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JAPAN INTERNATIONAL COOPERATION AGENCY
MINISTRY OF HEALTH, LAO PEOPLE'S DEMOCRATIC REPUBLIC

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES IN LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT
SUPPORTING REPORT

DECEMBER 1995

KOKUSAI KOGYO CO., LTD.
CONSTRUCTION PROJECT CONSULTANTS, INC.

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Currency Conversions

(As of July 1995)

US$1.00 = Kip 820

US$1.00 = Yen 88.45

Yen 1 = Kip 9.27

Composition of Reports

1.	Summary Report	English, Japanese and Lao Versions
2.	Main Report	English Version
3.	Supporting Report	English Version
4.	Data Book	English Version
5.	Operation and Maintenance Manual	Lao Version with English Text
6.	Hydrogeological Map	English Version

SUPPORTING REPORT

CHAPTER 1 ANALYSIS OF LANDSAT IMAGES

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1. ANALYSIS OF LANDSAT IMAGES

1.1 Outline of Analysis

An analysis of remote sensing images was conducted to help interpret the hydrogeologic features of the Study Area.

The satellite image analysis consisted of the following:

(1) Compilation of false color image
(2) Land cover classification
(3) Water content classification
(4) Comprehensive analysis

In (1) through (3), three kinds of thematic maps (scale: 1/200,000) were prepared using digital images obtained from LANDSAT TM data (Figure 1.1)

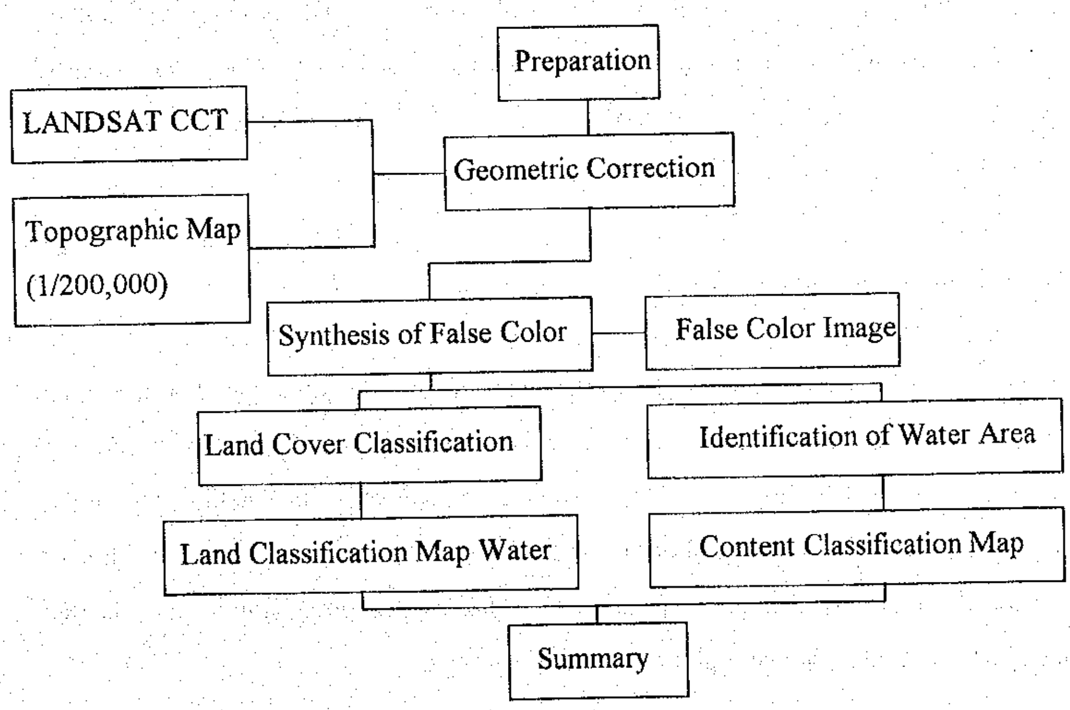

Figure 1.1 Flow Chart of Landsat Image Analysis

1.2 Procedure of Analysis

(1) Retrieval and acquisition of LANDSAT TM data

The data retrieved from EOSAT of the U.S.A. was examined for cloud cover and picture quality. As a result, two scenes, i.e. Path 126 - Row 49 and Path 126 - Row 50 taken on February 19, 1994, were selected (Figure 1.2). All acquired TM data used for the analysis were in magnetic tapes for CCT computer processing.

(2) Geometric correction

The LANDSAT TM data have an image that incline to the east by about 10 degrees and have greater gaps in the geographic position as compared with the topographic maps. Geometric correction was made to rectify these gaps.

Geometric correction is a process to eliminate the deviations in a LANDSAT image and convert the data so as to correspond with the coordinates of the topographic maps. The ground control points (GCP) were used in the geometric correction, and the LANDSAT coordinates were converted to topographic map coordinates.

(3) Compilation of false color image

The false color image is used to identify the natural environments and geographic features of the Study Area. It was also used as the basic map for site survey. Among the seven bands of LANDSAT TM data, the false color image was synthesized by placing the blue filter on Band 2, the green filter on Band 3 and the red filter on Band 4. These synthesized data were printed on the film using the image output photo-printer. The false color photographic map is then reproduced in 1/200,000 scale using photographic processing.

(4) Mapping of land cover classification

The land use of the Study Area is very complicated due to topographic changes. A land cover classification map was prepared by analyzing the LANDSAT images to identify suitable land for well drilling.

The land cover classification is analyzed using the maximum likelihood method, a multivariable analytical method. The training fields for each category were input to the automatic interpretation of the images.

It is necessary to obtain adequate knowledge and information of the field to determine the training fields and categories of classification.

Classification was made automatically based on the maximum likelihood method. However, a modification was made to obtain higher accuracy using existing data, interpretation of TM false color photographic map and digital image analysis. Based on this modification, a final land cover classification map (scale: 1/200,000) was made.

(5) Mapping of water content classification

Distribution of water area is easily identified by level slicing method. This method takes advantage of the nature of the near-infrared data (Band 4) which reflects absorption of light by water and is represented in dark color in the image. The water content classification map was prepared based on these data.

1.3 Results and Discussions

(1) False color image

Figures 1.3 (A) and (B) show the reduced pictures of the false color image. In the false color image, the forest is generally indicated by red color, the grassland by chinese yellow-pink color, and the farm land by white color. Table 1.1 shows the list of colors expressed in the false color image.

Table 1.1 Color of False Color Image

COLOR	LAND COVER
Red	Forest
Chinese yellow - pink	Grassland
White - bluish white	Farm land
Deep blue	Forest (deciduous)
Faint Blue	Village and others
Light blue	River and lake

As a whole, the Study Area is largely occupied by deep red colored areas with altitudes of 600m or higher. These areas are covered mostly by forest. With the neighboring countries like Cambodia and Thailand as examples, the areas of altitudes of 800m and higher are considered to be covered by evergreen trees.

Sixty percent (60%) of Laos are mountain areas, and low, flat lands are scarce. The areas expressed by bluish white color along the river at altitude of about 150m are farms, which was confirmed by site survey as mostly rice farms.

The small areas expressed by chinese yellow-pink color and scattered around mountain areas are grassland, which are considered to be cut-and-burn fields. Especially, the areas expressed by deep blue color and distributed among the deciduous forests are areas where no vegetation exists at present.

The areas expressed by bluish white-chinese yellow color in the mountain areas are grasslands, and deep red areas are distributed among the ecotone (mixed) forests.

The light blue areas scattered along rivers are flooded areas in the rainy season and may vary in size depending on the amount of rainfall.

Based on the false color image, the lineament of the Study Area was interpreted and presented on the map (Figure 1.4). The map presents the regional geological structures, such as fault, folding, syncline and anticline.

(2) Land cover classification map

After confirming the colors in the false color images, land covers in the images were categorized based on the results of the field survey (Figures 1.5.A and B). Table 1.2 shows the list of categories.

The red areas in the images are forests, and deep red areas at high altitudes are evergreen forests. It is known in the neighboring Thailand and Cambodia that evergreen trees cover the altitudes 800m and higher. However, they could not be clearly identified on the topographic map, but the areas indicated by a slightly faint color is identified as the ecotone.

Also, light red area is considered to be a rubber tree forest. Since the area is too wide, and artificial demarcation was not observed, it was included in the evergreen forest.

The flesh color (Chinese yellow) areas are considered to be cut-and-burn fields, and the reddish areas are grasslands. Areas covered by clouds were classified as "others".

Blue color indicates water areas. But its extent along rivers differs from the topographic map because water areas change annually depending on rainfall amount.

Table 1.2 List of Classification Categories

Categories
1 Evergreen forest
2 Deciduous forest
3 Mixed forest
4 Grassland
5 Farm land
6 Water area
7 Others

(3) Water content classification map

The water content of land surface was interpreted by intensity sectioning method using the Band 4 (Infrared band) of LANDSAT data. The mountain area has high water content, while the bear ground like farms has low water content. The level slicing process was used to classify areas into five (5) grades considering the land cover classification map. The water areas were clearly separated from the blue areas in the false color images.

The locations of the candidate villages to be studied in Phase II are plotted on the surface water content map (Figures 1.6.A-E). These villages are located not necessarily in water abundant areas because the map reflects the water content of the vegetation in the mountain area and not the water content of the real ground surface.

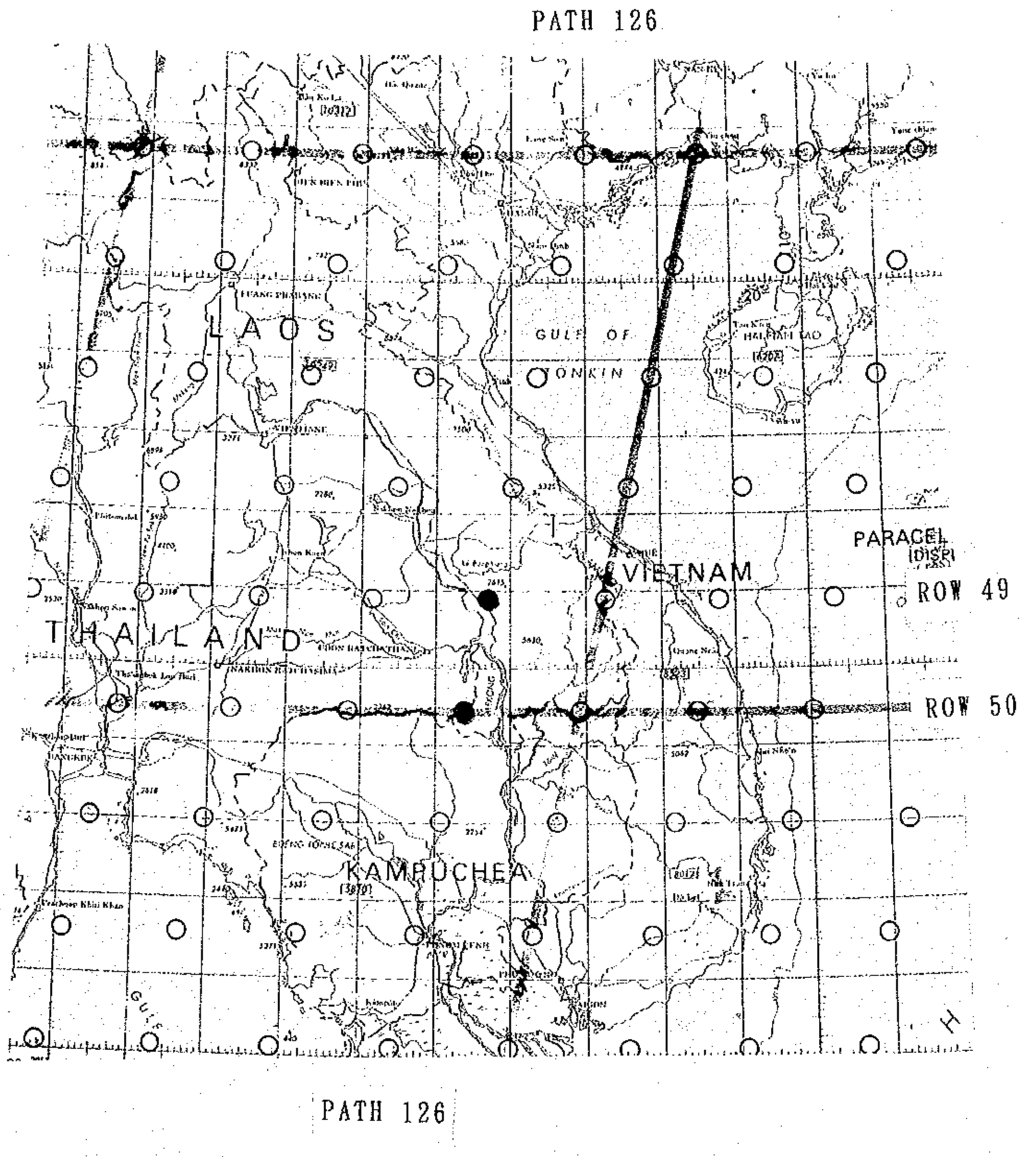

Figure 1.2	Landsat Coverage Map

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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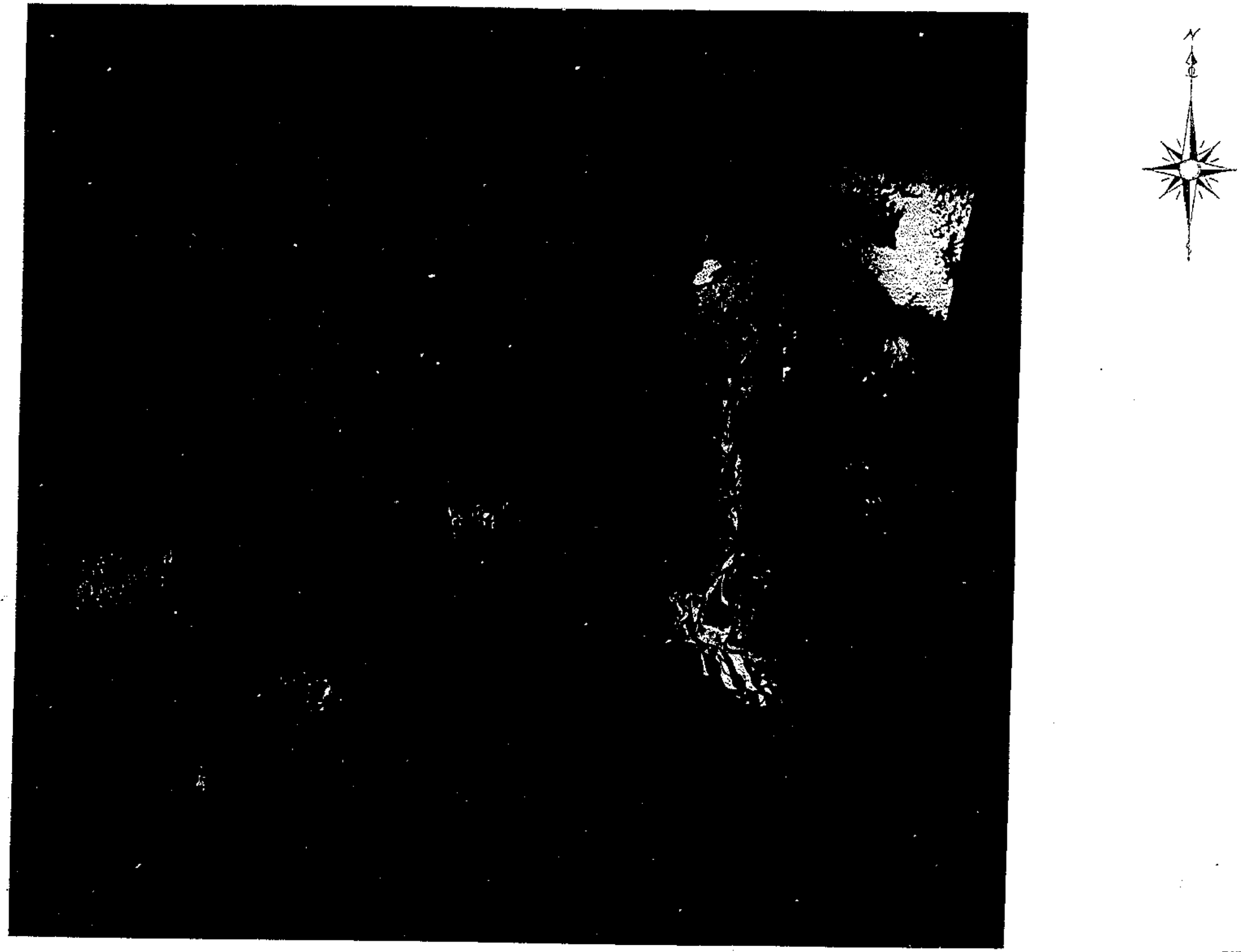

Figure 1.3A False Color Image 1

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

KOKUSAI KOGYO CO.,LTD. CONSTRUCTION PROJECT CONSULTANTS,INC.

