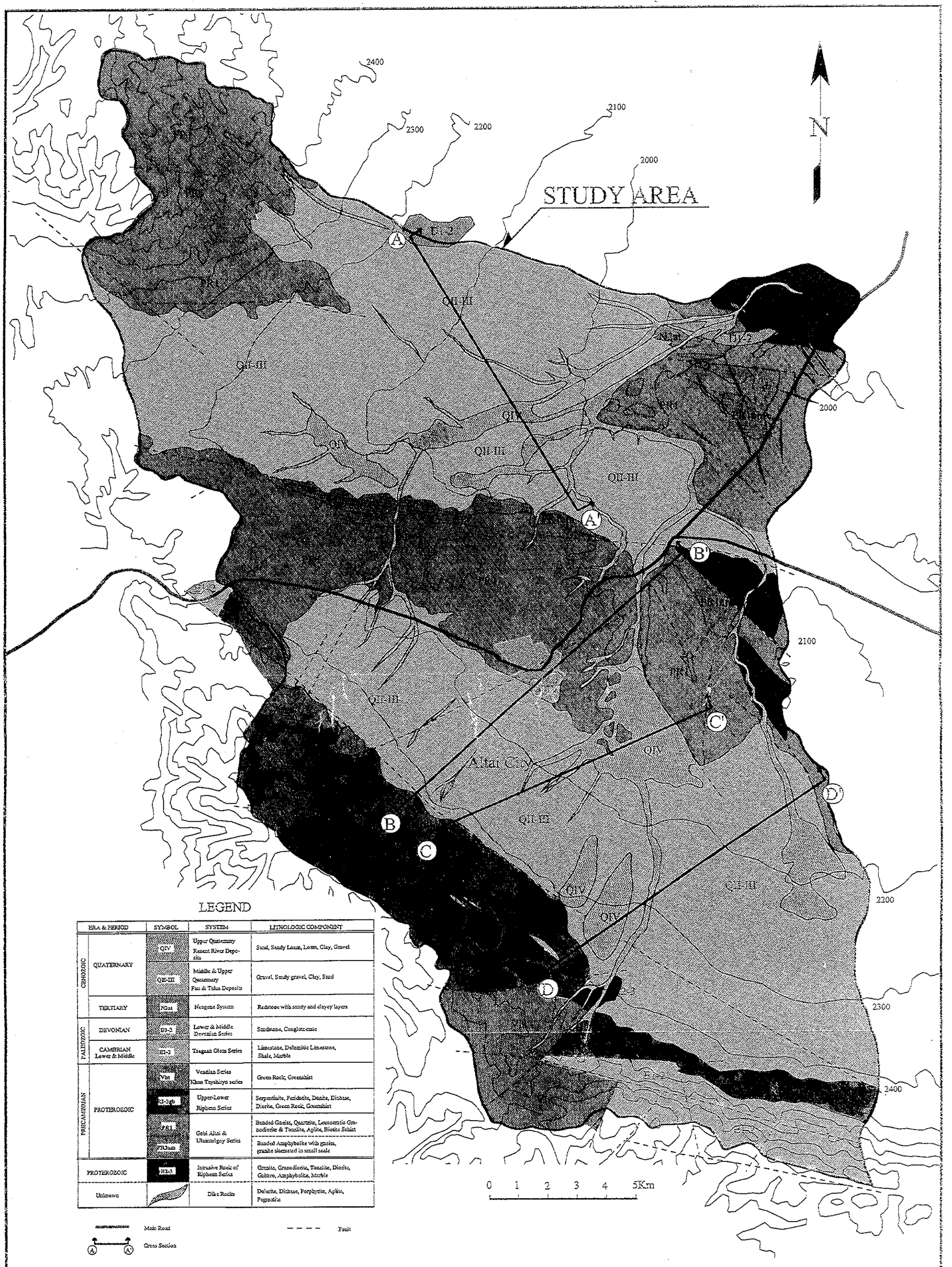
