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ການສຳຫຼວດ ພັດທະນານ້ຳໃຕ້ດິນ
ແຂວງຈຳປາສັກ ແລະສາລະວັນ
ສາທາລະນະລັດ ປະຊາທິປະໄຕ ປະຊາຊົນລາວ

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

ແຜທີ່ ທໍລະນີສາດ ນ້ຳໃຕ້ດິນ ແຂວງ ສາລະວັນ ແລະ ຈຳປາສັກ

Hydrogeological Map Of CHAMPASAK And SARAVAN Provinces
1:200,000 ...... 2 Sheets

ແຜນທີ່ ສະແດງຄວາມສາມາດມີນ້ຳ ໃຕ້ດິນ ຕາມຫລັກການ ທໍລະນີສາດ ນ້ຳໃຕ້ດິນ

Groundwater Potential Map Based On Hydrogeology
1:500,000 ...... 1 Sheet

December 1995

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

HYDROGEOLOGY

OF

CHAMPASAK AND SARAVAN PROVINCES

IN

LAO PEOPLE'S DEMOCRATIC REPUBLIC

Hydrogeological Map 1:200,000..................2 Sheets

Groundwater Potential Map 1:500,000............1 Sheet

DECEMBER 1995

JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF HEALTH, LAO PEOPLE'S DEMOCRATIC REPUBLIC

INTRODUCTION

This report is summary on the Study on Groundwater Development for Champasak and Saravan Provinces in Lao PDR(hereinafter referred to us "the Study"). This report presents the results of the studies on the geology, hydrology of the area as well as a evaluation of its groundwater potential.

The Study Team which was organized by the Japan International Cooperation Agency(JICA), has conducted an intensive survey work covering an area of about 26,000 k㎡ of the Champasak and Saravan Provinces. The Study was carried out in accordance with the Scope of Work(SW) which was agreed upon between the Ministry of Health(MOH) Lao PDR and the JICA. The Study was launched in late March 1994 and completed at the end of December 1995.

Study Team

For this Study, the Clean Water Institute(CWI) which is under the National Institute of Hygiene and Epidemiology(NIHE) of MOH, the Provincial Health Department Champasak(PHDC) and the Provincial Health Department Saravan(PHDS) act as the counterpart agencies.

The Study was carried out jointly by the JICA Study Team experts and the counterpart personnel from CWI,PHDC and PHDS.