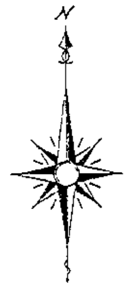

Figure 1.3B False Color Image 2

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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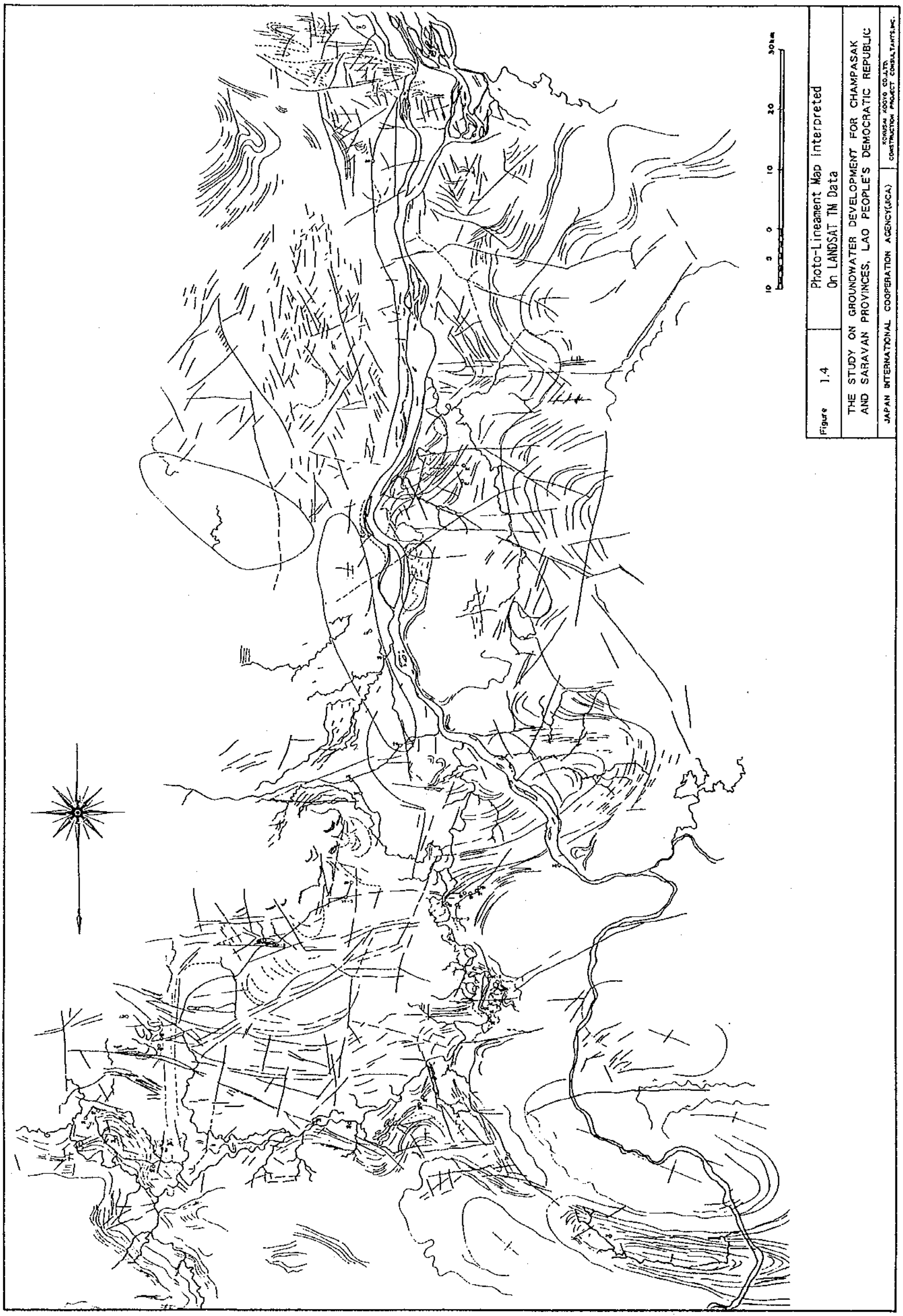
10 5 0 10 20 30km
Figure 1.4
Photo-Lineament Map Interpreted
On LANDSAT TM Data
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK
AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC
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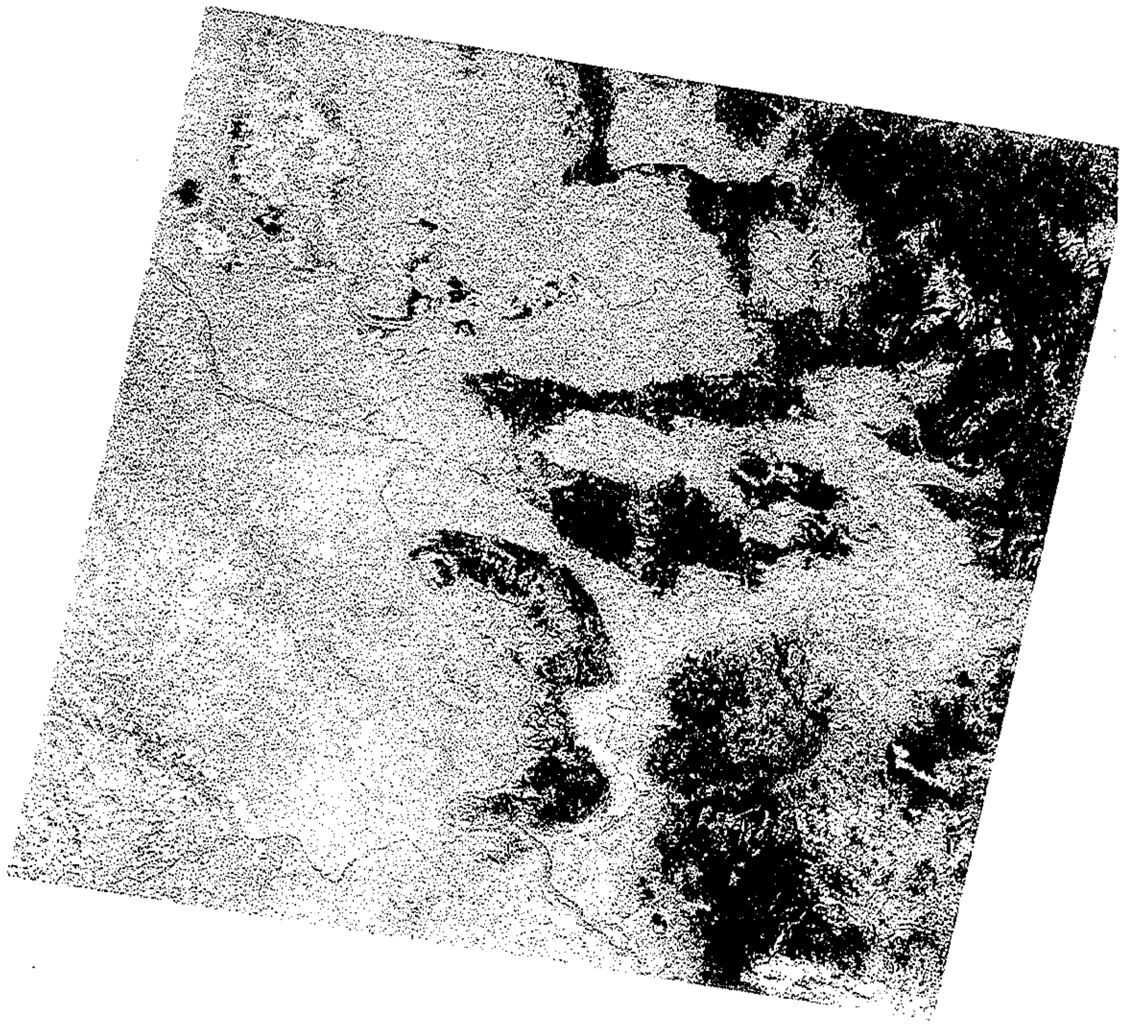

LEGEND

- Evergreen Forest
- Deciduous Forest
- Mixed Forest
- Grass
- Field
- Water
- Other

Figure 1.5A	Land Use Classification Image 1
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
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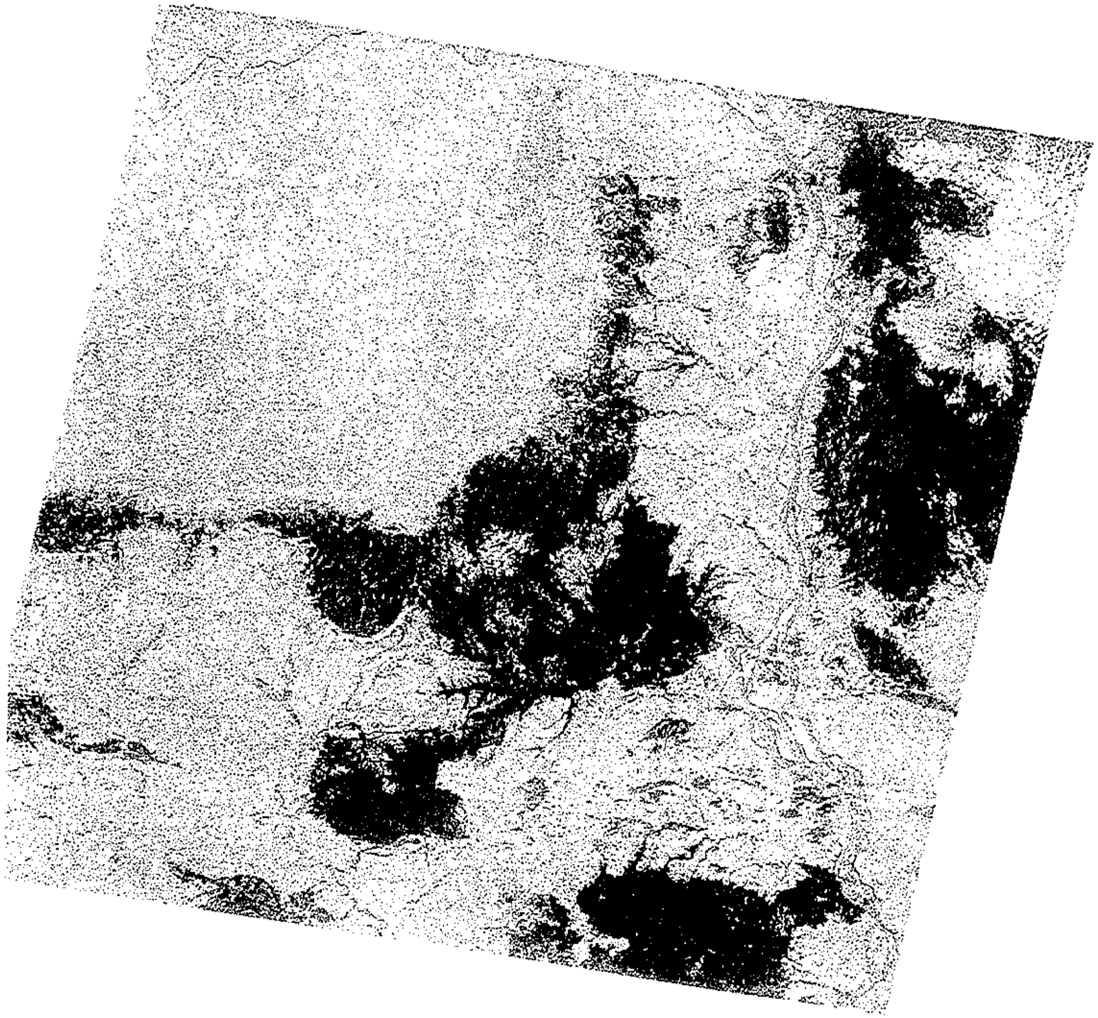

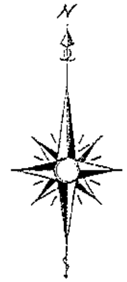

LEGEND

- Evergreen Forest
- Deciduous Forest
- Mixed Forest
- Grass
- Field
- Water
- Other

Figure 1.5B	Land Use Classification Image 2
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
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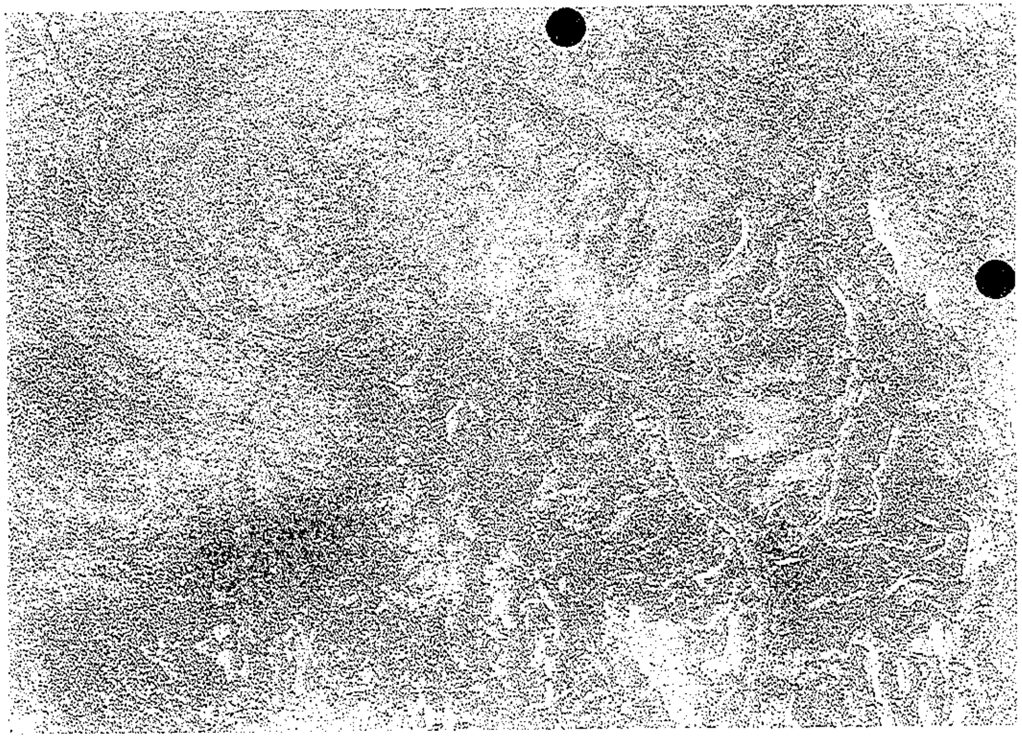

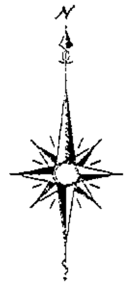

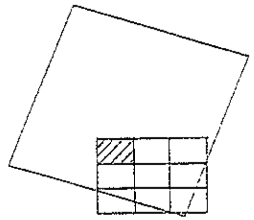

PATH126-ROW49

LEGEND

Water Area
More Abundant
Abundant
Middle
Scanty
PRIORITY SECTION

1 : 200,000

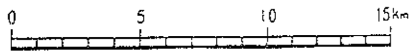

Figure 1.6A	Surface Water Content Image (1)
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
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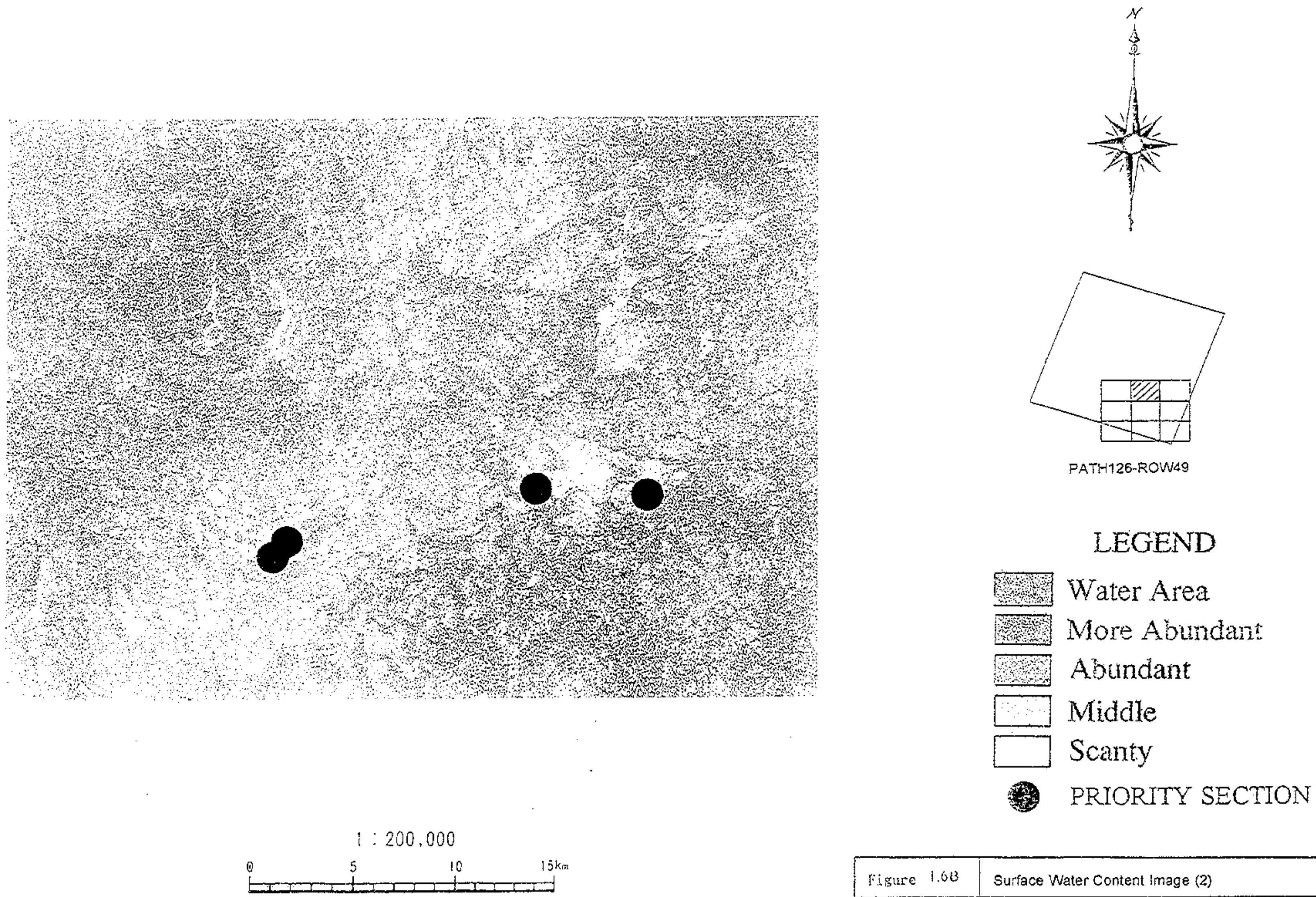

Figure 1.6B Surface Water Content Image (2)

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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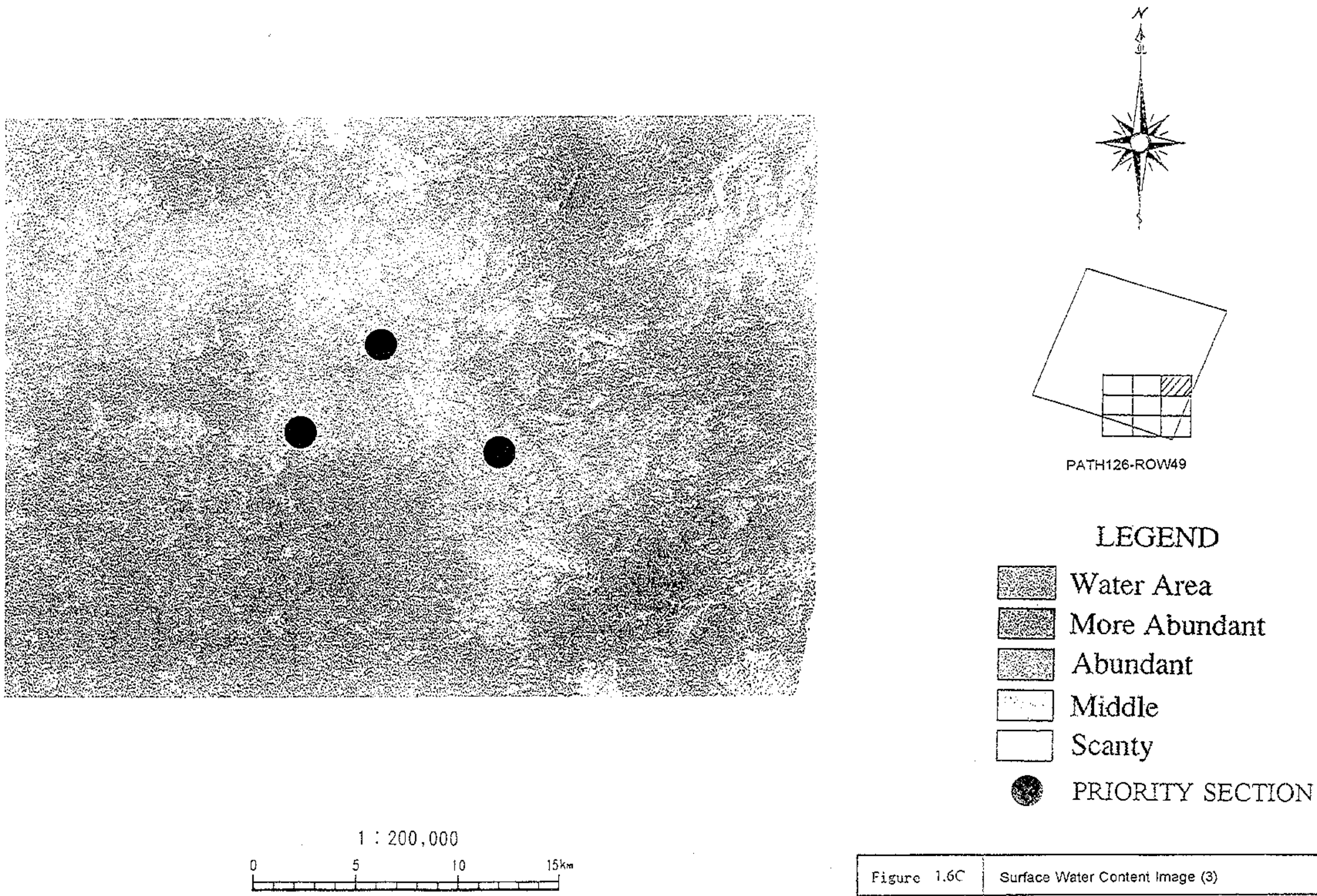