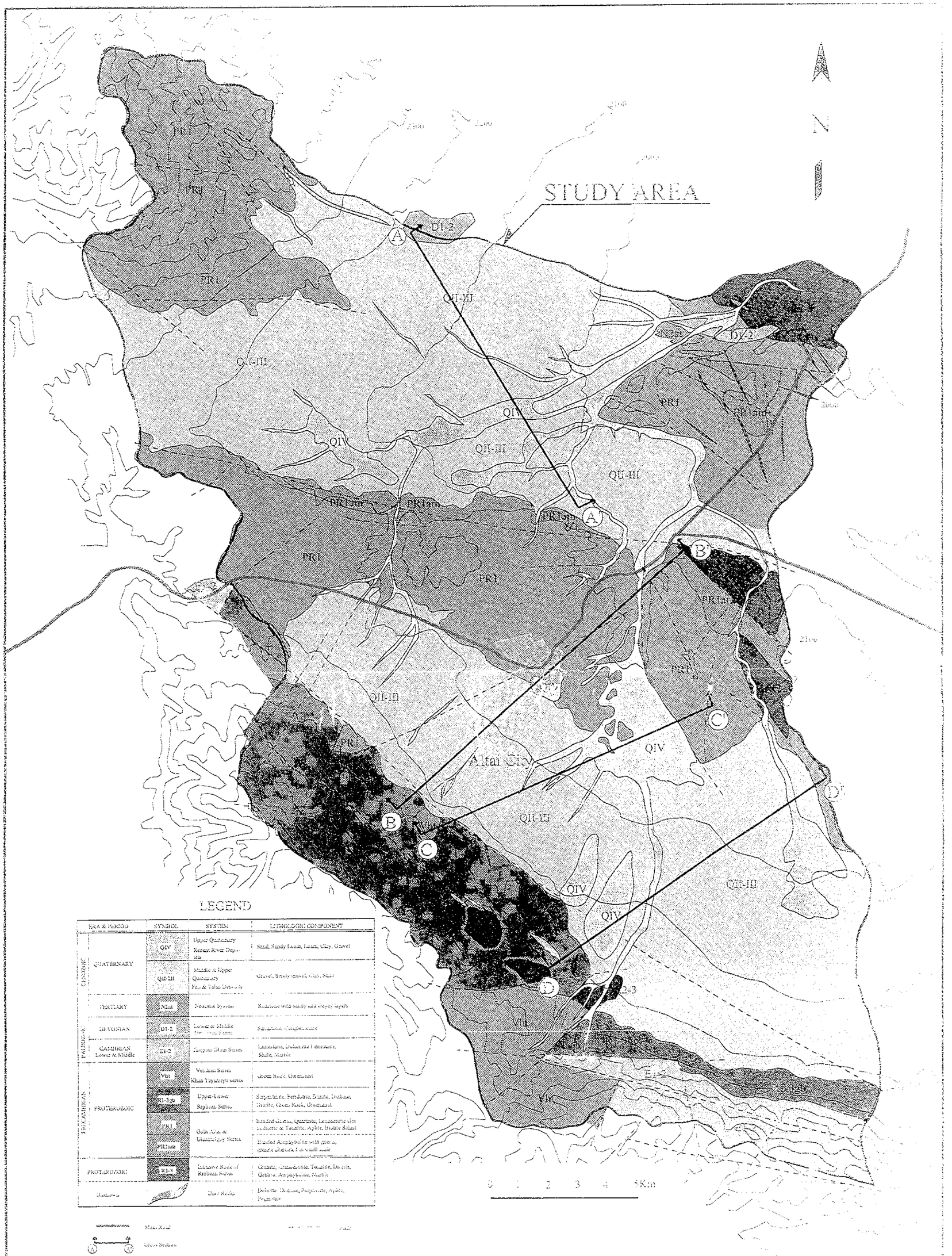