<u>JICA Study Team</u>

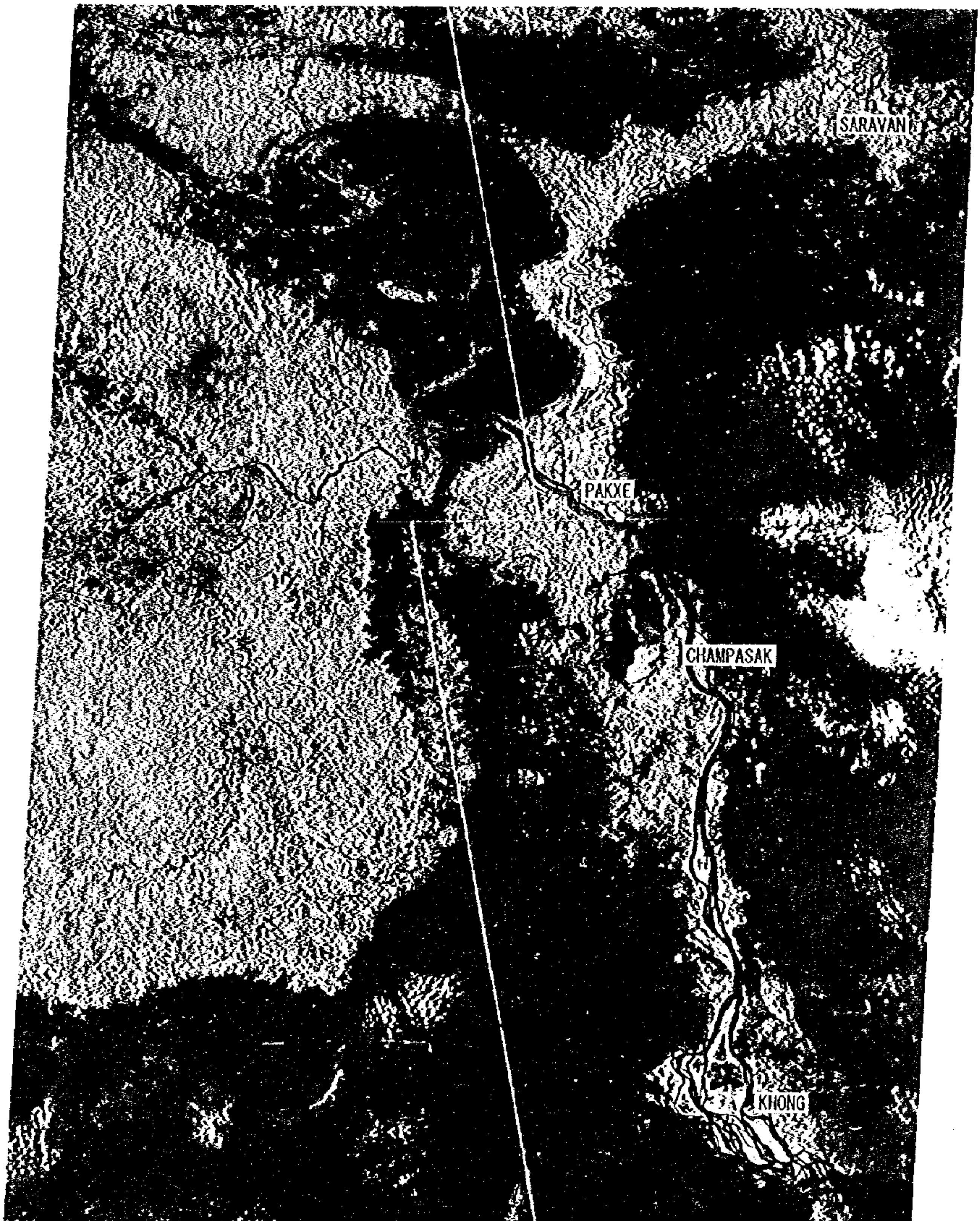
Dr.Akira KAMATA	Team Leader/Hydrogeologist
Mr.Shoichi OHMORI	Hydrogeologist
Dr.Msao HIGUCHI	Hydrologist
Mr.Hiroshi IBARAKI	Geophysicist
Mr.Eiji TAKEMORI	Water Supply Engineer
Mr.Kensuke SAKATO	Civil Engineer(Well Maintenance)
Mr.Syoji MASUMURA	Socio-economist
Mr.Precha CHUNTAKORN	Civil Engineer(Village Survey)
Mr.Akio MURAYAMA	Coordinator

<u>CWI</u>

Dr.Nouanta MANIPHOUSAY	Deputy Director
Dr.Khamvieng VILAPHANH	Medical Doctor
Mr.Kongkham SUTHAMMAVONG	Civil Engineer

<u>PHDS</u> Dr.Vath KONGKEO Chief,DWSES

<u>PHDS</u> Dr.Khoutdara VONSARAVANE Director



LANDSAT-TM Images of the Study Area

(Feb. 19. 1994. False Color Image) 1 : 1,000,000

CONTENTS

List of Tables and Figures

Tables

Figures

1.Natural Environment of Lao P.D.R.

1.1 Location and Extent

Lao People's Democratic Republic(Lao P.D.R) is located in the southeastern part of Asia, bounded on the north by China and Myanmar, on the east by Vietnam; on the south by Cambodia: on the west by Thailand.The Mekong River flowing from the north towards the southeast and partly separates Lao from Thailand.

Lao has an area of 236,800 square kilometers. Its greatest length from north-west to south-east is about 1,100 kilometers and its greatest width is about 500 kilometers. Its lies between 14° N and 22° 30' N latitude, and between 100° E and 108° E longitude.

The study area comprises an area of 26,016 square kilometers and lies between 14° N and 16.5° N latitude, and between 105.2° E and 107° East longitude.

1.2 climate

The climate in Laos is influenced by seasonal monsoon winds. During the northeast monsoon, from November to February, cold dry air from the China mainland enters the country, though considerably modified during its southward surge. From May to September, the southwest monsoon brings a stream of warm moist air from the Indian Ocean,causing abundant rain over the country.