Figure 1.6C	Surface Water Content Image (3)
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
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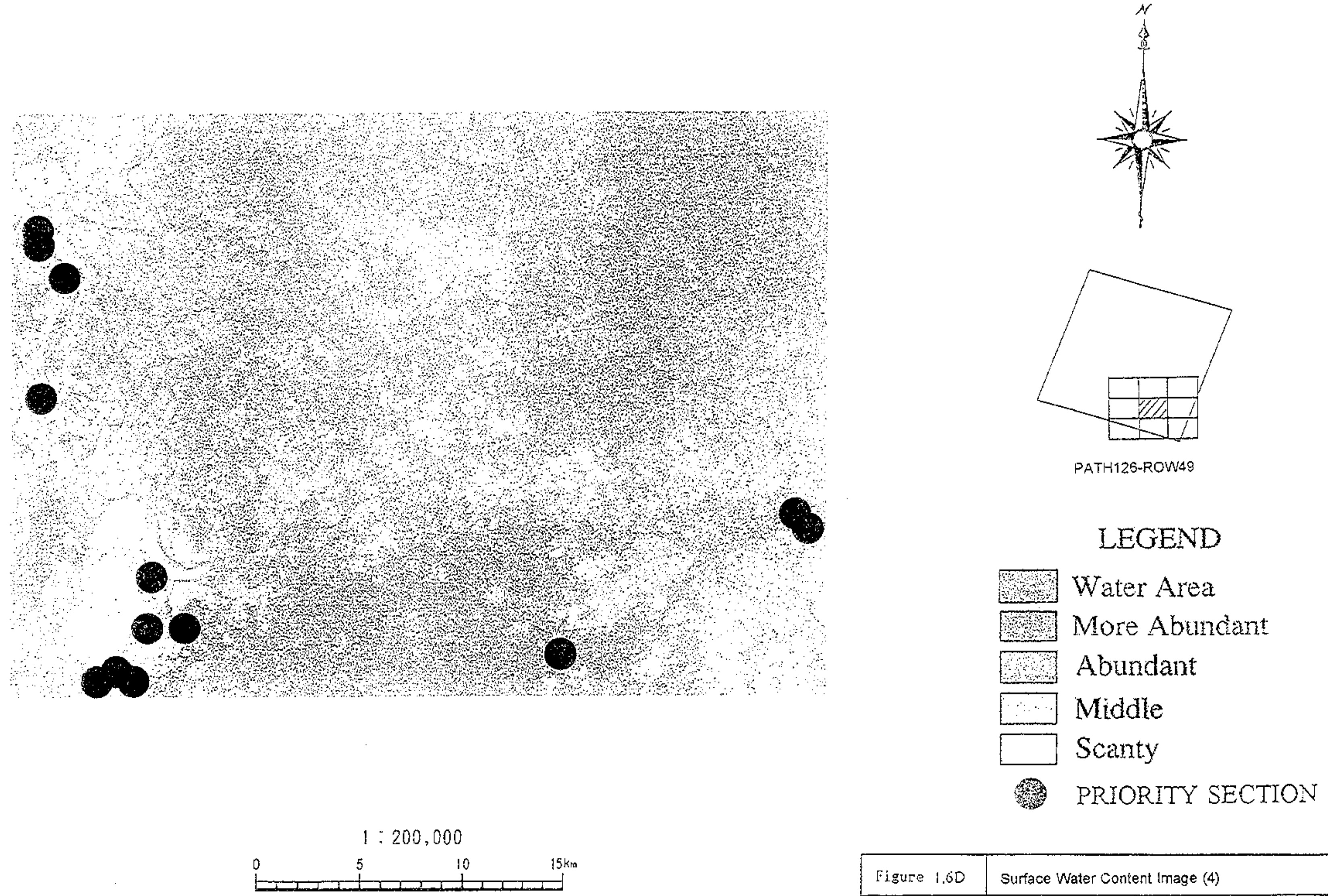

Figure 1.6D	Surface Water Content Image (4)

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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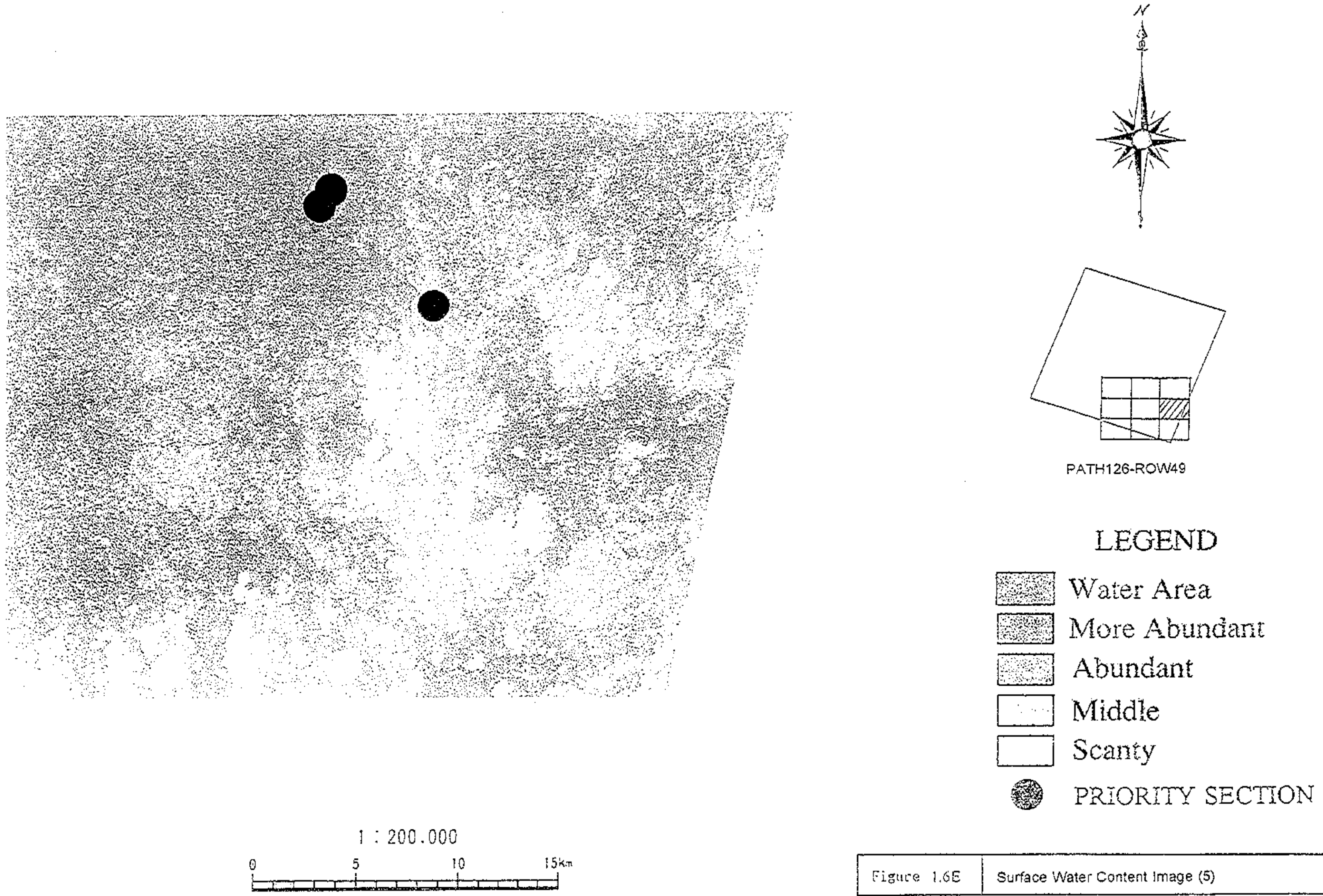

Figure 1.6E	Surface Water Content Image (5)
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
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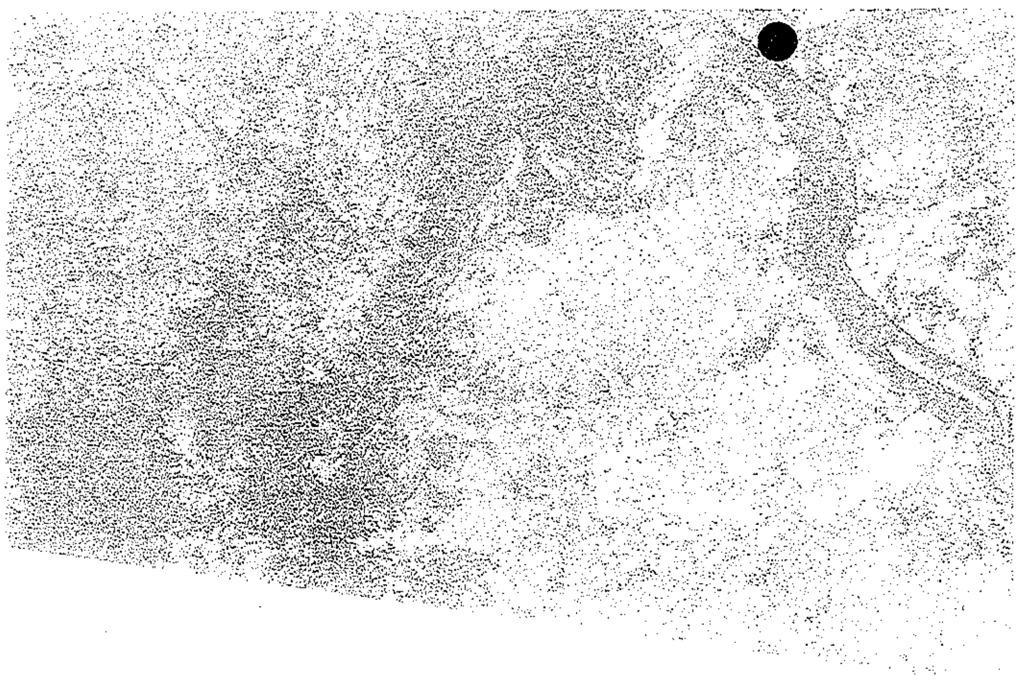

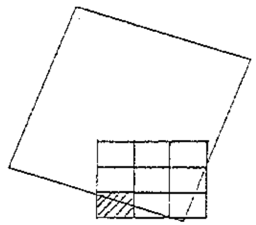

1 : 200,000

0 5 10 15km

LEGEND

- Water Area
- More Abundant
- Abundant
- Middle
- Scanty
- PRIORITY SECTION

Figure 1.6F	Surface Water Content Image (6)
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)	KOKUSAI KOGYO CO.,LTD. CONSTRUCTION PROJECT CONSULTANTS,INC.

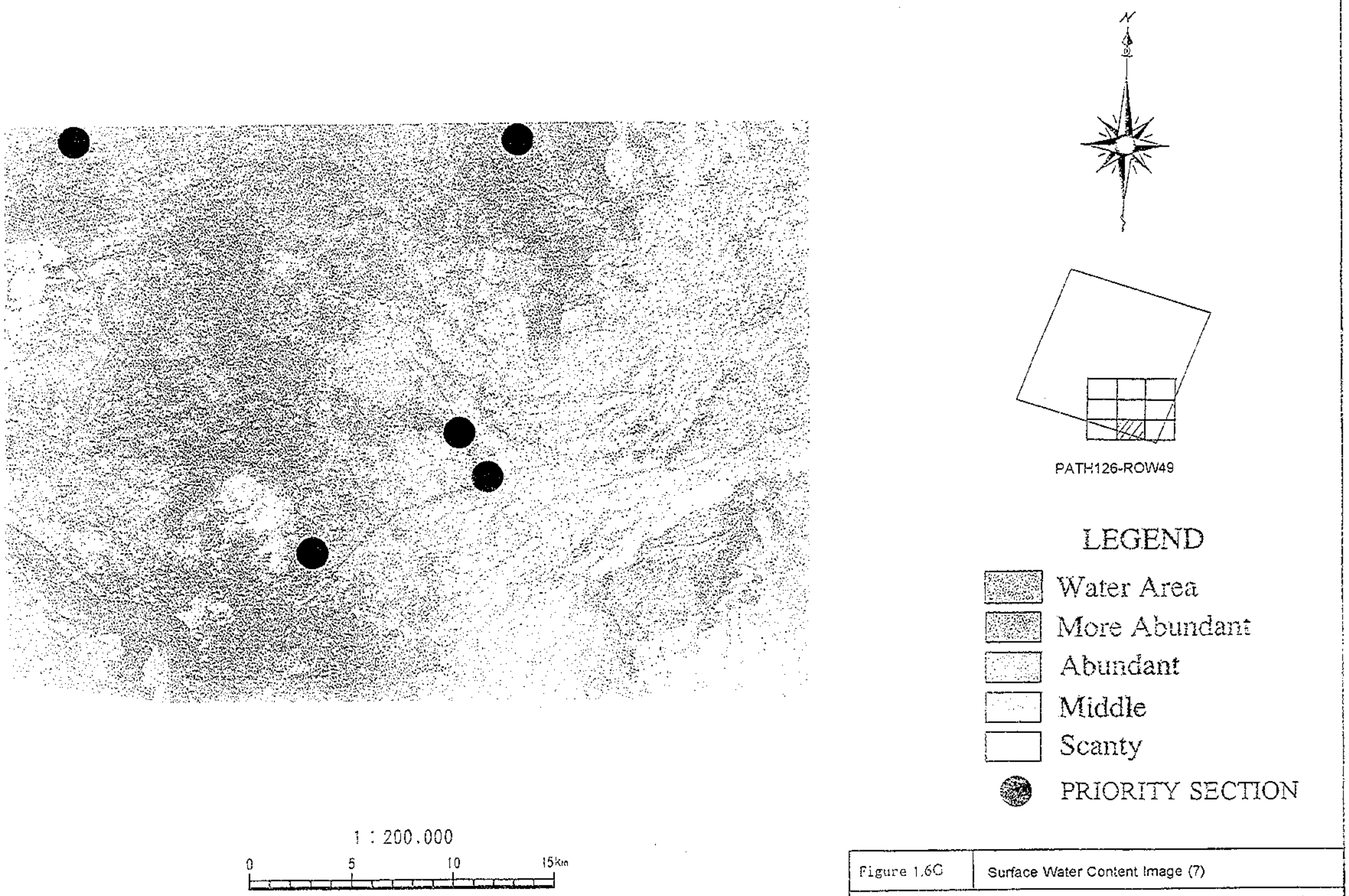

Figure 1.6C	Surface Water Content Image (7)
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
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SUPPORTING REPORT

CHAPTER 2 SELECTION OF PRIORITIZED AREA

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2. SELECTION OF PRIORITIZED AREA

2.1 Village Categorization

Based on the combination of geology and topography, the study area can be classified into ten (10) hydrogeologic units, i.e, Qf, Qt, Ep, Eh, Ba1, Ba2, Ba3, Et, P and M. All of the surveyed villages were categorized according to the hydrogological unit. Number of the categorized villages are as follows:

Village Categorization

Hydrogologic Unit	Champasak	Saravan
Qf	24	22
Qt	1	2
Ep	8	29
Eh	19	15
Ba1	21	4
Ba2	13	13
Ba3	4	15
Et	10	-
P	-	-
M	-	-

The villages are also categorized according to their main water sources, i.e., river, dug well, borehole, pond, spring and others. Percentage of each water sources in two provinces are illustrated in Figure 2.1. Therefore, all villages can be classified according to the combination of hydrologic unit and water source.

2.2 Selection of Prioritized Area

A total of forty (40) villages were selected as the prioritized area for detailed study in Phase II. The following conditions were considered in the selection of the village.

(1) Community conditions

Present status of water sources in the 200 villages in Champasak and Saravan provinces was surveyed in detail. According to this survey, the following factors were essential in planning groundwater development.

1) Borehole requirement

Safe and clean water are needed in those villages where dug well and pond are mainly used for supply and shortage of water frequently happens in the dry season. Some villages already have boreholes (tube wells) equipped with Dempster hand pumps, which were installed late 1960's. However, most of the pumps are not functioning well or broken. Construction of new wells is necessary for these villages. More than 50% of the villages use river and spring for their water supply. However, some of water sources are contaminated and dry up. Considering status of existing water source, villages can be evaluated form the viewpoint of necessity of new boreholes. Therefore village needs can be qualitatively ranked as A, B and C.

A : Water source is very poor
B : Water source is poor
C : Water source is good

2) Urgency of countermeasures

Due to shortage and inferior quality of water, many patients contracted by Malaria and diarrhea were seen in the villages. It was observed that the number of patients might be proportional to poorness of water supply. Health factor must be primarily taken into consideration in evaluation of the urgency of countermeasures. Therefore, the villages were ranked as follows:

A : Very urgent
B : Urgent
C : Ordinary

3) Social consciousness

Community participation in the operation and maintenance of the water supply system is an essential part of groundwater development project. Most of the surveyed villages showed their willingness to pay for operation and maintenance costs, though their financial status is low. Organization of water management administration of the village is also understood by most of villagers. In the prioritization of the villages, the social consciousness was ranked qualitatively as follows:

A : eager
B : positive
C : ordinary

4) Accessibility

The surveyed villages are mostly located along the main road of Champasak and Saravan, however, road condition is particularly bad in the rainy season and some villages located several hundred meters far from the main road are not accessible by vehicle even in the dry season. Accessibility to the village is an important factor for conducting study in limited time. Therefore, it was evaluated according to the following :

A : Access is good
B : Access is poor
C : Access by vehicle is difficult

Factors as mentioned above were comprehensively evaluated and each village was ranked individually as shown in Table 2.1 (Champasak) and Table 2.2 (Saravan).

(2) Hydrogeological condition

As mentioned previously, all villages were categorized according to hydrogeologic unit. In addition, water level in the dry season and the yield of shallow tube well, and groundwater potential of the hydrogeologic unit were evaluated for prioritization.

1) Water level (Depth of water table)

The water levels were classified into:

S : 0 - 5 m

M: 5 -10 m

D : more than 10 m

2) Yield

L : 0 - 5 m^3/hour

M: 5 - 10 m^3/hour

H : more than 10 m^3/hour

3) Groundwater potential

Considering two factors mentioned above, groundwater potential was evaluated individually as:

A : High

B : Medium

C : Low

Consequently, forty (40) villages ranked "A" were selected according to the combination of conditions of community and groundwater potential (Figure 2.2). The distribution of the selected villages by hydrogeological unit is shown in Table 2.3 and by districts in Table 2.4. The tables indicate that the selected villages represent each category of hydrogeology and of district in the provinces.

Champasak Province

1) Sanasomboon District (8 villages)

No.C-4 B. Nongphai, No.C-7 B. Nongdou, No.C-8 B. Houaxe, No.C-10

B. Dong, No.C-12 B. Nongkham, No.C-15 B. Nongkhen, No.C-16 B. Louy, No.C-24 B. Boungkha

2) Bachiang District (5 villages)
   No.C-42 B.Thongkim, No.C-44 B.Thongsala, No.C-48 B.Phasouam, No.C-49 B.Lak-21, No.C-53 B.Nongkhamkhao
3) Pathoomphone District (3 villages)
   No.C-65 B.Lak-24, No.C-67 B.Houakhoua, No.C-75 B.Nongkhe
4) Sukhuma District (2 villages)
   No.C-78 B.Bak, No.C-79 B.Samkhanboua
5) Khong District (2 villages)
   No.C-88 Maisivilai, No.C-89 B.Nasenphan

Saravan Province

1) Lakhonepheng District (2 villages)
   NO.S-4 B.Houaykapho, No.S-12 B.Nongsano
2) Khongxedon (5 villages)
   No.S-24 B.Donmuang, No.S-25 B.Hinxiou, No.S-30 B.Nonsamlan, No.S-35 B.Hatdou, No.S-38 B.Kouttabeng
3) Vapy District (4 villages)
   No.S-39 B.Nongngong, No.S-48 B.Mouang, No.S-50 B.Samia, No.S-56 B.Chong
4) Saravan District (7 villages)
   No.S-64 B.Phonphai, No.S-70 B.Saokadi-Tai, No.S-74 B.That-Noy, No.S-75 B.Nakasao, No.S-84 B.Beng, No.S-87 B.Lavang, No.S-88 B.Senvang-Noy
5) Lao ngam District (2 villages)
   No.S-99 Beng, No.S-100 B.Houn-Tai

The selected method of 40 villages are as shown in Figure 2.2.

2.3 Test Well Drilling Sites

Twenty (20) test well drillings will be conducted at the selected village in the Phase II of the study. Test wells will be converted to pilot water supply systems by installation of pumps and construction of facilities, such as communal faucet and water tank. Purpose of test well drilling and construction of pilot water supply systems are as follows:

- To obtain hydrogeological information of each hydrogeologic unit
- To obtain design standard of the water supply systems
- To verify village capability of operation and maintenance
- To demonstrate pilot water supply system to rural communities for improvement of health conditions

Urgency and accessibility of the village were considered in the selection of test well drilling sites.