Figure 2.4.7 Geological Map of the Study Area

JICA | The Study on Groundwater Development for Altai City



LEGEND

ERA & PERIOD		SYMBOL	SYSTEM	LITHOLOGIC COMPONENT
CENOZOIC	QUATERNARY	QIV	Upper Quaternary Recent River Deposits	Sand, Sandy Loam, Loam, Clay, Gravel
		QI-III	Middle & Upper Quaternary Fan & Talus Deposits	Gravel, Sandy gravel, Clay, Sand
	TERTIARY	NI-II	Neogene System	Mudstone with sandy and clayey layers
PALEOZOIC	DEVONIAN	DI-2	Lower & Middle [illegible] Series	Sandstone, Conglomerate
	CAMBRIAN Lower & Middle	EI-2	Tergusun Group Series	Limestone, Dolomitic Limestone, Shale, Marble
PRECAMBRIAN	PROTEROZOIC	Vm	Vendian Series Khan Taryatyn series	Green Rock, Greenstone
		PR1-2ab	Upper-Lower Riphean Series	Serpentinite, Pendotite, Diorite, Dolerite, Diorite, Green Rock, Greenstone
		PR1gn	Gobi Altai & Dzamchigiyn Series	Banded Gneiss, Quartzite, Leucocratic Gneiss, Anthonite & Tonalite, Aplite, Biotite Schist
		PR1am		Banded Amphybolite with gneiss, Granite Gneiss & Granulite rocks
PROTEROZOIC		PR1-3	Intrusive Rocks of Riphean Series	Granite, Granodiorite, Tonalite, Diorite, Gabbro, Amphybolite, Marble
Boundary			Dike Rocks	Dolerite Diabase, Porphyrite, Aplite, Pegmatite