The onset of the monsoon varies to some extent. The southwest monsoon usually starts in May and ends in September. The northeast monsoon normally sets in during November and ends in February, but occasional surges of the northeast monsoon may still be experienced in March up to early April.

From the meteorological point of view, the climate of Laos may be divided into four seasons:
a.Winter,or northeast monsoon season, from November to February. This is the mildest period of the year.
b.Pre-monsoon season or summer, in March and April. This is the transitional period from the northeast to southwest monsoon.It is hottest in April.
c.Rainy or Southwest monsoon from May to September, The Southwest wind from the Indian Ocean is most active in July and abundant rain occurs over the whole country.Peak of rainfall

usually occurs in August.

d.Post-monsoon season in October. It is the transitional period from the southwest to the northeast monsoon season.

Dry weather over the plain persists in the cold season, November-February and throughout the hot season, but it is generally broken in early May with frequent rains and thunderstorms.Although rains generally continue from June to September, occasional dry spells occur in June.Maximum rainfall is in August and September.

The annual rainfall varies greatly over the country, about 1300mm in the northern valley to over 3700mm in the southern mountains. Heaviest rainfall usually occurring along the windward side of mountain ranges lying across the path of the southwest monsoon such as the Annamite Mountain Range.

According to Soukhathammavong(1992),rainfall measurements started from 1900 at Khong, Attapeu, Muongmai, Savannakhet, Vientiane, Luangprabang, Xiengkhouang ville. At present, there are 80 rainfall stations with at least 10 years of records in the whole country of Laos. An isohyetal map of annual precipitation is shown in Figure 1-1. Low rainfall zones are distributed in Xayaboury Province, the Namkhane Valley and Savannakhet Province. High rainfall zones are located in the northern and southern Highlands and Annamite Mountain Range. Annual mean precipitation of 80 stations in Laos is 1953mm/year as shown in Table 1.1.

Table 1.1 Monthly and Annual Precipitation in LAO P.D.R. (mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Laos	8	21	41	107	231	316	403	408	281	91	32	14	1953
Basin	8	15	40	77	198	241	269	292	299	163	54	14	1672

* :The whole country of Laos with 80 rainfall stations

**:The lower Mekong Basin with 245 rainfall stations

On the average, a monthly value of more than 400mm is observed in July and August. A monthly value exceeding 900mm is observed in the highlands.