The 20 villages from the provinces of Champasak and Saravan that were given priority as shown below. The location map of these villages is illustrated in Figure 2.3.

<u>Champasak Province</u>

District Name	Village No.	Hydrogeologic Unit	Village Name
1. Sanasomboon	C- 4	E h	B.Nongphai
2. Sanasomboon	C- 8	Qf	B.Houaxe (submersible Pump)
3. Sanasomboon	C-16	Eh	B.Louy
4. Bachiang	C-44	Ba2	B.Thongsala
5. Bachiang	C-49	Ba1	B.Lak-21
6. Pathoomhone	C-65	Ba3	B.Lak-24
7. Pathoomhone	C-75	Qf	B.Nongkhe
8. Sukhma	C-79	Ep	B.Samkhanaboua
9. Khong	C-88	Et	B.Maisivilai
10. Khong	C-89	Et	B.Nasenphan

Saravan Province

District Name	Village No.	Hydrogeologic Unit	Village Name
11. Lakonepheng	S- 4	Eh	B.Houaykapho
12. Lakonepheng	S-12	Eh	B.Nongsano
13. Khongxedon	S-24	Qf	B.Donmuang
14. Khongxedon	S-38	Ep	B.Kouttabeng
15. Vapy	S-50	Qf	B.Samia
16. Vapy	S-56	Ba3	B.Chong
17. Saravan	S-64	Ep	B.Phonphai
18. Saravan	S-75	Ep	B.Nakasao
19. Saravan	S-84	Ba2	B.Beng (submersible pump)
20. Lao ngam	S-100	Ba1	B.Houn-Tai

Figure 2.4.a and 2.4.b show the geologic columns of the selected forty villages estimated from the gelogical and geophysical surveys.

Table 2.1 (1/4) Hydrogeological Data and Test Boring Sites Evaluation (Champasak)

No.	District and Village Name	①Surface Grading for Village Survay	②Hydrogeologically Based Groundwater Potential				Evaluation ①+②	Selected Villages ○
			1) Hydro-geological Types	2) Water TableDepth Dry season	3) Shallow ,Tubewell Yield	4) Ground-water Potential		
Sanasomboon District								
C- 1	B.Nakham	B	Qf	(M)	(M)	A	A	
C- 2	B.Phonthat	(A)	Eh	D	(M)	C	B	
C- 3	B.Nonsavan	A	Eh	D	(M)	C	B	
C- 4	B.Nongphai	(A)	Eh	D	(M)	B	A	○
C- 5	B.Souvannakihli	A	Qf	(D)	(M)	B	B	
C- 6	B.Nanai	A	Eh	(M)	(M)	B	B	
C- 7	B.Nongdou	(A)	Eh	M	(M)	B	A	○
C- 8	B.Houaxe	(A)	Qf	(M)	(H)	B	A	○
C- 9	B.Pongsan	A	Eh	S	(M)	B	B	
C-10	B.Dong	(A)	Eh	(S)	(M)	B	A	○
C-11	B.Hangam	A	Eh	D	(L)	C	B	
C-12	B.Nongkham	(A)	Eh	S	(M)	B	A	○
C-13	B.Khampeng	A	Eh	(M)	(M)	B	B	
C-14	B.Khamngoua	A	Eh	(M)	(M)	B	B	
C-15	B.Nongkhen	(A)	Eh	(M)	(M)	B	A	○
C-16	B.Louy	(A)	Eh	M	M	B	A	○
C-17	B.Solo-Gnai	B-C	Qf	(M)	(M)	A	B	
C-18	B.Solo-Noy	A-B	Qf	(M)	(M)	A	B	
C-19	B.Xonphak	A	Eh	M	M	B	B	
C-20	B.Khamlouang	A	Eh	(M)	(L)	C	B	
C-21	B.Sithouan	B	Eh	M	(L)	C	C	
C-22	B.Mouang	B-C	Qf	M	H	A	B	
C-23	B.Okumuana	B	Qf	(M)	(H)	A	A	
C-24	B.Boungkha	A	Qf	(M)	(H)	A	A	○
C-25	B.Latsua(Nongmek)	B-C	Qf	(M)	(H)	A	B	
C-26	B.Nalak	B	Ep	M	H	A	A	
C-27	B.Dongkalong	A	Eh	M	(M)	B	B	

Remak:1)To see Fig.A, 2)S=0-5,M=5-10,D=Over10m, 3)L=0-5,M=5-10,H=Over10 t/h, 4)A=Hight,B=Usual,C=Low

Table 2.1 (2/4) Hydrogeological Data and Test Boring Sites Evaluation (Champasak)

No.	District and Village Name	①Surface Grading for Village Survay	②Hydrogeologically Based Groundwater Potential				Evaluation ①+②	Selected Villages ○
			1) Hydro-geological Types	2) Water TableDepth Dry season	3) Shallow .Tubewell Yield	4) Ground-water Potential		
C-28	B.Nalong	A-B	Ep	S	H	A	A	
C-29	B.Naxon	B	Ep	M	(H)	B	B	
C-30	B.Thangbengsivilai	B	Eh	M	M	B	B	
C-31	B.Nonxat	A-B	Ep	D	H	B	B	
C-32	B.Donphek	A-B	Eh	D	(L)	C	C	
C-33	B.Dua-Nua	A-B	Qf	(M)	(H)	A	A	
C-34	B.Kengkeo	B-C	Qf	(M)	(H)	A	B	
C-35	B.Ngouadeng	B-C	Qf	(M)	(H)	A	B	
C-36	B.Pakxon	B	Qf	D	(M)	B	B	
	Sub-Total							8
Bachiang District								
C-37	B.Nongsai	C	Ba_3	(M)	(M)	C	C	
C-38	B.Bachiang	B	Ba_1	M	(M)	B	B	
C-39	B.Makngeo	A	Ba_1	(M)	(M)	B	B	
C-40	B.Nongbok-Noy	A	Ba_1	(M)	(M)	B	B	
C-41	B.Nongbok-Gnai	B-C	Ba_1	(M)	(M)	B	B	
C-42	B.Thongkim	A	Ba_1	M	(H)	A	A	○
C-43	B.Kenggnao	C	Ba_2	(M)	(H)	A	B	
C-44	B.Thongsala	A	Ba_2	(S)	(M)	A	A	○
C-45	B.Mouangkhai	A	Ba_1	D	(L)	C	B	
C-46	B.Pakonay	(A)	Ba_1	D	(L)	C	B	
C-47	B.Oudomsouk	A	Ba_1	D	H	B	B	
C-48	B.Phasouam	(A)	Ba_1	D	M	B	A	○
C-49	B.Lak-21	(A)	Ba_1	(D)	(M)	B	A	○
C-50	B.Phin	A	Ba_1	D	H	B	B	
C-51	B.Lak-23	A-B	Ba_1	D	H	B	B	
C-52	B.Lak-25	B	Ba_1	D	H	B	B	
C-53	B.Nongkhamkhao	A	Ba_1	(D)	(H)	A	A	○

Remak: 1) To see Fig.A, 2) S=0-5, M=5-10, D=Over10m, 3) L=0-5, M=5-10, H=Over10 t/h, 4) A=Hight, B=Usual, C=Low

Table 2.1 (3/4) Hydrogeological Data and Test Boring Sites Evaluation (Champasak)

No.	District and Village Name	①Surface Grading for Village Survay	②Hydrogeologically Based Groundwater Potential				Evalua-tion ①+②	Selected Villages ○
			1) Hydro-geological Types	2) Water TableDepth Dry season	3) Shallow ,Tubewell Yield	4) Ground-water Potential		
C-54	B.Senkeo	A-B	Ba1	(D)	(M)	C	B	
C-55	B.Houayten	A	Ba1	D	M	B	B	
C-56	B.Talan (B.Lak-17)	A	Ba1	D	M	B	B	
C-57	B.Nonsaat	A-B	Ba1	D	M	B	B	
C-58	B.Nongmak-Euk	A-B	Ba1	M	H	A	A	
C-59	B.Lak-13	A	Ba1	M	(M)	B	B	
C-60	B.Nonhouaydua	A	Ba2	(M)	(M)	B	B	
C-61	B.Kagno	A-B	Ba2	(M)	(M)	B	B	
	Sub-Total							5
Pathoomphone District								
C-62	B.Lak-19	A	Ba2	(M)	(M)	B	B	
C-63	B.Lak-20	A	Ba2	(M)	(M)	B	B	
C-64	B.Mophou	B	Qf	(M)	(M)	A	A	
C-65	B.Lak-24	(A)	Ba3	(S)	(M)	B	A	○
C-66	B.Sanamxaysouk	A	Ba3	(S)	(M)	B	B	
C-67	B.Houakhoua (L-29)	(A)	Ba2	D	(M)	B	A	○
C-68	B.Lak-31	A-B	Ba2	D	(L)	C	B	
C-69	B.Lak-34	A	Ba2	S	(M)	B	B	
C-70	B.Khouatouay (L-36)	A-B	Ba2	(M)	(M)	B	B	
C-71	B.Tomo-Nak	A-B	Ba2	M	(M)	B	B	
C-72	B.Tao-Tai	B	Ba2	S	(M)	B	B	
C-73	B.Nakham-Noy	A	Ba2	S	(M)	B	B	
C-74	B.Thangbeng	A-B	Ba3	S	(M)	B	B	
C-75	B.Nongkhe	A	Qf	M	(M)	A	A	○
C-76	B.Napho	B-C	Qf	(M)	(M)	A	B	
	Sub-Total							3
Sukhuma District								
C-77	B.Chikthangngo	A	Ep	M	(M)	B	B	

Remak: 1) To see Fig.A. 2) S=0-5.M=5-10.D=Over10m. 3) L=0-5.M=5-10.H=Over10 t/h. 4) A=Hight.B=Usual.C=Low

Table 2.1 (4/4) Hydrogeological Data and Test Boring Sites Evaluation (Champasak)

No.	District and Village Name	①Surface Grading for Village Survay	②Hydrogeologically Based Groundwater Potential				Evaluation ①+②	Selected Villages ○
			1) Hydro-geological Types	2) Water TableDepth Dry season	3) Shallow ,Tubewell Yield	4) Ground-water Potential		
C-78	B. Bak	(A)	Ep	(M)	(M)	B	A	○
C-79	B. Samkhanaboua	(A)	Ep	(M)	(M)	B	A	○
C-80	B. Phonpheung	B-C	Qf	M	(M)	A	B	
C-81	B. Pako	B	Ep	M	(M)	B	B	
C-82	B. Thapcham	B	Qf	M	(H)	A	A	
C-83	B. Kouttaboun	B-C	Qf	S	(M)	A	B	
	Sub-Total							2
Khong District								
C-84	B. Boun-Tai	B-C	Qf	(M)	(M)	A	B	
C-85	B. Keng	B	Qf	(M)	(M)	A	A	
C-86	B. Phonsaat	A	Et	(D)	(L)	C	B	
C-87	B. Naveng	A	Et	M	(L)	C	B	
C-88	B. Maisivilai	(A)	Et	(S)	(L)	B	A	○
C-89	B. Nasenphan	(A)	Et	S	(L)	B	A	○
C-90	B. Naxuak (Hang)	B	Et	D	(L)	C	C	
C-91	B. Xongpuay	B-C	Qf	(M)	(M)	A	B	
C-92	B. Nasomhong	B	Et	M	(L)	C	C	
C-93	B. Boung	A-B	Qf	(M)	(M)	A	A	
C-94	B. Hatxaykhoun	A-B	Et	(M)	(L)	C	B	
C-95	B. Veunkhao	A-B	Qf	(M)	(M)	A	A	
C-96	B. Phondeng	B	Et	(M)	(L)	C	C	
C-97	B. Kadan	B	Qf	(M)	(M)	A	A	
C-98	B. Khinak	B-C	Et	(M)	(L)	C	C	
C-99	B. Settaolek	A	Et	(M)	(L)	C	B	
C-100	B. Tapusy	B-C	Qt	S	(L)	C	C	
	Sub-Total							2
	TOTAL							20

Remak: 1) To see Fig.A. 2) S=0-5.M=5-10.D=Over10m. 3) L=0-5.M=5-10.H=Over10 t/h. 4) A=Hight.B=Usual.C=Low

Table 2.2 (1/4) Hydrogeological Data and Test Boring Sites Evaluation (Saravan)

No.	District and Village Name	①Surface Grading for Village Survey	② Hydrogeologically Based Groundwater Potential				Evaluation ① + ②	Selected Village ○
			1) Hydro-geological Types	2) Water TabldDepth Dry season	3) Borehole Yield	4) Ground-water Potential		
Lakhonepheng District								
S- 1	B.Nonsavang	A	Eh	(D)	(L)	C	B	
S- 2	B.Nadou	B	Eh	M	(M)	B	B	
S- 3	B.Nadoumai	B	Eh	M	(M)	B	B	
S- 4	B.Houaykapho	A	Eh	M	(H)	A	A	○
S- 5	B.Lakhosi-Tai	B	Eh	M	(M)	B	B	
S- 6	B.Lakhosi-Nua	(A)	Eh	(D)	(L)	C	B	
S- 7	B.Khonsay	A	Eh	(D)	(L)	C	B	
S- 8	B.Kengpadek	A	Eh	(M)	(M)	B	B	
S- 9	B.Nondinxay	A	Eh	M	(M)	B	B	
S-10	B.Nakhandai	B	Eh	M	(H)	A	A	
S-11	B.Phoudaocheng-Noy	A	Eh	M	(M)	B	B	
S-12	B.Nongsano	A	Eh	M	M	B	A	○
S-13	B.Phoudaocheng-Gnai	A	Eh	M	(M)	B	B	
S-14	B.Thangbeng	A	Eh	S	(M)	B	B	
S-15	B.Bouttaphan	A	Ep	M	(M)	B	B	
S-16	B.Houaykhen	B	Ep	M	(M)	B	B	
	Sub-Total							2
Khongxedon District								
S-17	B.Napong	B	Ep	M	M	B	B	
S-18	B.Vang Kan Hong	B	Qf	M	L	B	B	
S-19	B.Napheng-Gnai	B	Eh	M	L	C	C	
S-20	B.Khong-Noy	B	Qf	(M)	(M)	A	A	
S-21	B.Nongsaphang	A	Qt	D	(M)	C	B	
S-22	B.Nongkoxong	B	Qf	(M)	(M)	A	A	
S-23	B.Nongboua	C	Qf	M	M	A	B	
S-24	B.Donmuang	(A)	Qf	M	(M)	A	A	○
S-25	B.Hinxiou	A	Qf	(M)	(M)	A	A	○

Remark:1) See Fig.5.B. 2) S=0-5.M=5-10.D=Over10m. 3) L=0-5.M=5-10.H=Over10m3/h.4) A=High.B=Moderate.C=Low

Table 2.2 (2/4) Hydrogeological Data and Test Boring Sites Evaluation (Saravan)

No.	District and Village Name	①Surface Grading for Village Survey	② Hydrogeologically Based Groundwater Potential 1) Hydro-geological Types	2) Water TabldDepth Dry season	3) Borehole Yield	4) Ground-water Potential	Evaluation ① + ②	Selected Village ○
S-26	B. Thakho	A	Qf	(D)	(M)	B	B	
S-27	B. Khok-Houaxang	A	Ep	D	(M)	C	B	
S-28	B. Namouang	A	Qt	D	M	B	B	
S-29	B. Khamthong-Gnai	B	Qf	(M)	(M)	A	A	
S-30	B. Nonsamlan	(A)	Qf	(M)	(M)	A	A	○
S-31	B. Nonghalou	A	Qf	(D)	(M)	B	B	
S-32	B. Thalouang	A	Qf	(M)	(L)	B	B	
S-33	B. Nongteng	A	Qf	(M)	(L)	B	B	
S-34	B. Houayxao	A	Qf	(M)	(L)	B	B	
S-35	B. Hatdou	(A)	Qf	M	(H)	A	A	○
S-36	B. Nakadao	A	Ep	M	(M)	B	B	
S-37	B. Koutlamphong	B-C	Ep	M	(H)	B	C	
S-38	B. Kouttabeng	(A)	Ep	M	H	A	A	○
	Sub-Total							5
Vapy District								
S-39	B. Nongngong	(A)	Ep	M	M	B	A	○
S-40	B. Donkha	A-B	Ep	M	M	C	B	
S-41	B. Naxat	B-C	Ep	M	L	B	B	
S-42	B. Houaykhou	B	Qf	(M)	(M)	A	A	
S-43	B. Vapy-Nua	A	Qf	M	L	B	B	
S-44	B. Vapy-Tai	A	Qf	M	L	B	B	
S-45	B. Nakang	A	Ep	M	M	B	B	
S-46	B. Bangkha	B	Qf	(M)	(M)	A	A	
S-47	B. Saphat	A	Qf	D	(M)	B	B	
S-48	B. Mouang	A	Qf	(M)	(M)	A	A	○
S-49	B. Hat	A	Qf	(D)	(M)	B	B	
S-50	B. Samia	A	Qf	(M)	(M)	A	A	○
S-51	B. Khoumta-Lat	B-C	Ba3	S	(M)	B	C	

Remark: 1) See Fig. 5. B. 2) S=0-5. M=5-10. D=Over10m. 3) L=0-5. M=5-10. H=Over10m3/h. 4) A=High. B=Moderate. C=Low

Table 2.2 (3/4) Hydrogeological Data and Test Boring Sites Evaluation (Saravan)

No.	District and Village Name	①Surface Grading for Village Survey	② Hydrogeologically Based Groundwater Potential				Evaluation ① + ②	Selected Village ○
			1) Hydro-geological Types	2) Water TabldDepth Dry season	3) Borehole Yield	4) Ground-water Potential		
S-52	B.Nongpho	A-B	Ba3	S	(L)	C	B	
S-53	B.Bungkham	A-B	Ba3	(S)	(L)	C	B	
S-54	B.Nongsai	A-B	Ep	(S)	(M)	B	B	
S-55	B.Bungxai	A-B	Ep	(S)	(M)	B	B	
S-56	B.Chong	(A)	Ba3	S	(M)	B	A	○
S-57	B.Phonkham	B-C	Ba3	M	M	C	C	
S-58	B.Koutmoung	A	Ba3	(M)	(M)	C	B	
S-59	B.Nongbou-Noy	B	Ba3	(M)	(M)	C	C	
	Sub-Total							4
Saravan District								
S-60	B.Dong-Nong	A	Ep	(S)	(M)	B	B	
S-61	B.May-Sivilai	A	Ba3	M	M	C	B	
S-62	B.Nakathian	A	Ep	(M)	(L)	C	B	
S-63	B.Nathon	A	Ep	M	M	B	B	
S-64	B.Phonphai	(A)	Ep	M	M	B	A	○
S-65	B.Nadon	A	Ep	(M)	(L)	C	B	
S-66	B.Nadonkhoang	A	Ep	M	(L)	C	B	
S-67	B.Thamuang-Kao	B	Ep	M	H	A	A	
S-68	B.Napheng-Gnai	(A)	Ep	M	L	C	B	
S-69	B.Napheng-Noy	A	Ep	M	(L)	C	B	
S-70	B.Saokadi-Tai	A	Ep	M	H	A	A	○
S-71	B.Dan-Gnai	A	Ep	(M)	(M)	B	B	
S-72	B.Kengsim-Tai	B	Ep	(M)	(M)	B	B	
S-73	B.Nobon-Tai	B	Ep	(M)	(H)	A	A	
S-74	B.That-Noy	(A)	Ep	(M)	(M)	B	A	○
S-75	B.Nakasao	(A)	Ep	(M)	(M)	B	A	○
S-76	B.Ko	A	Ba3	(S)	(M)	B	B	
S-77	B.Phao-Gnai	A	Ba3	(S)	(M)	B	B	

Remark: 1) See Fig.5.B. 2) S=0-5. M=5-10. D=Over10m. 3) L=0-5. M=5-10. H=Over10m3/h. 4) A=High. B=Moderate. C=Low

Table 2.2 (4/4) Hydrogeological Data and Test Boring Sites Evaluation (Saravan)

No.	District and Village Name	① Surface Grading for Village Survey	② Hydrogeologically Based Groundwater Potential				Evaluation ① + ②	Selected Village ○
			1) Hydro-geological Types	2) Water TabldDepth Dry season	3) Borehole Yield	4) Ground-water Potential		
S-78	B. Soung	A	Ba_3	(S)	(M)	B	B	
S-79	B. Thongkapok	A	Ba_3	(M)	(M)	C	B	
S-80	B. Naxai-Gnai	A	Ba_3	(M)	(M)	C	B	
S-81	B. Naxai-Noy	B	Ba_3	(M)	(M)	C	C	
S-82	B. Maknao	A	Ba_3	(M)	(M)	C	B	
S-83	B. Dongko-Nua	(A)	Ba_3	(M)	(M)	C	B	
S-84	B. Beng	(A)	Ba_2	(M)	(M)	B	A	○
S-85	B. Khiangphoukhong	A	Ba_2	(M)	(M)	B	B	
S-86	B. Kadap	A	Ba_2	(D)	(M)	C	B	
S-87	B. Lavang	(A)	Ba_2	(M)	(M)	B	A	○
S-88	B. Senvang-Noy	(A)	Ba_2	(M)	(M)	B	A	○
S-89	B. Houakhoua	B-C	Ba_2	(M)	(M)	B	C	
	Sub-Total							7
Lao ngam District								
S-90	B. Kiangtat	B	Ba_2	(M)	(M)	B	B	
S-91	B. Xanum	A	Ba_2	(S)	(M)	B	B	
S-92	B. Xanumnok	A-B	Ba_2	(M)	(M)	B	B	
S-93	B. Baktheung	A-B	Ba_2	(M)	(M)	B	B	
S-94	B. Vangpuay	A-B	Ba_2	(D)	(M)	C	B	
S-95	B. Sangthong-Noy	B	Ba_2	(D)	(M)	C	C	
S-96	B. Sangthong-Gnai	A	Ba_2	(M)	(M)	B	B	
S-97	B. Laongam	C	Ba_1	(M)	(M)	B	C	
S-98	B. Hokong	A	Ba_1	(D)	(M)	B	B	
S-99	B. Beng	(A)	Ba_1	(D)	(M)	B	A	○
S-100	B. Houn-Tai	(A)	Ba_1	(D)	(H)	B	A	○
	Sub-Total							2
	TOTAL							20

Remark: 1) See Fig. 5. B. 2) S=0-5. M=5-10. D=Over10m. 3) L=0-5. M=5-10. H=Over10m3/h. 4) A=High. B=Moderate. C=Low

Table 2.3

Types of Hydrogeologic Features

Consitute of 40 Selected Villages.