Main Road

Cross Section

Figure 2.4.7 Geological Map of the Study Area

JICA | The Study on Groundwater Development for Altai City

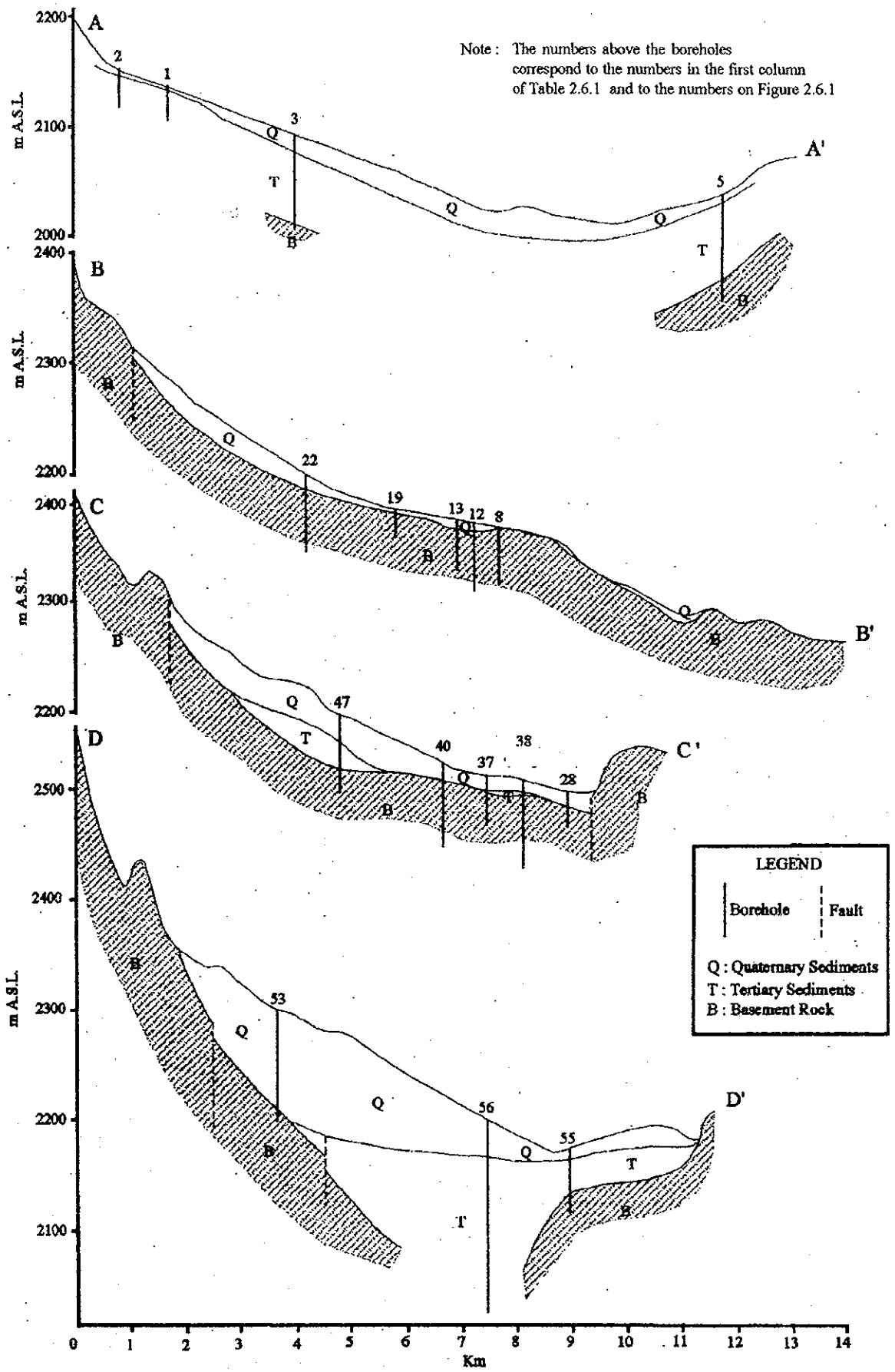


Figure 2.4.8 Schematic Geological Sections

JICA	The Study on Groundwater Development for Altai City

2.5 TEST WELL CONSTRUCTION

2.5.1 Location of the Wells

A total number of 10 wells were drilled in this study. The location of each test well was determined based on the results of satellite image and aerial photograph interpretation, geophysical survey and field survey at each site. Some other aspects that were taken into account when deciding the sites are, type of rocks at the sites, surrounding environment and distance from the city center.

The test wells are classified into two different categories, "A" series and "B" series, in terms of their target aquifer. "A" series wells target fissure aquifer as their principal water source while "B" series target alluvial aquifer as its main water source. The location of the test wells expressed in coordinate system is shown in Table 2.5.1 along with other relevant information. Their locations are also mapped in Figure 2.5.1.

2.5.2 Lithology of Wells

Lithology of each test well is compiled in Annex V of the Data Book together with well logging results and boring information. Generally speaking, lithological variation within a single borehole, especially in the basement rocks, is not so great. This is because all the wells are drilled in similar sedimentary settings and in the basement rocks with steep or nearly vertical dips.

For example, typical overlaying layers are those of quartenary alluvial sediments. These are alternation of thin sand layers and gravel layers with clay. The sorting of usually angular to sub-angular pebble and gravel is moderate but the matrix of the sand and gravel layers contains yellowish silt and clay to some extent. On the other hand, all of the "A" series well were drilled into hard basement rocks of Gobi-Altai and Ulaanlolgoy series that typically outcrop in and around Altai City. Deformation structures such as small faulting, kink folding and boudinage are common however all of which are old ones and consequently don't accompany open cracks.

Well B-5 and B-6 turned out to be very important in terms of production rate and water quality. The lithology of these two wells is given below.

B-5, B-6: These two wells are located in Oloon Nuur where thick blanket of alluvial sediment forms virtually flat topographic feature. This alluvial sediment comprises sand and sandy gravel layers in upper part and Tertiary reddish clay layers with some sand and gravel make up the lower part. Gravels are those of angular to subangular green rock, granitic gneiss, and small amount of peridotite and carbonate rocks.

2.5.3 Results of Logging

(1) General

Well logging is quite useful in getting more details of underground layers (i.e. detecting water bearing layers). It provides more direct information while geophysical and field survey gives only indirect and rough information. The logging was carried out immediately after the drilling of each well using a logging machine supplied by JICA.

The items that were measured and their measuring units are as follows

Item measured	Unit
resistivity short (16 inch)	ohm-m
resistivity long (64 inch)	ohm-m
natural gamma ray	Cps
spontaneous potential	MV
SPR	Ohms
temperature	degrees Celsius
conductivity	mS/cm

(2) Result of the logging

The logging result is graphed in Annex 5 of the Data Book. The logging data was used to determine the position of screens as well as to estimate the depth of water yielding layers.

2.5.4 Pumping Test

Two kinds of pumping test were carried out after each drilling was finished and the well was cleaned. Step draw down pumping test was first carried out in order to determine the proper discharge rate for the continuous pumping test. Then the constant discharge test was carried out with that discharge for the purpose of clarifying the characteristics of the aquifer.