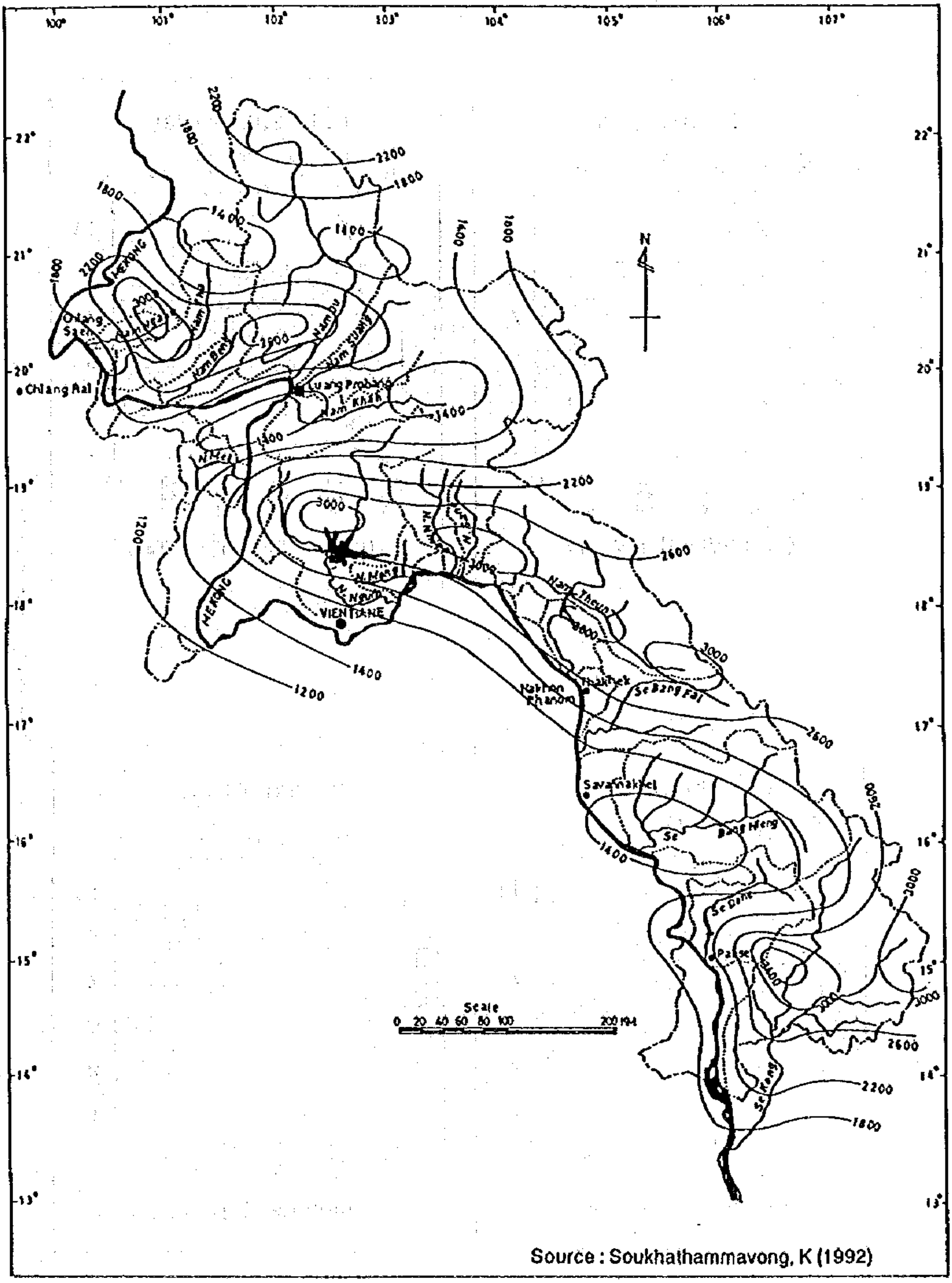


Figure 1.1 Isohyetal Map of Annual Precipitation in Laos

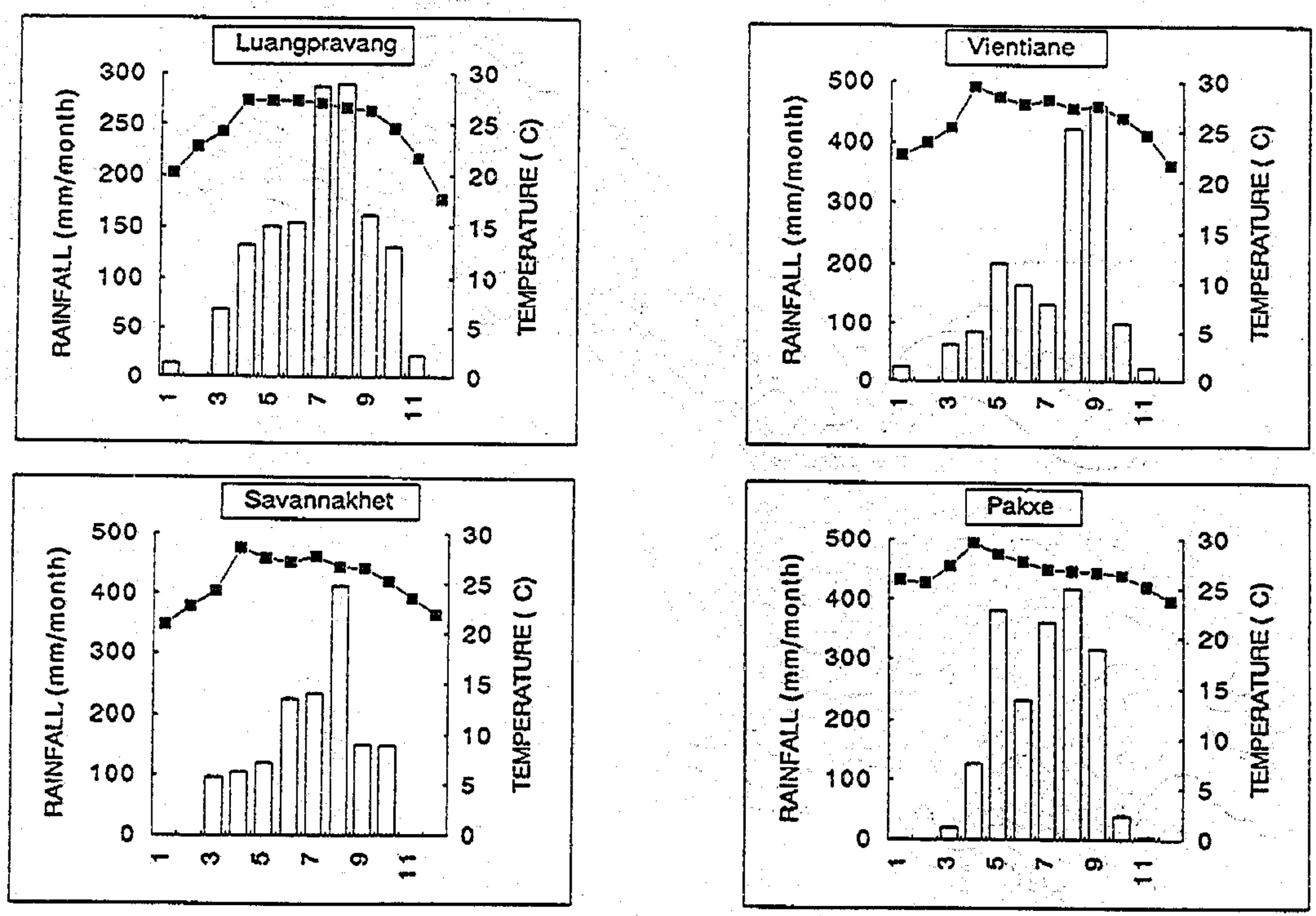


Figure 1.2 **Climate Graphs in Laos**

1.3 Hydrology

The Mekhong River runs along the western side of Laos and forms the border with Thailand. Originating in China, the Mekong River and its tributaries drain regions in six countries:China,Myanmar,Lao P.D.R, Thailand, Cambodia and Vietnam. The Mekong River is one of the major rivers in the world. The drainage area is 783,000k㎡, which ranks 30th among the largest drainage basins in the world. The length of the river is 4,300km, which is the world's 15th longest river. The average to the ocean is 15,000m3/sec, which is the sixth largest in the world.

General hydrologic characteristics of the Mekong River are listed in Table 1.2. The discharge increases very rapidly downstream of the Chinese border. The main Mekong River between Nong Khai and Khong Chiam receives the flows from several large tributaries from the rainy mountain chain in Laos. The runoff increases down to Khong Chiam. The main Mekong River between Khong Chiam and Pakse receives the flow of Nam Mun from the Korat Plateau in Thailand. This increases the drainage area but does not