Hydrogiologic Feature Types	Champasak Province	Saravan Province	Sub Total
Qf	4	6	10
Ep	2	6	8
Eh	6	2	8
Ba1	4	2	6
Ba2	2	3	5
Ba3	1	1	2
Et	1	0	1
Total	20	20	40

Table 2.4

Proportion of Selected Villages

Champasak Province

District	No. of Vilg	Selected Vilg.
Sanasomboon	36	8 (21%)
Bachiang	25	5 (20%)
Pathoompone	15	3 (20%)
Sukuma	7	2 (27%)
Khong	17	2 (12%)
Total	100	20 (100%)

Saravan Province

District	No. of Vilg.	Selected Vilg.
Lakhonepheng	16	2 (14%)
Khongxedon	22	5 (23%)
Vapy	21	4 (20%)
Saravan	30	7 (24%)
Lao ngam	11	2 (19%)
Total	100	20 (100%)

Figure 2.1a **Water Source in 100 Villages, Champasak Province**

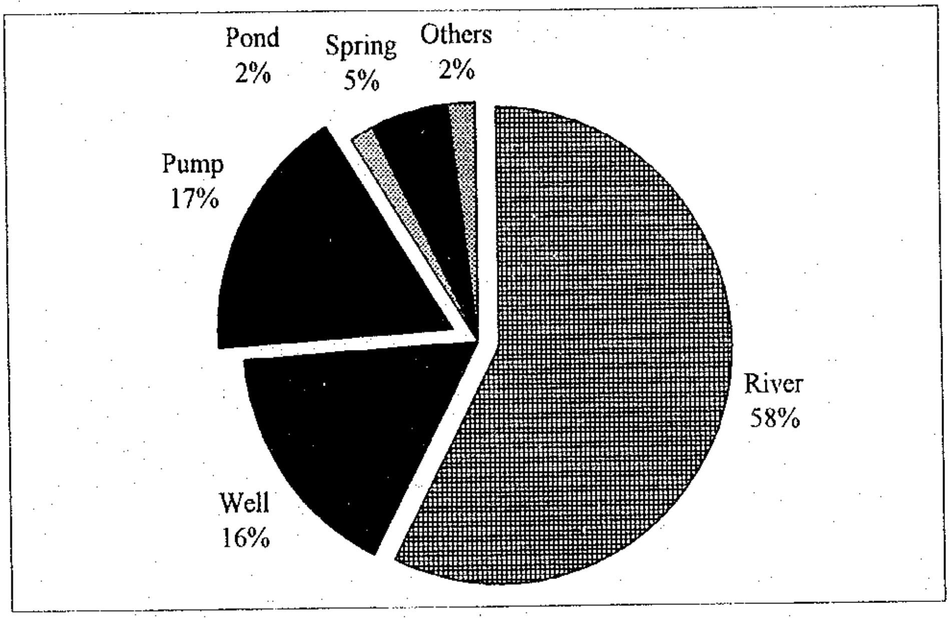

Figure 2.1b **Water Source in 100 Villages, Saravan Province**

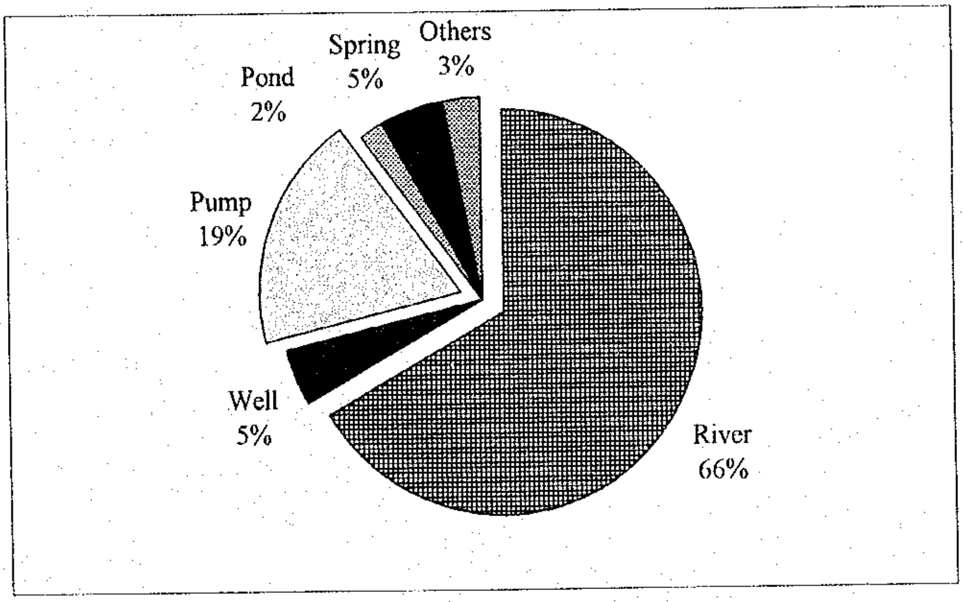

Figure 2.2

Prioritized Ranking Method

① Surface Evaluation

② Groundwater Evaluation

	(A)	A	B	C
A	A	A	A	B
B	A	B	B	C
C	B	B	C	C

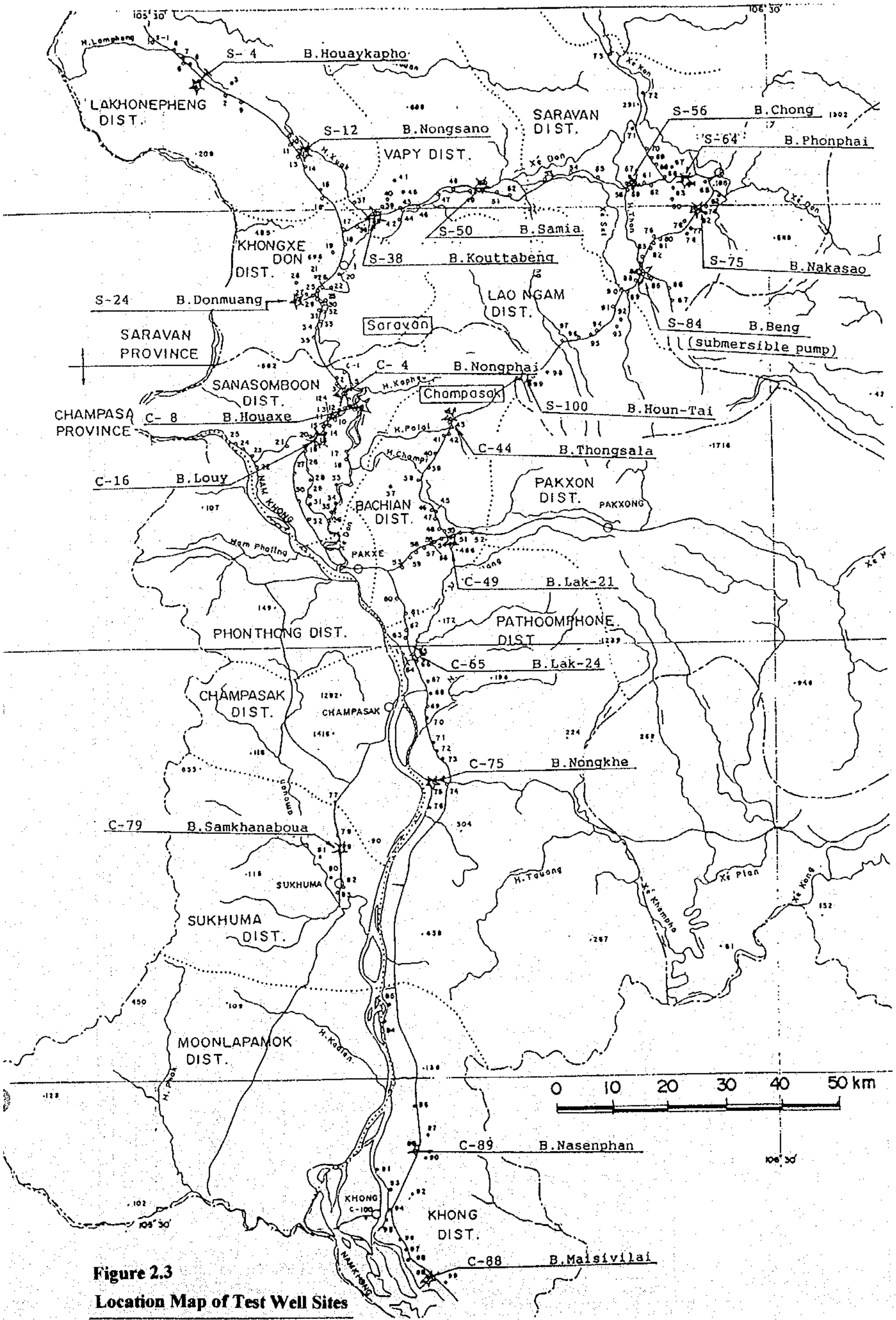

Figure 2.3

Location Map of Test Well Sites

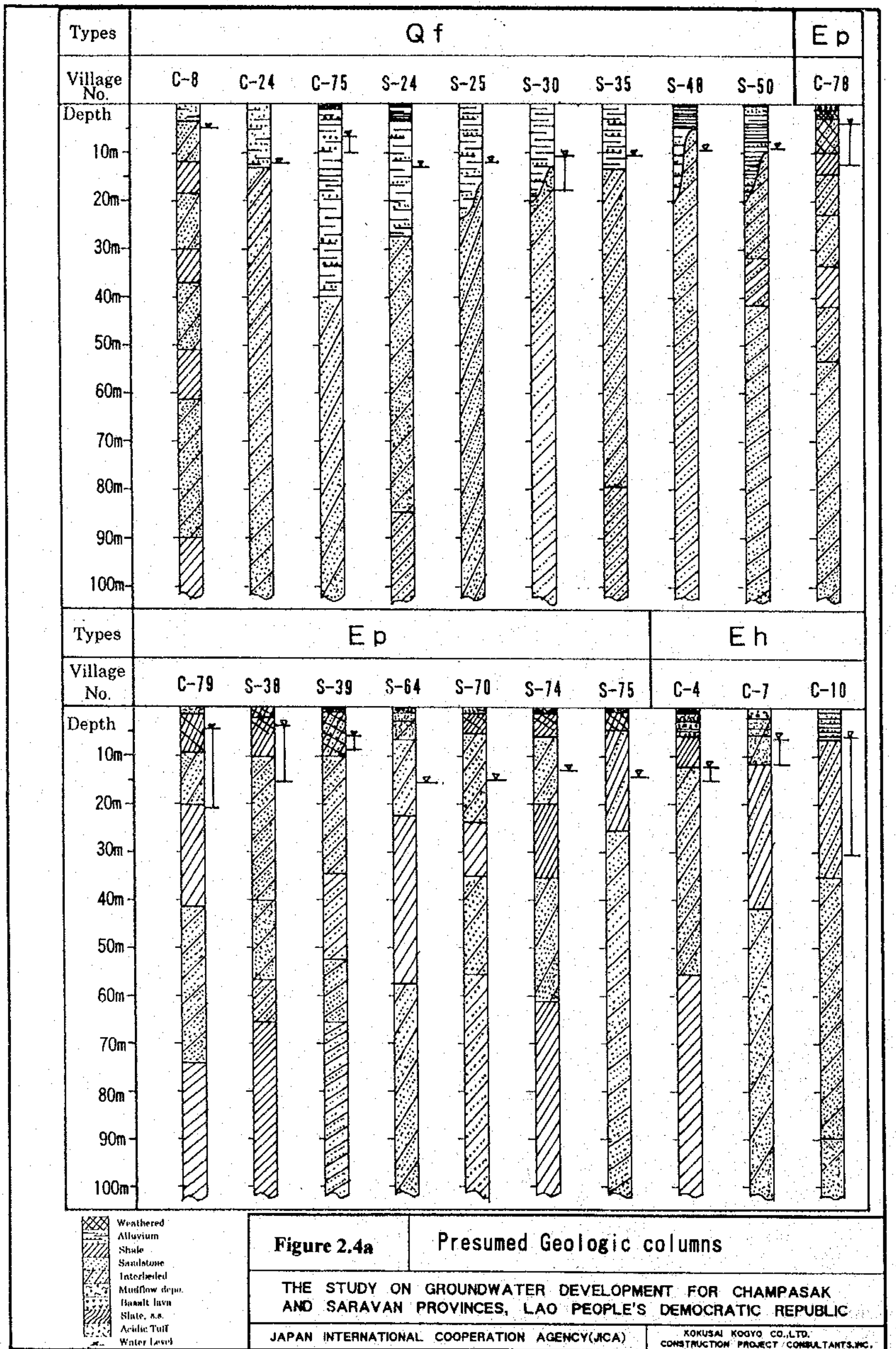

Figure 2.4a Presumed Geologic columns

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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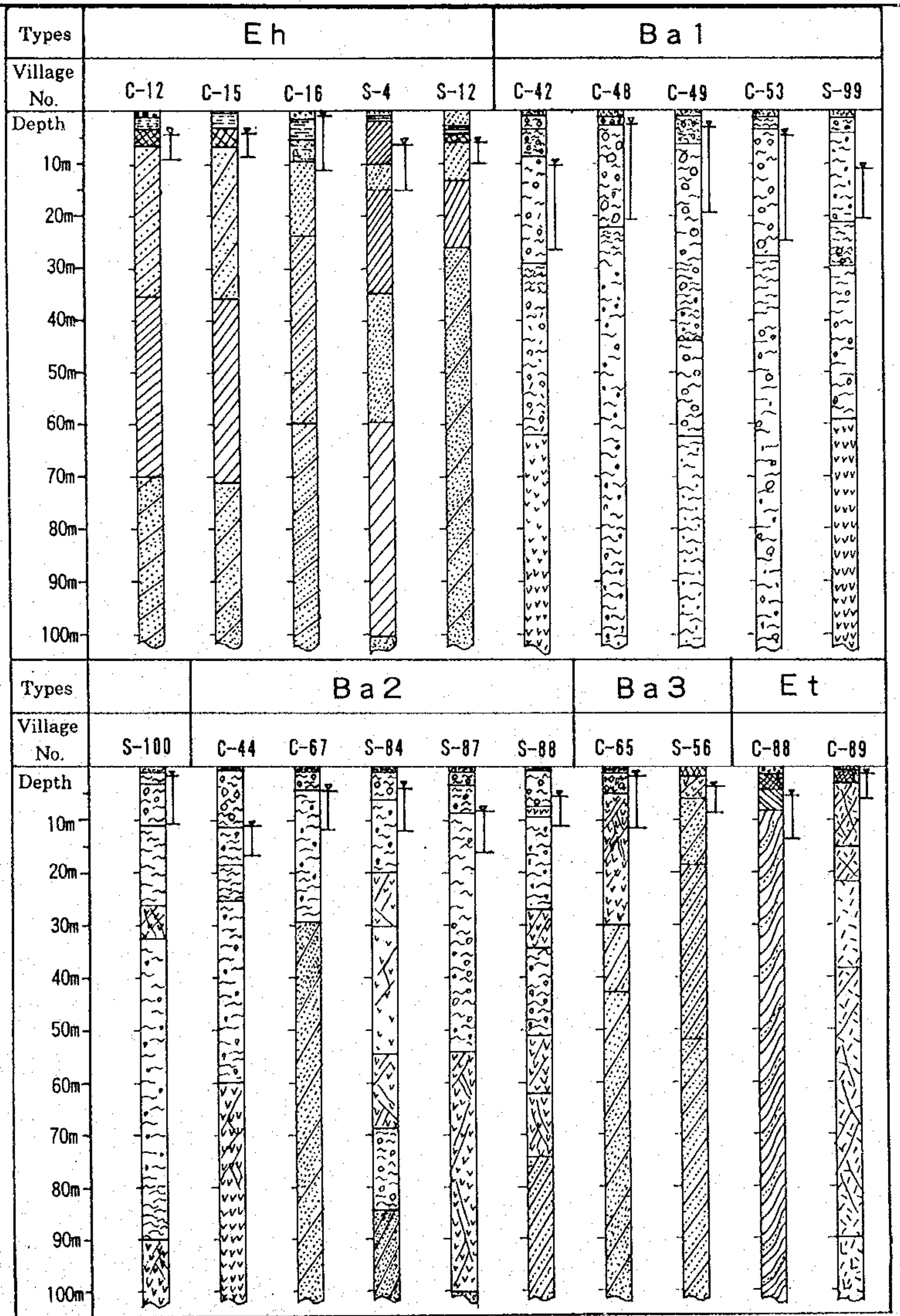

Figure 2.4b Presumed Geologic columns

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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KOKUSAI KOGYO CO.,LTD.
CONSTRUCTION PROJECT CONSULTANTS,INC.

SUPPORTING REPORT

CHAPTER 3 GEOPHYSICAL SURVEYS

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3. GEOPHYSICAL SURVEYS

Two kinds of geophysical exploration, Vertical Electrical Sounding (VES, resistivity method) and Electro-Magnetic prospecting method using Very Low Frequency (VLF) waves, were conducted. The VES was adopted for detecting the resistivity structure of the underground, while the VLF prospecting method was used for the investigation of large and deeper geological structure such as faults and fracture zones of the ground.

3.1 Vertical Electrical Sounding (VES)

Wenner arrangement is adopted for VES survey in this study and is considered to be the most commonly used arrangement for groundwater prospecting. The configuration of electrodes is spaced in a line and the pair of current electrodes is placed on the outside of the pair of the potential electrodes. In spite of the simple geometry, this arrangement is considered often quite inconvenient for field work. However, it is the fundamental for resistivity sounding and effective to detect a flat layered model. The geological structure in the study area is considered to be horizontal and the Wenner configuration is adopted for the site survey of this study.