Table 2.5.2 and Table 2.5.3 show the result of the step drawdown tests and the constant discharge tests, respectively. The figure indicates that A-3, A-4, B-5, and B-6 are more productive than the other test wells (see Figure 2.5.2).

Specific Capacity shows various values. The wells drilled in the north of Altai City have generally low Specific Capacity except A-4. Specific Capacity of B-5 and B-6 that were constructed in near Olon Nuur are higher than the others, especially the

value of B-6 is considerably high. A productive aquifer occurs most likely in this area.

Table 2.5.1 Drilling Data for the Wells

New No.	Location (Lat , Long.) (deg, min, sec)	Remarks	Dia. (mm)	Total Depth (m)	S.W.L GL-(AGLm	ground level (m)	casing stickup (m)	casing position, material (m)		Screen position,	Scr. Total (m)	Gravel pack	Drilling method	Rig	sampling date	*comple. date	Pump. test (cont.) D.W.L/Disch	Water Quality (hardness)
A1	N 46, 22, 19 E 96, 14, 50	East of the Park	244	200.3	11.12	2165	0.29	200	FRP	56-68, 86-92, 104-116, 128-140, 152-170, 182-194	72	yes	DTH, Rotary	SM-300H	8th Sep	3rd Sep.	87.91m/200l/mi	1000
A2	N 46, 24, 19 E 96, 18, 19	North of the bridge	244	193.0	2.6	2060	0.18	193	FRP	91-103, 109-127, 133-139, 157-169, 175-187,	60	yes	DTH, Rotary	SM-300H	6th Aug	4th Aug	7.8m/60l/min	373
A3	N 46, 24, 29 E 96, 11, 39	Upstreem of Khadaasan	244	150.3	3.91	2150	0.29	150	FRP	12-36, 60-72, 108-114, 138-144	48	yes	DTH, Rotary	SM-300H	13th Oct.	10th Oct.	64.58m/600l/mi	363
A4	N 46, 22, 50 E 96, 16, 42	Across the oil reservoir	244	160.2	4.61	2120	0.18	160	FRP	16-22, 28-40, 64-70, 100-118, 148-154	48	yes	Rotary	SM-300H	5th Oct.	23rd Sep.	16.1m/1000l/mi	1875
				703.8							228							
B-1	N 46, 22, 10 E 96, 14, 17	West of the park	244	56.2	20.14	2175	0.23	56	FRP	8-20, 26-38, 44-50	30	yes	Rotary	URB-2A	17th Sep.	5th Sep.	32.52m/74l/min	875
B-2	N 46, 25, 36 E 96, 18, 12	Easten edge of Sukhiin hooloi	244	73.6	11.67	2030	0.2	73	FRP	31-43, 49-61	24	yes	Rotary	URB-3A	15th Aug	8th Aug	22.61m/30l/min	845
B-3	N 46, 24, 55 E 96, 18, 26	Easten edge of Sukhiin hooloi	244	131.0	25.7	2050	0.33	130	FRP	76-94, 106-118	30	yes	Rotary	URB-3A	6th July	10th July	116m/80l/min	1950
B-4	N 46, 26, 04 E 96, 19, 38	on a dry river	244	41.6	4.2	2020	0.1	41	FRP	5-23, 29-41	30	yes	Rotary	URB-2A	2nd July	20th June	14.8m/75l/min	900
B-5	N 46, 20, 24 E 96, 19, 01	on a ex-riverbase	244	80.0	3.08	2157	0.2	80	FRP	26-38, 44-56, 68-74	30	yes	Rotary	URB-2A	19th July	10th July	23m/400l/min	225
B-6	N 46, 19, 11 E 96, 20, 45	outskirt of a fan on a small stream	244	120.0	24.51	2190	0.2	120	FRP	24-42, 48-54, 60-78 108-114	48	yes	Rotary	URB-2A	24th Sep.	5th Aug.	25.05m/60l/mi	258
				502.4							192							
				1206.2							420							

* Completion date: defined as the date when the rig was removed

Table 2.5.2 The Result of Step Drawdown Test

A-1 (Depth: 200 m) Altai Park

S.W.L 11.48 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	50	1.67	43.1
2nd step	100	5.95	24.2
3rd step	200	42.43	6.8
4th step	250	112.60	3.2