contribute too much to the discharge. Thus the runoff decreases between Khong Chain and Pakse. The main Mekong River receives the flows from the eastern mountains in Laos, and both the discharge and runoff increase downstream of Pakse.

The flow of the Mekong River and its tributaries is closely related to the rainfall pattern as shown in Figure 1.3. The flow begins to rise at the beginning of the wet season, April to May, and reaches a peak in August or September. The flow decreases after October and reaches a minimum in March or April. Generally about 85% of the runoff occurs in the wet season.

Table 1.2 Hydrological Characteristics of the Mekong River

Hydrological station	Drainage basin k㎡	Daily discharge, m3/sec Mean	Max	Min	Runoff mm/year
Chinese border	160,000	-	-	-	-
Chiang Saen	189,000	2,693	23,500 [1966]	543 [1966]	448
Luang Prabang	268,000	3,973	25,200 [1966]	652 [1966]	467
Nong Khai	302,000	4,620	26,000 [1966]	701 [1966]	483
Mukdahan	391,000	7,583	36,400 [1978]	970 [1966]	612
Khong Chain	419,000	9,352	54,300 [1978]	1,230 [1966]	703
Pakse	545,000	9,805	56,000 [1978]	1,060 [1966]	568
Stung Treng	635,000	13,800	65,700 [1939]	934 [1966]	686
Kratie	646,000	14,000	66,700 [1939]	1,250 [1966]	684

source: Mekong Secretariat (1984)