3.1.1 Wenner arrangement

All resistivity methods measure apparent resistivities of subsurface materials. The Wenner arrangement is effective to detect a flat layered geological structure as shown in Figure 3.1.1.

When current I penetrates through the electrodes C1 and C2, the potential gradient is introduced at two potential electrodes P1 and P2 on the ground surface as shown in Figure 3.1.1. The potentials at the two electrodes P1 and P2 are expressed as follows,

$$V(P1) = IR/2\pi\ (1/P1C1 - 1/P1C2) \qquad .....(1)$$

$$V(P2) = IR/2\pi\ (1/P2C1 - 1/P2C2) \qquad .....(2)$$

R is resistivity in ohm-m. P1C1 is the distance from potential electrode P1 to current electrode C1 and P1C2 is that of P1 to C2. Similarly, the potentials at P2 and C1 are P2C1 and P2C2, respectively.

Subtracting equations (2) from (1) and solving for R, the following relation can be obtained.

$$Ra = 2\pi \ V/I \ (1/((1/P1C1 - 1/P1C2) - (1/P2C1 - 1/P2C2))) \quad .....(3)$$

The potential difference V(P1)-V(P2) is measured by a potentiometer between two potential electrodes. As the intervals of electrodes between C1 and P1, P1 and P2, P2 and C2 equal 'a,' P1C1 and P2C2 equal a and P1C2 and P2C1 equal '2a'. The equation (3) is expressed as follows,

$$Ra = 2\pi aV/I \quad .....(4)$$

Therefore, the apparent resistivity of each interval of electrodes can be calculated using the equation (4).

When the electrode spacing is distributed closely in the case of two layers as shown in Figure 3.1.1, the current flow is confined to the upper layer and the resistivity measured at the surface is nearly equal to that of the upper layer. As the electrode spacing increases, the measured resistivity approaches that of the lower layer.

VES curves are analyzed by the graphical method using standard curves and computer aided program.

3.1.2 Resistivity of Rocks

The resistivity range of rocks and sediments is large and the resistivities extend from less that 0.1 to more than 10000 ohm-m. There is no consistent difference between the range of resistivities of igneous rock and that of sedimentary rocks, although metamorphics show higher resistivity on statistics. Fractures and fault zones tend to have high conductivities with respect to surrounding rocks and show low resistivities as shown in Table 3.1.1.

3.1.3 Survey

Two OYO McOHM meters were used for the VES survey in this study. This instrument is an electric survey unit of stacking type. The VES surveys were carried out at the candidate 40 villages for test drilling sites in order to make clear basic information on drilling points and depths as shown in Figure 3.1.2.

3.2 Very Low Frequency Method (VLF)

VLF Electro-Magnetic method aims at detecting conductive zones located at shallow depths. The VLF EM method uses the magnetic components of the electromagnetic field generated by long-distance radio transmitters in the VLF band. Transmitter stations are located at several points around the earth as shown in Figure 3.2.1 and the stations broadcast at 10-30 kHz, which is low compared to the normal broadcast band. The purpose of these stations is to allow communication with submarines. The low frequency allows some penetration of the conductive ocean water. Skin depth is approximately $503\sqrt{R/Hz}$ meters, where R is the resistivity of a homogeneous material in ohm-m and Hz is the frequency. On the assumption that the frequency is 20 kHz and that the material is magnetically nonpolarizable, the skin depth is approximately $3.6\sqrt{R}$. Since the area to be prospected normally is very far from the transmitter stations, the primary field is uniform in the area and rather simple mathematics is allowed to be used in anomaly prediction and analysis. The primary field induces a secondary field when it intersects conductive bodies as shown in Figure 3.2.1. Thus, the measurement of the two fields (primary and secondary) at the surface of the earth can help to detect underground structures.

An ABEM WADI was used for the VLF survey in this study. This instrument is based on the well-known and time-tested VLF mineral prospecting method. The instrument measures the radio signal distortion and presents the result on a display screen. Observed lines of VLF-EM survey were carried out along the profiles of VES survey in the candidate 40 villages and in the surrounding villages. The lines were around 1,000 m or more in length. The observed villages and survey lines are shown in Table 3.2.1 and Figure 3.2.2.

3.3 Results of Geophysical Explorations

3.3.1 VES Survey

The analysis was first carried out graphically using the standard curves and the estimated resistivities were inputted as initial values for the computer program. Resistivities and depths of layers were estimated by the forward program.

According to Okuzono (1973), groundwater aquifers should be estimated to range from 20 to 200 ohm-m as shown in Figure 3.3.1. As talus deposits and Tertiary layers may have the similar values, the results of geological and geomorphological field surveys were also taken into consideration.

The resistivity profiles for villages are shown in Figure 3.3.2. The distribution of resistivity of layers is indicated in Table 3.3.1. The resistivity ranges of rocks and sediments in the Study area are shown in Table 3.3.2.

The following assumptions are considered generally.

1. The resistivity structure of layers consists of 3 to 5 layers.
2. Resistivities are distributed complicatedly right below the ground surface of the earth.
3. Resistivities of layers range from less than 10 to several thousand's ohm-m. Generally, higher resistivity appears near the ground surface of the earth.

3.3.2 VLF Survey

The WADI instrument measures two magnetic components, vertical and horizontal, of electromagnetic field generated by long-distance radio transmitters in the VLF band. Normalized ratio of the vertical and horizontal components is expressed as a complex number. Real (in phase) and imaginary (quadrature) parts are analyzed using the computer aided program including a filtering. As a fault fractured zone with groundwater forms a good conductive body, the real part measured at the zone expresses a maximum value. The maximum value of the real component is estimated to be a VLF anomaly as shown in Figures 3.3.3 to 3.3.5. Therefore, groundwater in the fault fractured zones can be detected by the VLF prospecting method.

Results of the VLF analysis are shown in Figure 3.3.6.

3.3.3 Results of Geophysical Explorations

(1) Champasak Province

1) C-4 Ban Nongphai

The profile is considered to be a horizontal 4 layered structure. The resistivity ranges of the top two layers are around 40-80 ohm-m and the depths are less than 10 m. The third layer shows a resistivity range of 235-560 ohm-m and a thickness range of 40-60 m. The fourth layer shows the resistivity range of 30-90 ohm-m. An anomaly can be seen at the center of the village on the VLF survey line. The second and fourth layers are considered to be water bearing layers. The second layer is very shallow and the fourth layer is expected to be an aquifer.

2) C-7 Ban Nongdou

The top layer is shallow and the resistivity is high at some points. The second layer's resistivity range shows 200-270 ohm-m and the thickness range is 30-40 m. The thickness of the second layer on No. 1 and 2 is deeper than on No. 3 to 5. The third layer has a resistivity range of 110-150 ohm-m. The fourth layer shows a resistivity range of 73-88 ohm-m. Both the third and fourth layers can be considered to be aquifers according to the resistivity analysis and several anomaly indications are obtained at the points across the VLF survey line near the VES survey line.

3) C-10 Ban Dong

Though the resistivity structure is classified as 4 layers, the top layer is considered to be a shallow layer (660-5000 ohm-m) and the lower layer (264-865 ohm-m). The second layer shows clear identifications in resistivities range of 52-77 ohm-m. The resistivity range of the third layer is 90-180 ohm-m and the fourth layer is deeper than 150 m on No. 1 and 2 (233-282 ohm-m in resistivity). An anomaly indication can be seen near the village according to the results of the VLF survey.

4) C-12 Ban Nongkham

When shallow and high resistivity layers are obtained near the ground surface, these layers are recognized as the first layer. Therefore, the resistivity profiles are classified as a 3 layered structure. The second layer shows low resistivity range of 25-48 ohm-m, and the third layer obtains resistivity range of 120-164 ohm-m. The boundaries of layers are almost horizontal, although the thickness of the second layer on No.6 is deeper. The second layer is recognized to be a clayey layer. Small anomaly is obtained beside the VES survey line along the VLF survey line.

5) C-15 Ban Nongkhen

As a resistivity range of several hundreds to more than a thousand ohm-m is obtained at a shallow part of the ground, these layers are considered to be the first layer. The thicknesses of the second layer are about 50m on No.5 and 6, but these on other points are more than a hundred meters. The Third layer with a resistivity range of 125-135 ohm-m appeared on No.5 and 6. The fourth layer obtained around 130 m in depth on No.1 to 5 and the resistivity range is 115-440 ohm-m. An anomaly indication is obtained at the southern edge of the VLF survey line that is close to the VES survey line.

6) C-16 Ban Louy

The first layer with a thickness of around 5 to 10 m has a resistivity range of more than 100 to several 1000 ohm-m. The resistivity range of the second layer is around 20-30 ohm-m the thickness range of the layer is 60-80 m. The lowest layer with irregularity of the upper boundary has a resistivity range of 100-170 ohm-m, although the resistivity of this layer on No.2 is 375 ohm-m. Some anomaly indications are obtained along the VLF survey line and the large anomaly can be seen at the VES survey line.

7) C-24 Ban Boungkha

The thickness of the first layer is around 20m on No.1 and 2, but the thickness of the other profiles is more thin. The second layer shows a resistivity range of 24-38 ohm-m and is distributed along No. 3 to 6. The third layer has similar distribution to the second layer with a resistivity range of 55-60 ohm-m. The fourth layer with a resistivity range of 21-32 ohm-m is a thickness of 50-80 m. The lowest layer with a resistivity range of 45-55 ohm-m has an irregularity of the upper boundary. The VLF survey line is perpendicular to the VES survey line. Strong anomaly indications are obtained along the VLF survey line.

8) C-42 Ban Thongkim

The resistivity structure is composed of four horizontal layers, but the second layer disappears on No.1 to 3. The second layer is distributed over the latter half of the VES survey line and the thickness and resistivity are around 10m and 180-270 ohm-m, respectively. The third layer is horizontally bedded and the resistivity range of 30-33 ohm-m is obtained. The lowest layer shows 90-117 ohm-m in resistivity. The VES survey line is located between two anomaly indications on the VLF survey line.

9) C-44 Ban Thongsala

The structure is composed of 5 layers. The first layer with a resistivity of more than 200 ohm-m contains an intercalated thin layer with a resistivity of 100 ohm-m. The resistivity of the second layer is 100-125 ohm-m on No. 2 to 6. The third layer of 1200 ohm-m in resistivity is underlain between the second and the fourth layer with a resistivity range of 20-103 ohm-m. The resistivity of the lowest layer ranges 135-350 ohm-m. The upper boundaries of the second and the lowest layers are considered to be irregular. No anomaly indications are obtained near the profile in VLF survey line.

10) C-48 Ban Pasouam

The first layer with a thickness of around 20-30 m obtains a resistivity range of 300-750 ohm-m. The second layer, which disappears on No.4 and 5, has a resistivity range of 100-233 ohm-m. The thickness of the third layer, which shows a resistivity range of 16-22 ohm-m, is 60-80 m on No.1 and 2 and 120-160 m on No.3 to 6. The resistivity of the fourth layer is 41-60 ohm-m. Any clear anomaly indications can not be seen along the VES survey line.

11) C-49 Ban Lak-21

The first layer with an interbed of a thin low resistivity layer of 33-47 ohm-m is around 5 m in thickness and 100-400 ohm-m in resistivity. The second layer of 330-720 ohm-m and the fourth layer of 7-20 ohm-m can be seen on the profile. The third layer of 50-80 ohm-m and the fifth layer of 100-300 ohm-m were obtained on No.4 and 5. An anomaly indication is obtained in the VLF survey line.

12) C-53 Ban Nongkham-Khao

The resistivity structure is composed of horizontal three layers. The resistivities of the second layer range 19-23 ohm-m and those of the third layer are 50-53 ohm-m. However, the first layer includes thin layers with high resistivity of more than 1000 ohm-m and with low resistivity of around 100 ohm-m. Two anomaly indications are obtained along the VES survey line.

13) C-65 Ban Lak-24

Three-layered resistivity structure is obtained. The resistivity of the first layer is 200-470 ohm-m and the resistivities of the second and third layers are 78-90 ohm-m and 138-820 ohm-m, respectively. The depth of upper boundary of the third layer shows deeper on No. 3 and 4 than on the other points. Any anomaly indications can not be seen on the VES survey line.

14) C-67 Ban Houakhoua (Lak-29)

Resistivity structure shows complicated distribution of resistivities and the boundaries of layers are irregular. The resistivity of the first layer ranges around 100 to 1000 ohm-m. The second layer with a resistivity range of 310-427 ohm-m is obtained on No.2 and 3. The third and fourth layers with 30-60 and 93-102 ohm-m change their thicknesses remarkably. The lowest layer has a resistivity range 20-55 ohm-m and it disappears on No.1. The anomaly indication is obtained clearly at the center of the VES survey line along the line II. No anomaly can be seen on the crossing point with the line I of the VLF survey line.

15) C-75 Ban Nongkhe

A four-layered structure is recognized. The resistivity of the first layer ranges some 100 to more than 2000 ohm-m. The resistivity of the second layer is 12-20 ohm-m and the third layer has a resistivity range of 35-80 ohm-m. The lowest fourth layer has resistivities of 85-136 ohm-m on No.2 to 5. There is an anomaly indication at the edge of the VES survey line.

16) C-78 Ban Bak

The thin first layer appears has a resistivity of more than 800 ohm-m. The second and third layers have resistivities of 20-28 and 45-78 ohm-m, respectively. The fourth layer with a resistivity range of 120-270 ohm-m is obtained in the first half of the profile and the upper boundary of this layer inclines to the north. Several anomaly indications are obtained on the VLF survey line, but no anomaly can be seen along the VES survey line.

17) C-79 Ban Samkhanaboua

The thin first layer with a resistivity range of 20-40 ohm-m can be seen right below the ground surface. The second layer has a resistivity range of 15-33 ohm-m and the third layer 44-75 ohm-m. The thickness of the second layer changes remarkably. There are large anomaly indications toward the south of the village, but no anomaly indications are detected along the VES survey line.

18) C-88 Ban Maisivilai

The resistivity structure is composed of three layers. The resistivities of the first and third layers are more than several hundreds. The second layer with a resistivity range of 11-30 ohm-m is considered to be clayey. No anomaly indications are detected beside the VES survey line, but some indications are obtained along the VLF survey line.

19) C-89 B. Nasenphan

The thin first layer has a resistivity of several hundreds and the second layer 4-30 ohm-m. The third layer with 300-450 ohm-m in resistivities considered to be thick and the fourth layer with a resistivity of 250 ohm-m appears on some points. A large anomaly indication on the line I is obtained along the VES survey line.

(2) Salavan Province

1) S-4 Ban Houaykapho

The resistivity structure is composed of four layers. A layer with a resistivity range of 18-52 ohm-m is underlain by a thin subsurface layer of 130-300 ohm-m in resistivity. The resistivity of the second layer ranges 50-110 ohm-m and the third layer 13-50 ohm-m. The fourth layer is divided into two parts. The resistivity ranges 110-130 ohm-m on No. 3 to 4 and more than 260 ohm-m on No. 1 to 2 and No. 5 to 6. Though the anomaly indication of the VLF survey line can be seen on the VES survey line, the strength of anomalies on the line II is larger than that on the line I.

2) S-12 Ban Nongsano

The first layer shows a resistivity of larger than 100 ohm-m. The resistivity of the second layer is 15-45 ohm-m. The resistivity of the lowest layer ranges 53-76 ohm-m and the lowest layer shows an irregular upper boundary. No anomaly indication is detected along the VES survey line.

3) S24 Ban Donmouang

The resistivity structure is composed of three layers. The first layer has two sub-layers of both 30-74 ohm-m and 6-14 ohm-m in resistivity. The second layer with a resistivity range of 34-35 ohm-m can be seen on No. 1 and 6. The third layer has a resistivity range of 75-105 ohm-m. Anomaly indications are obtained on both edges of the VES survey line.

4) S-25 Ban Hinxiou

The depth of the first layer is 10-15 m and the second layer with a resistivity of 140-160 ohm-m appears on No. 1 and 2. The boundary between the third layer with a resistivity range of 40-88 ohm-m and the fourth layer with a resistivity range of 110-500 ohm-m is distributed irregularly. No anomaly indications are appeared along the VES survey line.

5) S-30 Ban Nonsamlan

The resistivity structure is composed of 3 layers. The first layer is consisted of two sub-layers of 11-56 and 70-440 ohm-m in resistivity. The thick second layer has a resistivity range of 60-96 ohm-m and the third layer appeared on No.3 and 4. An anomaly indication is obtained along the VES survey line.

6) S-35 Ban Hatdou

The first layer is thin and less than 5 m in depth and the resistivity ranges 40-600 ohm-m. The resistivity of the second layer is 8-30 ohm-m and the thickness is 10-30 m. The third layer appears on No. 3 to 6. Though the resistivity of the fourth layer is 120-280 ohm-m on No.1 to 5, the resistivity of No. 6 is 70 ohm-m. The VLF survey line is parallel to the VES survey line and the distance between two lines is 71m. An anomaly indication of the VLF survey line is obtained toward the VES survey line.

7) S-38 Ban Kouttabeng

The first layer with a resistivity range of 70-110 ohm-m appears on No.4 to 6 and the thickness of the second layer with 11-20 ohm-m is 10 to 20 m. The third layer with a resistivity of 130 ohm-m appears only on No.2 and the fifth layer with a resistivity of 120 ohm-m is obtained on No.3. The fourth layer has a resistivity of 50-95 ohm-m. Anomaly indications appear on both ends of the VLF survey line. Any anomaly can not be seen along the VES survey line.

8) S-48 Ban Mouang

The resistivity structure is composed of 3 layers. The resistivity range of the first layer is 8-100 ohm-m and the thickness ranges 15-25 m. The thickness of the second layer with a resistivity range of 54-80 ohm-m ranges 130-150 m and the third(lowest) layer has a resistivity range of 85-140 ohm-m. An anomaly indication appears at the east edge of the VES survey line.

9) S-50 Ban Samia

The thin first layer has a resistivity range of 175-380 ohm-m and the second layer a resistivity range of 70-144 ohm-m. The resistivity of the third layer ranges 12-30 ohm-m and the resistivity of the fourth layer 50-88 ohm-m. The lowest layer with a resistivity range of 66-90 ohm-m disappears on No.6. Anomaly indications are obtained at the starting point of the VLF survey line, but no anomaly appears along the VES survey line.

10) S-56 Ban Chong

The first layer has a resistivity range of 87-360 ohm-m and the second layer a resistivity range of 8-25 ohm-m. The third layer with a thickness of around 100 m has a resistivity range of 50-68 ohm-m. The upper boundary of the lowest layer appears below 100 m and the resistivity of the layer ranges 110-200 ohm-m. Anomaly indications are obtained at the starting and the middle points of the VES survey line.

11) S-64 Ban Phonpai

The first layer has a high resistivity, but the thickness of this layer is 10 m on No.5. The second layer with a resistivity range of 16-19 ohm-m appears on No.1 to 3 and 6, but this layer joins with the third layer with a resistivity range of 25-54 ohm-m. The resistivity of the fourth layer is 90-140 ohm-m. An anomaly indication can be seen on the VES survey line.

12) S-66 Ban Nadonkhoang

The structure is composed of a 5-layered case and indicates complex resistivity distribution on some points. A thin layer with a resistivity range of 300-1150 ohm-m is included by the first layer with a resistivity range of 22-33 ohm-m. However the resistivity of the second layer showed 75-88 ohm-m and increases to 96-192 ohm-m in the middle part of the VES survey line. The third and fourth layer can be seen in some parts of the VES survey line. The resistivity of the lowest layer ranges 59-75 ohm-m. An anomaly indication is obtained at the middle of the VES survey line.

13) S-70 Ban Saokadi-Tai

The distribution of resistivities is complicated. The second third layers with a resistivity range of 32-60 ohm-m and of 93-144 ohm-m change their thicknesses remarkably. The resistivity of the fourth layer showed 270-840 ohm-m. Anomaly indications are obtained along the VES survey line.