A-2 (Depth: 193 m) NE of Altai

S.W.L 2.82 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	20	0.61	47.2
2nd step	40	1.38	41.7
3rd step	60	3.41	25.3
4th step	80	6.94	16.6

A-3 (Depth: 150 m) Khadaasan

S.W.L 4.07 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	152	1.83	119.6
2nd step	300	6.33	68.2
3rd step	455	16.95	38.7
4th step	594	34.32	24.9

A-4 (Depth: 150 m) NE of Altai

S.W.L 4.61 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	200	0.98	293.9
2nd step	500	2.90	248.3
3rd step	750	5.99	180.3
4th step	1000	10.68	134.8

B-1 (Depth: 54 m) Altai Park

S.W.L 20.7 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	25	0.89	40.4
2nd step	50	2.35	30.6
3rd step	75	7.81	13.8
4th step	100	13.10	11.0

B-2 (Depth: 73.6 m) Downstream of Esuitiin Sair

S.W.L 12.37 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	30.4	14.85	2.9
2nd step	49.3	49.83	1.4

B-3 (Depth: 131 m) Downstream of Esuitiin Sair

S.W.L 26.06 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	20	5.98	4.8
2nd step	40	27.82	2.1
3rd step	60	33.30	2.6
4th step	80	89.94	1.3

B-4 (Depth: 41.6 m) Downstream of Esuitiin Sair

S.W.L 4.36 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	15	0.46	47.0
2nd step	50	1.31	55.0
3rd step	57	3.21	25.6
4th step	74	8.62	12.4
5th step	100	24.52	5.9

B-5 (Depth: 80 m) Olon Nuur

S.W.L 3.53 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	40	1.48	38.9
2nd step	60	2.00	43.2
3rd step	80	2.55	45.2
4th step	100	3.18	45.3
5th step	120	3.82	45.2
6th step	143	4.27	48.2
7th step	177	6.81	37.4
8th step	222	8.32	38.4
9th step	300	12.05	35.9
10th step	353	15.42	33.0
11th step	419	18.94	31.9
12th step	502	24.10	30.0

B-6 (Depth: 120 m) Olon Nuur

S.W.L 24.56 m

	Q (l/min.)	*ds* (m)	Sc (m^2/day)
1st step	150	0.08	2700
2nd step	300	0.29	1490
3rd step	450	0.57	1137
4th step	600	0.88	982

Table 2.5.3 The Summarized Result of Constant Discharge Test

New	Ground level	Drilled Dia.	Depth	Screen Pipes		S.W.L	S.W.L	P.W.L	Discharge rate	Drawdown	Specific capacity	Transmissivity (m^2/day)				Hydraulic conductivity
No.	(m.asl)	(mm)	(m)	Total length (m)	I.D (mm)	GL-m	m.asl	GL-m	Q (l/min)	ds (m)	Sc (m^2/day)	Cooper-Jacob	Huntush	Recovery	Average	(m/day)
A1	2165	244	200.3	(190)	(244)	11.12	2153.88	84.59	200	73.47	3.9	1.4	1.5	1.0	1.3	0.01
A2	2060	244	193.0	60	155	2.60	2057.40	7.62	59.6	5.02	17.1	10.6	10.9	9.7	10.4	0.17
A3	2150	244	150.3	(140)	(244)	3.90	2146.10	64.03	594	60.13	14.2	9.3	8.9	2.9	7.0	0.05
A4	2120	244	160.2	(150)	(244)	4.16	2115.84	15.65	1000	11.49	125.3	212	157	246	205	1.37
B-1	2175	244	56.2	34	155	20.15	2154.85	32.53	74	12.38	8.6	3.7	2.9	3.1	3.2	0.10
B-2	2030	244	73.6	24	155	11.67	2018.33	22.61	30	10.94	3.9	5.3	4.5	5.6	5.1	0.21
B-3	2050	244	131.0	30	155	25.22	2024.78	57.77	40	32.55	1.8	1.7	1.7	0.4	1.3	0.04
B-4	2020	244	41.6	(35)	(244)	4.20	2015.80	14.70	74	10.5	10.1	4.5	4.1	2.4	3.7	0.10
B-5	2157	244	80.0	30	155	3.22	2153.78	22.45	402	19.23	30.1	36.4	34.7	46.5	39.2	1.31
B-6	2190	244	120.0	42	155	24.01	2165.99	25.05	605	1.04	837.7	39456	16704	38016	31392	747

In brackets:open hole

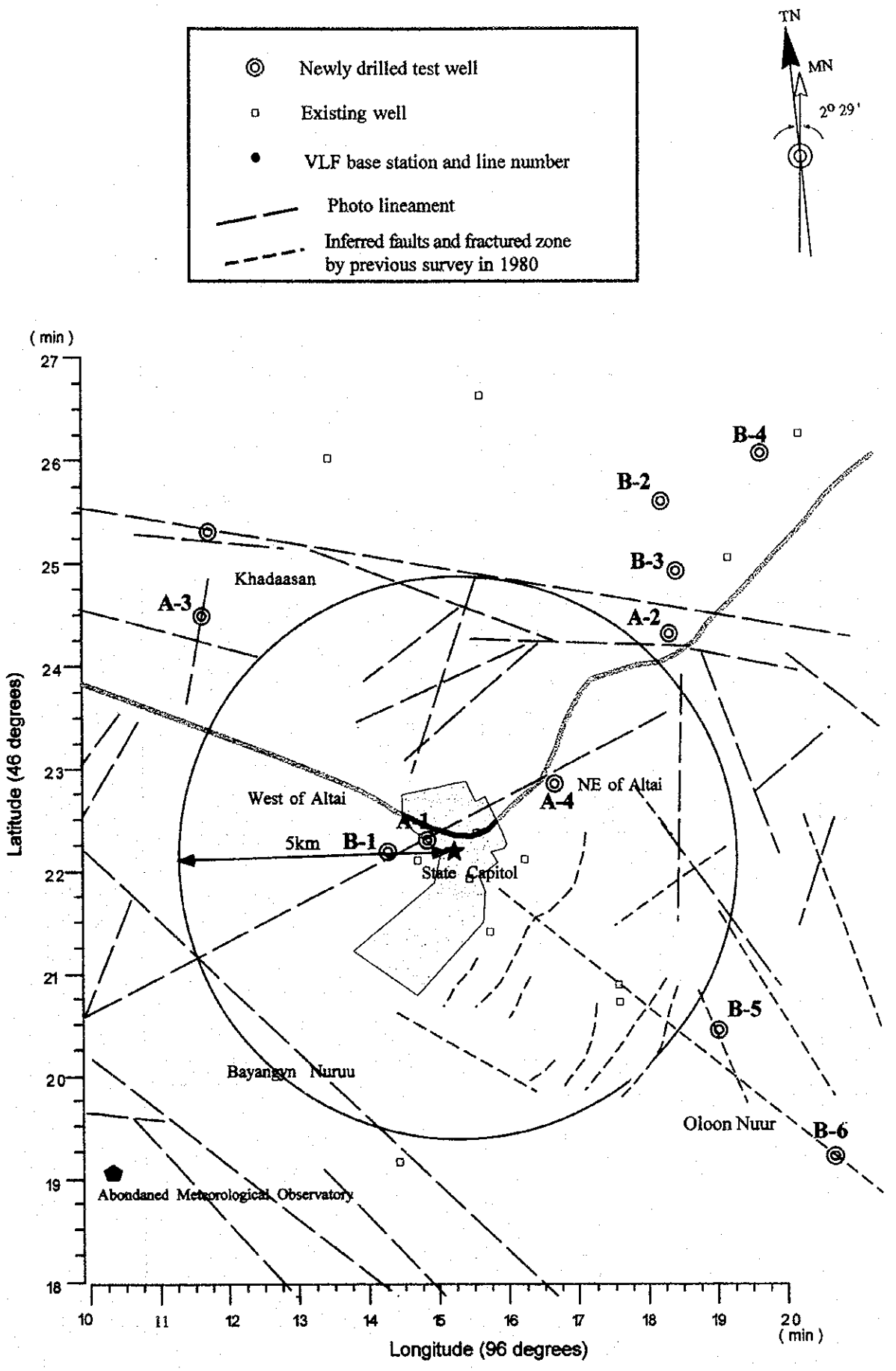


Figure 2.5.1 Location for Test Well

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