14) S-74 Ban That-Noy

The structure is composed of 4 layers, but the second and fourth layers are distributed partially. The resistivities of the first, second, third and fourth layers range 18-880, 145-200, 40-120 and 117-180 ohm-m, respectively. An anomaly indication is obtained at the crossing point between the VLF survey line and the VES survey line.

15) S-75 Ban Nakasao

The first and second layers are thin and the resistivities range 170-700 and 13-33 ohm-m. The thickness of third layer with a resistivity range of 96-156 ohm-m is around 60-70 m. The fourth layer shows a resistivity range of 190-250 ohm-m. Some anomaly indications can be seen along the line II of the VLF survey line and an anomaly is recognized at the starting point of the line I of the VLF survey line.

16) S-84 Ban Beng

The structure is expressed as 4 layers, but resistivities show complex distribution. The second layer disappears along No.1 to 5. The upper boundary between the third layer and the fourth layer with resistivity ranges of 175-400 ohm-m and of 30-70 ohm-m inclines toward the north-east. Any anomaly indications are not detected along the line I, but an anomaly indication is obtained along the line II that is perpendicular to line I beside the VES survey line.

17) S-87 Ban Lavang

The first and second layers have resistivity ranges of 260-1100 and 75-150 ohm-m. High resistivity layers of 600-2000 ohm-m are distributed in the third layer. The fourth layer shows a resistivity range of 30-97 ohm-m. Some anomaly indications are obtained at both edges of the VES survey line.

18) S-88 Ban Senvang-Noy

The first and second layers that the resistivities range 160-800 and 100-170 ohm-m, respectively, are composed of thin layers. The resistivity of the lower layer is 59-83 ohm-m. No anomalies are detected along the VES survey line and the VLF survey line.

19) S-99 Ban Beng

The first layer has a resistivity range of 340-1700 ohm-m and the second layer with a resistivity range of 400-500 ohm-m disappears on No.1 to 3. The third layer distributes to more than 100 m in thickness and shows a resistivity range of 19-24 ohm-m. The fourth layer shows a resistivity range of 33-43 ohm-m. A small anomaly indication appears on the VLF survey line.

20) S-100 Ban Houn-Tai

The profile is formed by three-layered structure. The first, second and third layers show a resistivity range of 80-1200, 23-32 and 51-96 ohm-m. The upper boundary of the third layer has a depth of 150-170 m. A large anomaly indication appears at the northern edge of the VES survey line.

Table 3.1.1

Resistivities of Rocks

Resistivities of sediments

Rock type	Resistivity range (Ωm)
Consolidated shales	$20–2 \times 10^3$
Argillites	$10–8 \times 10^2$
Conglomerates	$2 \times 10^3–10^4$
Sandstones	$1–6{\cdot}4 \times 10^8$
Limestones	$50–10^7$
Dolomite	$3{\cdot}5 \times 10^2–5 \times 10^3$
Unconsolidated wet clay	20
Marls	3–70
Clays	1–100
Alluvium and sands	10–800
Oil sands	4–800

Resistivities of igneous and metamorphic rocks

Rock type	Resistivity range (Ωm)
Granite	$3 \times 10^2–10^6$
Granite porphyry	$4{\cdot}5 \times 10^3$ (wet)–$1{\cdot}3 \times 10^6$ (dry)
Feldspar porphyry	4×10^3 (wet)
Albite	3×10^2 (wet)–$3{\cdot}3 \times 10^3$ (dry)
Syenite	$10^2–10^6$
Diorite	$10^4–10^5$
Diorite porphyry	$1{\cdot}9 \times 10^3$ (wet)–$2{\cdot}8 \times 10^4$ (dry)
Porphyrite	$10–5 \times 10^4$ (wet)–$3{\cdot}3 \times 10^3$ (dry)
Carbonatized porphyry	$2{\cdot}5 \times 10^3$ (wet)–6×10^4 (dry)
Quartz porphyry	$3 \times 10^2–9 \times 10^5$
Quartz diorite	$2 \times 10^4–2 \times 10^6$ (wet)–$1{\cdot}8 \times 10^5$ (dry)
Porphyry (various)	$60–10^4$
Dacite	2×10^4 (wet)
Andesite	$4{\cdot}5 \times 10^4$ (wet)–$1{\cdot}7 \times 10^2$ (dry)
Diabase porphyry	10^3 (wet)–$1{\cdot}7 \times 10^5$ (dry)
Diabase (various)	$20–5 \times 10^7$
Lavas	$10^2–5 \times 10^4$
Gabbro	$10^3–10^6$
Basalt	$10–1{\cdot}3 \times 10^7$ (dry)
Olivine norite	$10^3–6 \times 10^4$ (wet)
Peridotite	3×10^3 (wet)–$6{\cdot}5 \times 10^3$ (dry)
Hornfels	8×10^3 (wet)–6×10^7 (dry)
Schists (calcareous and mica)	$20–10^4$
Tuffs	2×10^3 (wet)–10^5 (dry)
Graphite schist	$10–10^2$
Slates (various)	$6 \times 10^2–4 \times 10^7$
Gneiss (various)	$6{\cdot}8 \times 10^4$ (wet)–3×10^6 (dry)
Marble	$10^2–2{\cdot}5 \times 10^8$ (dry)
Skarn	$2{\cdot}5 \times 10^2$ (wet)–$2{\cdot}5 \times 10^8$ (dry)
Quartzites (various)	$10–2 \times 10^8$

Table 3.2.1 The Length of VLF Survey Lines

	Village (Champasak Province	Length (m)		Village (Saravan Province	Length (m)
C4*	B. Nongphai	1000, 400	S4*	B. Houaykapho	1100, 500
C7	B. Nongdou	1200	S12*	B. Nongsano	1100
C8*	B. Houaxe	1400, 100	S24*	B. Donmouang	1000
C10	C. Dong	900	S25	B. Hinxiou	900, 500
C12	B. Nongkham	1400	S30	B. Nongsamlan	1000
C15	B. Nongkhen	600	S35	B. Hatdou	710
C16*	B. Louy	1050	S38*	B. Kouttabeng	1000
C24	B. Voungkha	1100	S48	B. Mouang	1100
C42	B. Thongkim	1200	S50*	B. Samia	1500
C44*	B. Thongsala	1200	S56*	B. Chong	700, 300
C48	B. Pasouam	1200	S64*	B. Phonphai	1000
C49*	B. Lak-21	1300, 700	S66	B. Nadongkhouang	1000
C53	B. Nongkham-Khao	1400	S70	B. Saokadi-Tai	1000
C65*	B. Lak-24	1200	S74	B. That-Noy	1000
C67	B. Houakhoua(Lak-29)	700, 500	S75*	B. Nakasao	1000, 600
C75*	B. Nongkhe	1100	S84*	B. Beng	1000, 400
C78	B. Bak	1200	S87	B. Lavang	1100
C79*	B. Samkhanaboua	1200	S88	B. Senvang-Noy	1200
C88*	B. Maisivilai	1000	S99	B. Beng	1100
C89*	B. Nasenphan	1000, 500	S100*	B. Houn-Tai	1200
C39	B. Makngeo	1600			
	B. Latbok	1400			
	Sub- total	27,550 m		Sub-Total	23,010 m
		Total length		50,560 m	

✲ : Test drilling site

Table 3.3.1 Distribution of Resistivity of Layers on Resistivity Profiles

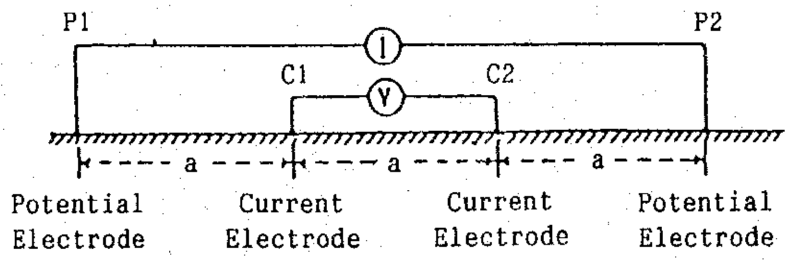
unit:ohm-m

	L1	L2	L3	L4	L5
Champasak Province					
C4* B.Nongphai	10-60	125-145	235-540	30-90	
C7 B.Nongdou	100-3700	9-33	72-740	320-368	
C8* B.Houaxe	300-1750	200-270	110-150	73-88	
C10 B.Dong	264-5000	38-77	90-180	233-282	
C12 B.Nongkham	275-2300	25-48	120-164		
C15 B.Nongkhen	287-1200	42-77	125-135	115-440	
C16* B.Louy	140-1800	14-60	100-375		
C24 B.Boungkha	15-425	24-40	55-60	21-32	45-55
C42 B.Thongkim	165-900	180-270	30-33	90-117	
C44* B.Thongsala	100-1700	70-273	1200	20-103	135-350
C48 B.Pasouam	135-750	100-233	16-22	41-60	
C49* B.Lak-21	33-400	330-720	50-80	7-20	100-130
C53 B.Nonkham-Khao	90-1640	19-20	50-53		
C65* B.Lak-24	140-470	52-90	138-820		
C67 B.Houakhoua (B.Lak-29)	100-1100	31-427	30-60	93-102	20-55
C75* B.Nongkhe	100-2000	12-20	35-80	85-136	
C78 B.Bak	800-2700	20-28	45-75	120-270	
C79* B.Samkhanaboua	40-550	15-33	44-75		
C88* B.Maisivilai	250-2300	11-30	900-1500		
C89* B.Nasenphan	165-900	4-30	300-450	250	
Salavan Province					
S4* B.Houaykapho	15-300	50-110	13-50	110-1000	
S12* B.Nongsano	67-900	15-32	53-76		
S24* B.Donmouang	10-120	34-45	75-105		
S25 B.Hinxiou	12-200	140-160	50-88	110-500	
S30 B.Nonsamlan	7-700	60-96	140-170		
S35 B.Hatdou	40-600	7-24	32-165	70-280	
S38* B.Kouttabeng	70-110	11-44	130	50-95	120
S48 B.Mouang	8-100	62-80	85-140		
S50* B.Samia	175-360	70-144	12-30	50-68	66-90
S56* B.Chong	87-360	5-25	50-68	110-200	
S64* B.Phonphai	65-490	15-19	24-54	88-140	
S66 B.Nadonkhoang	22-1120	75-102	96-175	175-225	59-75
S70 B.Saokadi-Tai	13-1000	30-60	60-144	129-940	
S74 B.That-Noy	18-880	145-200	40-117	117-180	
S75* B.Nakasao	85-700	13-33	96-144	144-250	
S84* B.Beng	40-700	20-100	120-400	30-150	
S87 B.Lavang	84-1580	75-120	600-2000	40-120	
S88 B.Senvang-Noy	160-900	63-170	59-83		
S99 B.Beng	340-1380	400-500	19-24	33-43	
S100* B.Houn-Tai	80-1200	23-32	51-96		

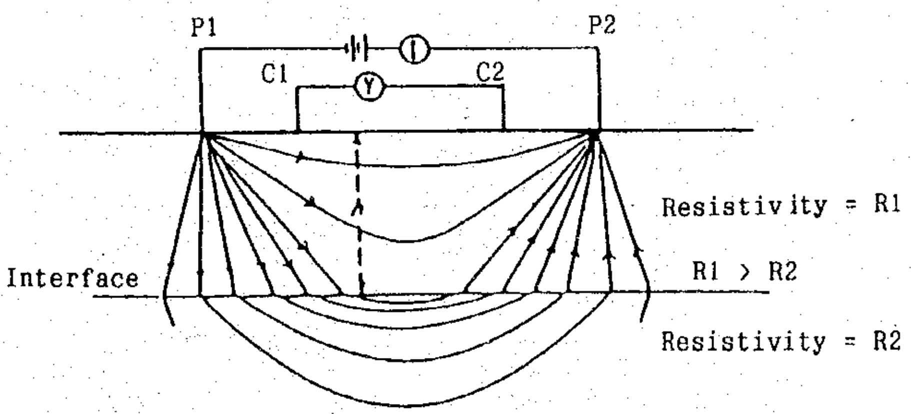
* Test drilling site

Table 3.3.2 Resistivities of Rocks and sediments in The Study Area (ohm-m)

Geologic time	Rocks and Sediments	ohm-m	0	100	200	300	400	500	600	700	800	1000	1500	Aquifer
Quaternary	Clay	6---23												
	Sand	70---150												*
Paleogene to	Basalt lava	800--2000												
Quaternary	Basalt Breccia	100--500												*
	Weathered Ba(dry).	100--700												*
	Weathered Ba.	10---100												
Jurassic	Sandstone	50---350												*
	Sandstone(hard)	200--600												
	Mudstone	15---70												
	Sandy Shale	20---90												*
	Hard Shale	12---50												
	Conglomerate	30---40												*
	Weathered.	10---100												
Triassic	Acidic Tuff	300--450												*
	Weathered.	4----20												
Permian	Slate	900--1500												*
	Weathered.	20---30												



WENNER Arrangement



Lines of Current Flow between
Electrodes P1 and P2 in Two-Layered earth

Figure 3.1.1
WENNER Arrangement and
Current Flow of Two-Layered earth

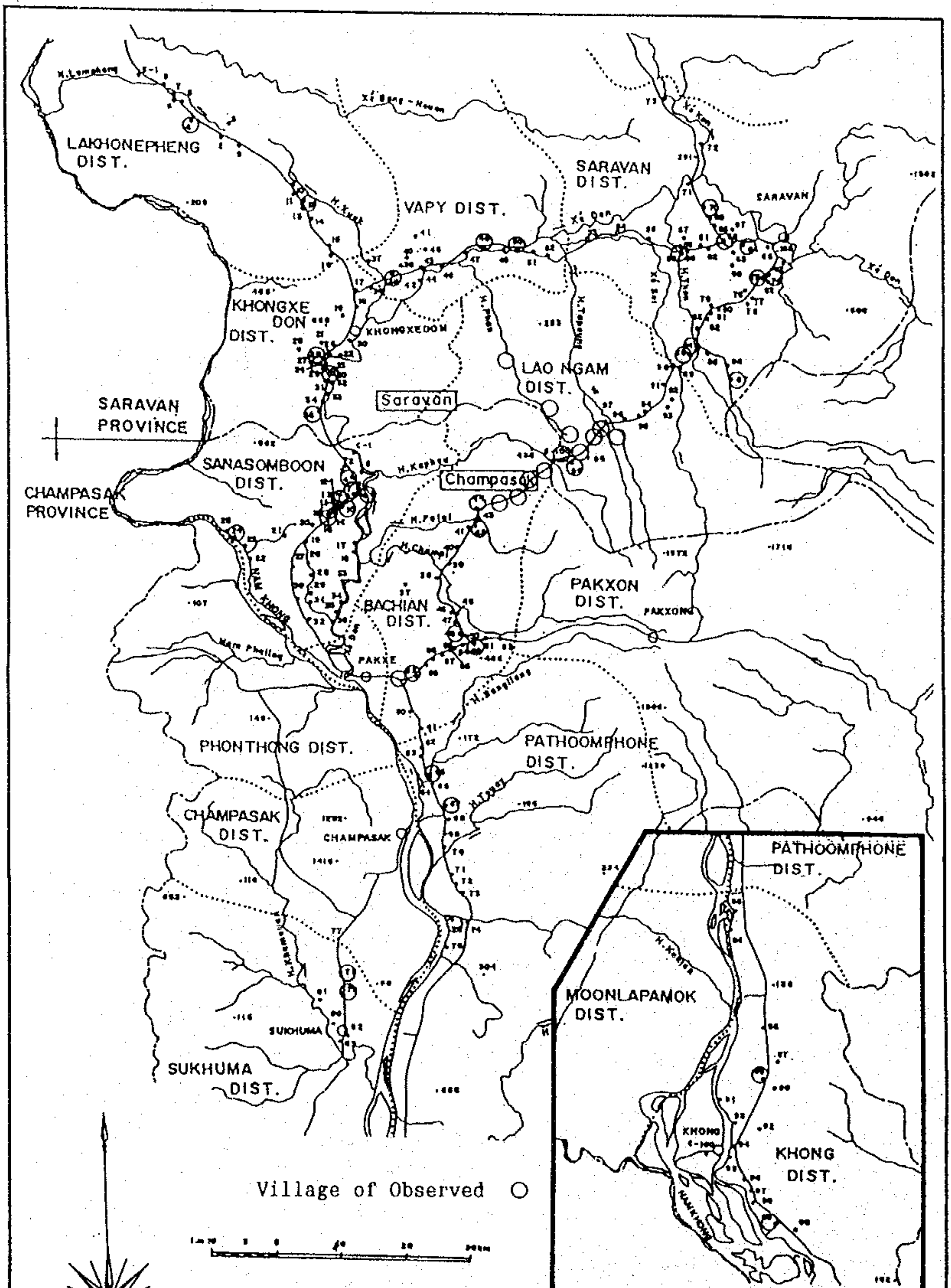


Figure 3.1.2	Location of Observed Points on Electrical Prospecting

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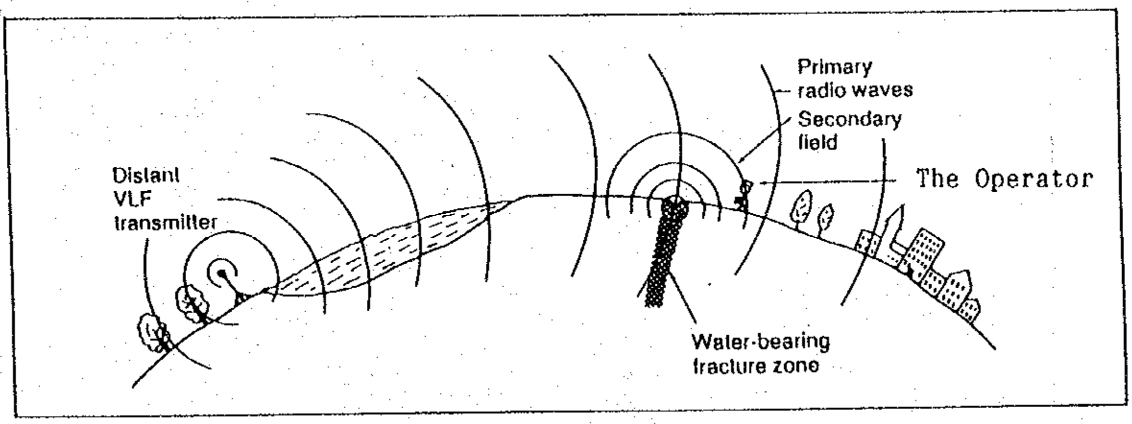
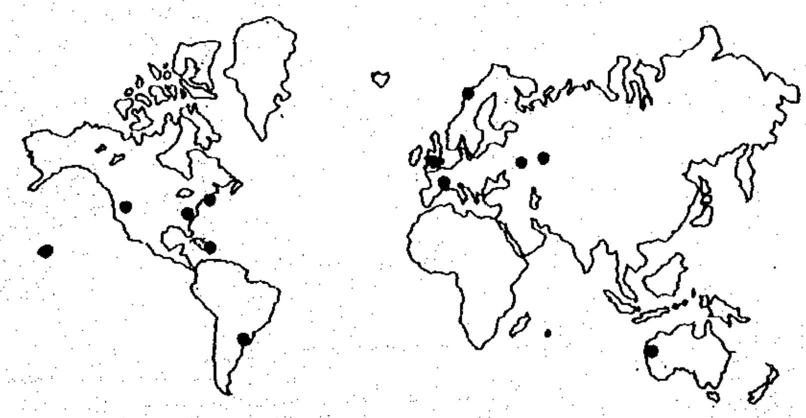


The Illustration of VLF Principle

VLF stations

	Frequency (kHz)	Power (kW)
Bordeaux, France (FUO)	15.1	500
Rugby, Great Britain (GBR)	16.0	750
Hegeland, Norway (JXZ)	16.4	350
Gorki, CIS (ROR)	17.0	315
Moscow, CIS (UMS)	17.1	1000
Murmansk, CIS (UPP)	18.1	
Oxford, Great Britain (GBZ)	19.6	550
Annapolis, USA (NSS)	21.4	400
Northwest Cape, Australia (NWC)	22.3	1000
Burlage, Germany (DHO)	23.4	
Lauiualei, Hawaii, USA (NPM)	23.4	600
Cutler, Maine, USA (NAA)	24.0	1000
Seattle, Washington, USA (NLK)	24.8	125
Aguada, Puerto Rico (NAU)	28.5	100