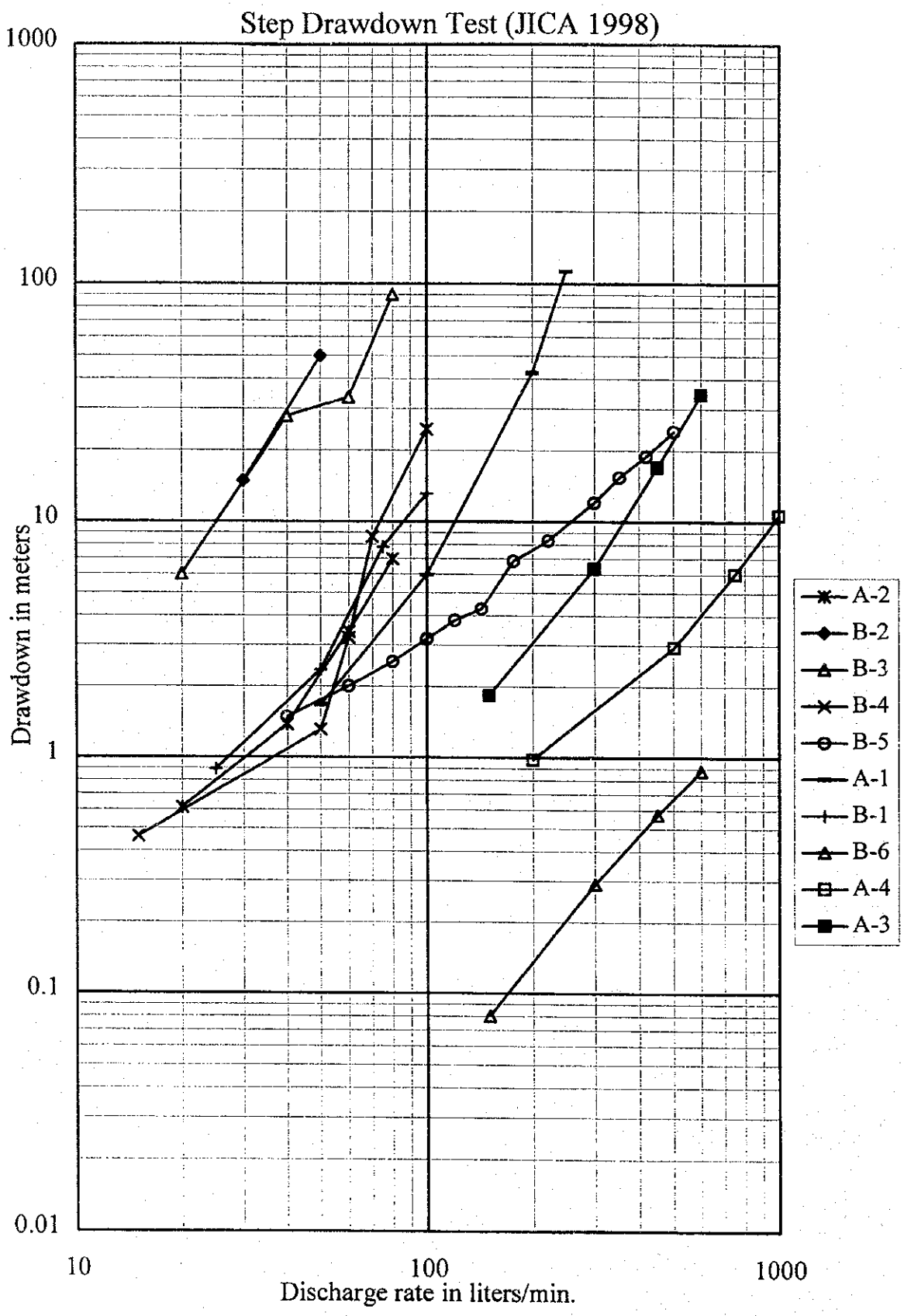

Figure 2.5.2 Result of Step-Drawdown Test for the Test Wells

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