The distribution of VLF Stations

Figure 3.2.1 VLF Principle and VLF Stations

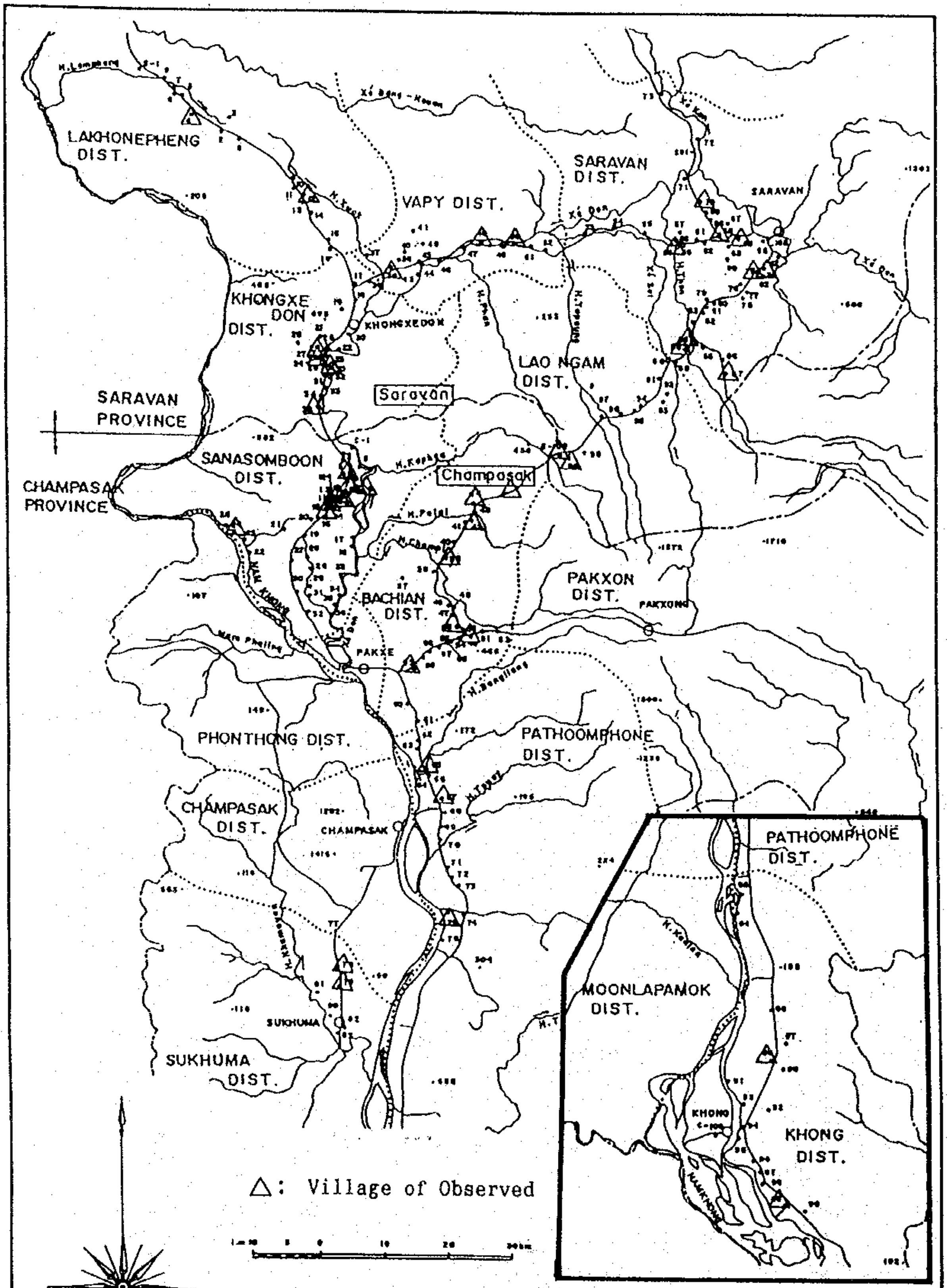


Figure 3.2.2	Location of Observed Line on VLF method

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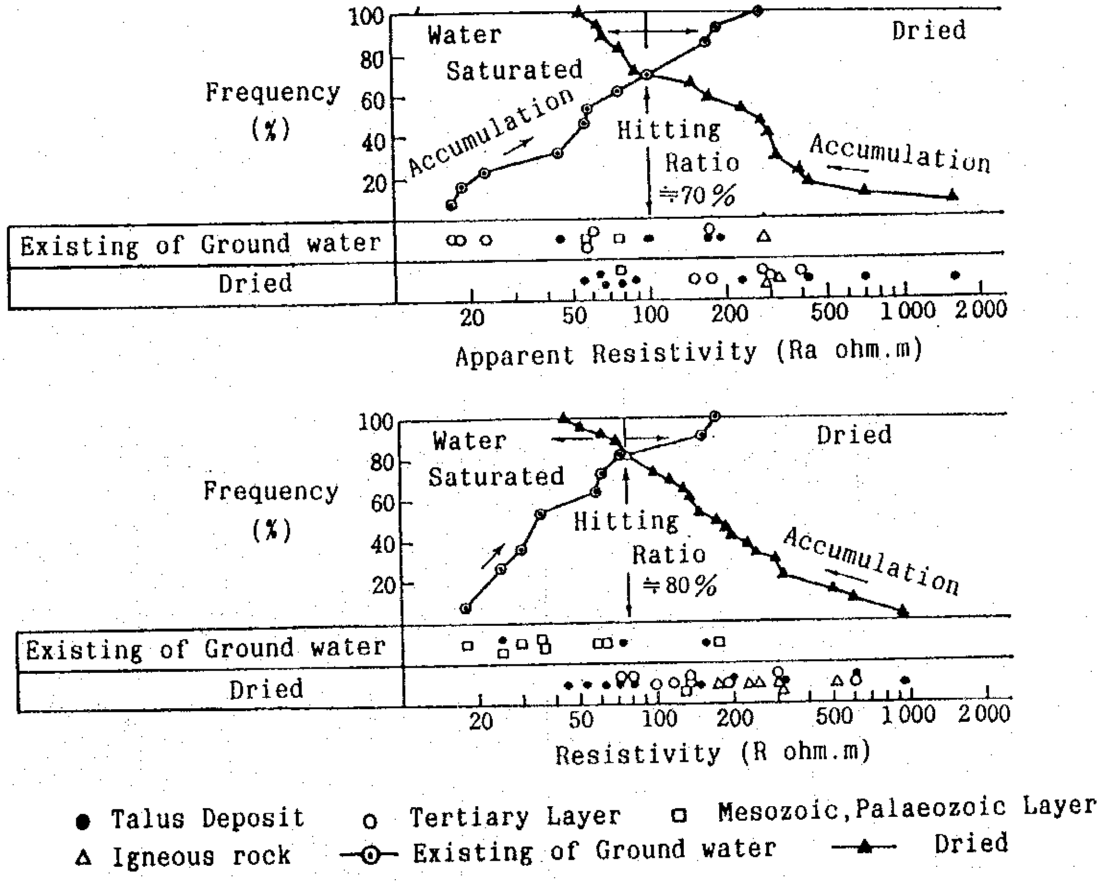
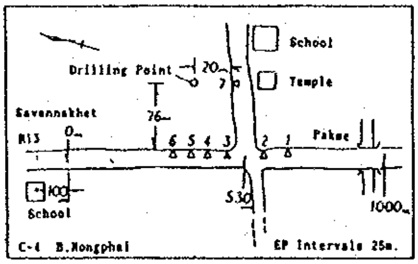
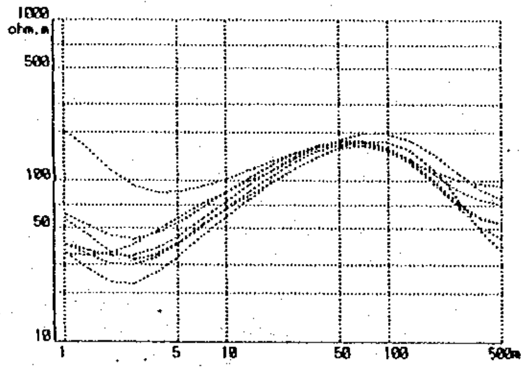


Figure 3.3.1
Evaluation of Soil Water by Resistivity Survey
From the textbook for the symposium : S.Okuzono 1973
(Society of Geophysical Exploration)



Location of E.P. Centre



Interpreted Resistivity Curves

Resistivity Profile

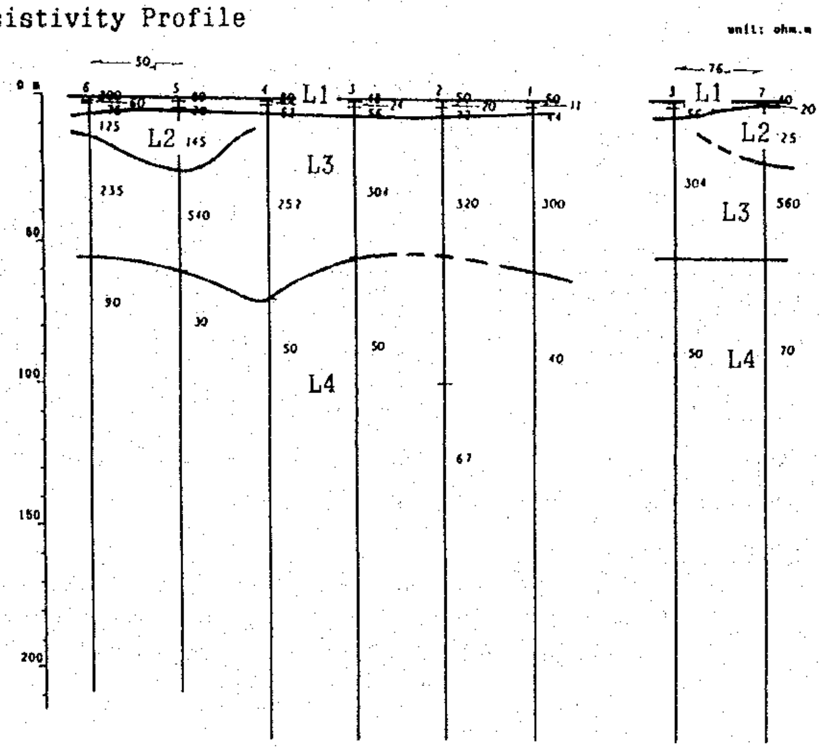


Figure 3.3.2(1/42)	Resistivity Profile C4 B.Nongphai
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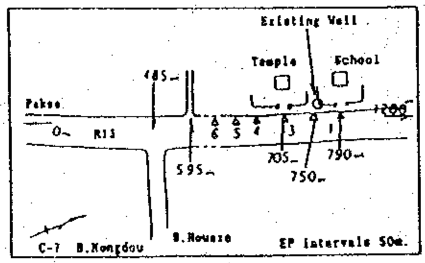
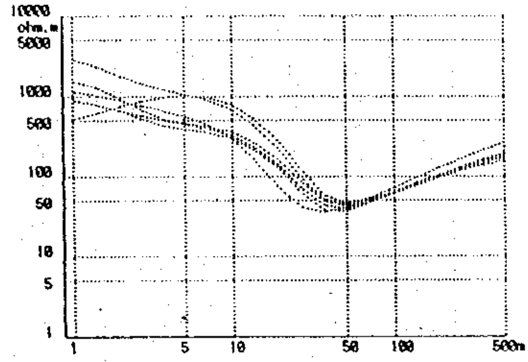


Location of E.P. Centre



Interpreted Resistivity Curves

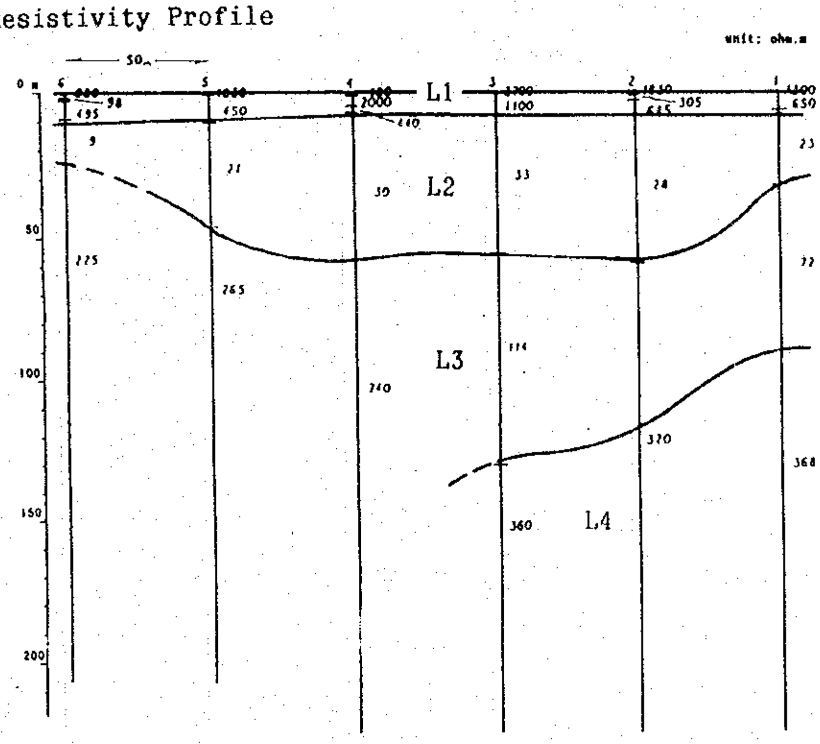


Figure 3.3.2(2/42)	Resistivity Profile C7 B.Nongdou

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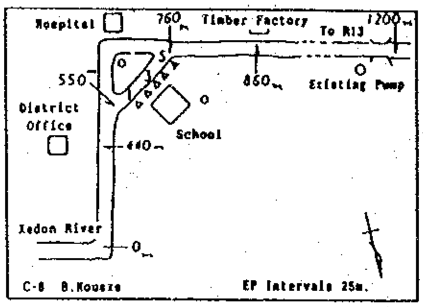
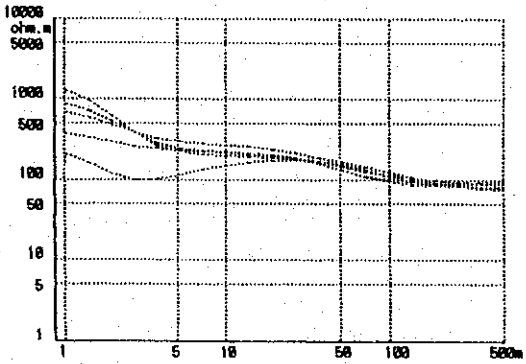


Location of E.P. Centre



Interpreted Resistivity Curves

Resistivity Profile

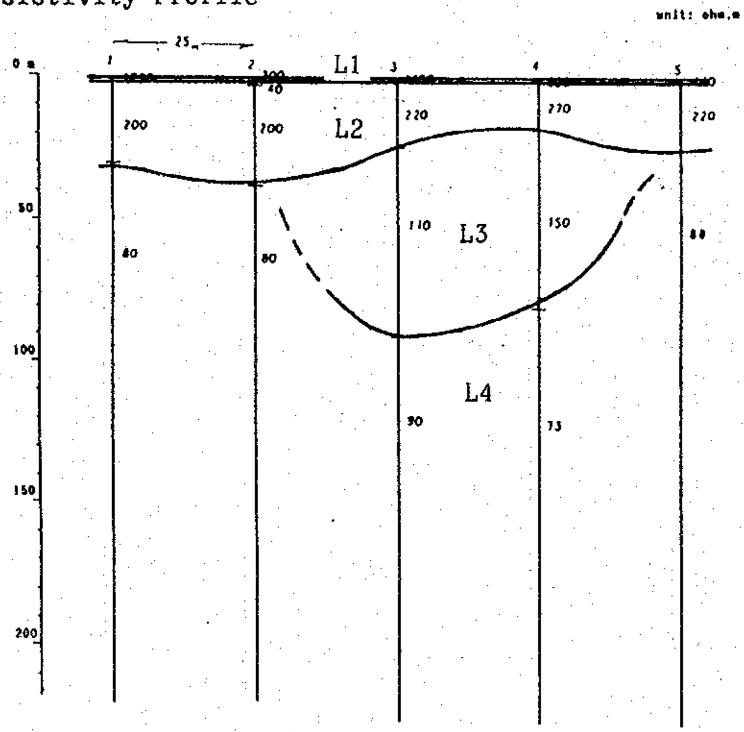


Figure 3.3.2(3/42)	Resistivity Profile C8 B.Houaxe

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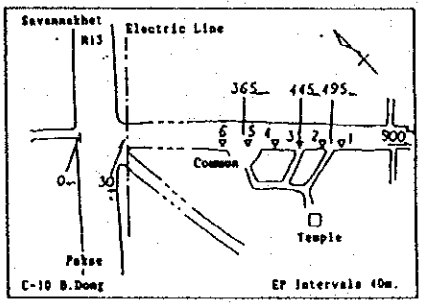
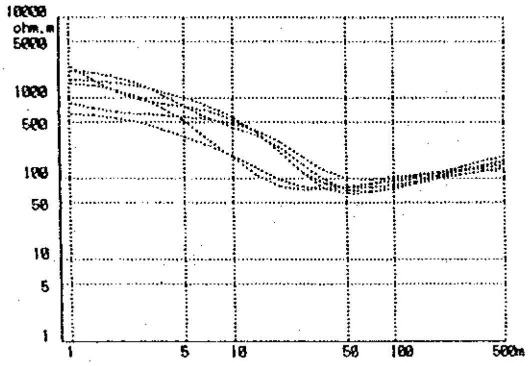


Location of E.P. Centre



Interpreted Resistivity Curves

Resistivity Profile

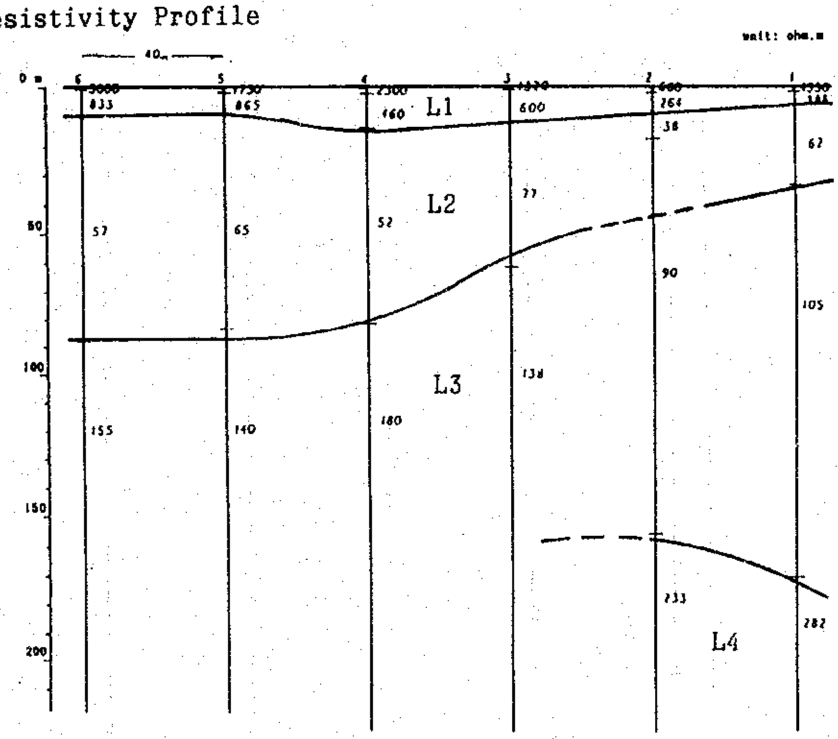


Figure 3.3.2(4/42)	Resistivity Profile C10 B.Dong
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