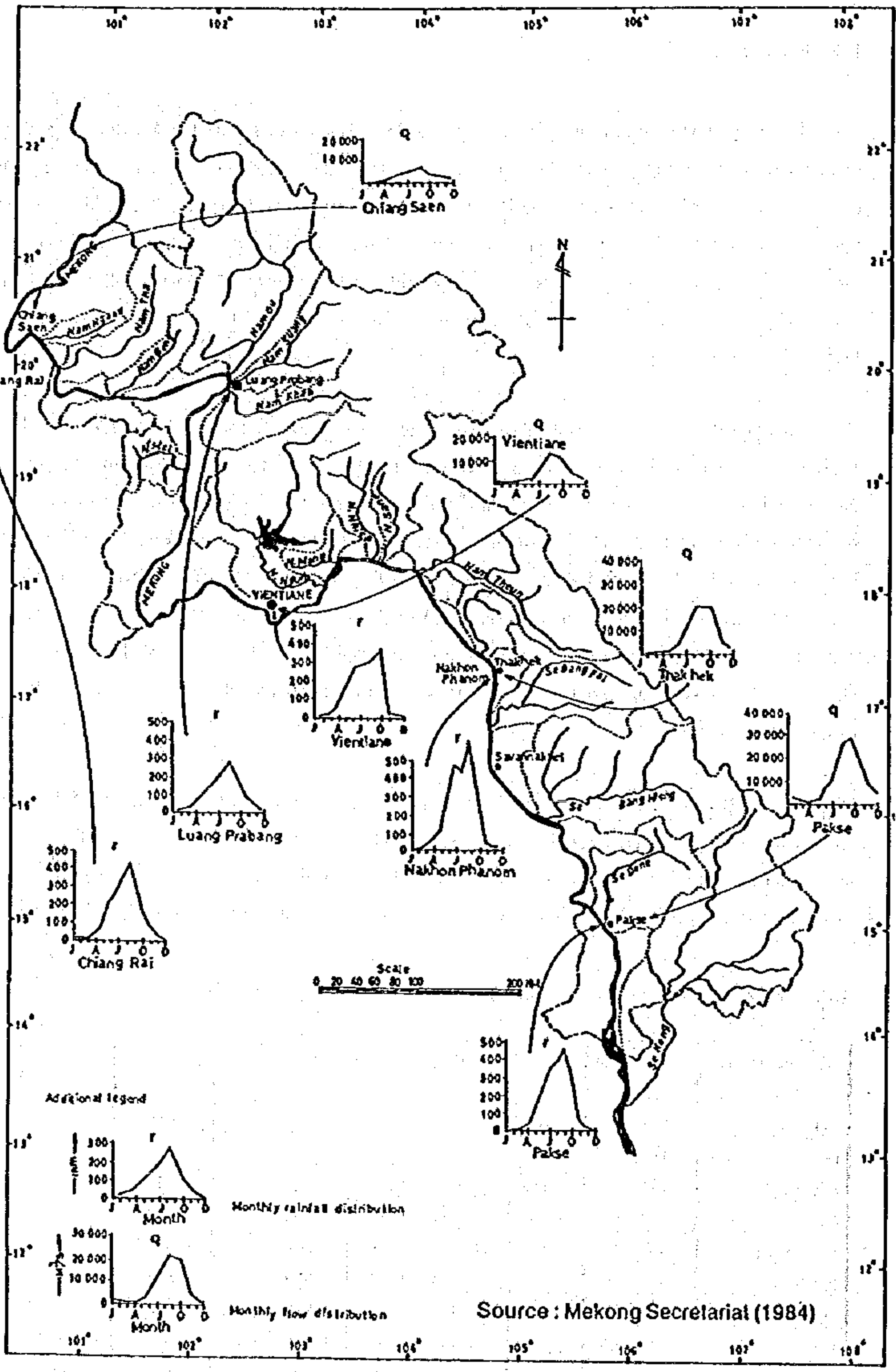


Figure 1.3 River Flow and Rainfall Pattern in Laos

1.4 Topography

Lao may be divided into four physiographic regions, i.e.,the mountain range,the undulated plain, the plateau and the alluvial low land along the Mekong River(Figure 1.4).

The mountain range, i.e.,the Annamite Mountain Range stretches from north-west to south-east along the border of Vietnam forming steep slope and deep V-shaped valley.The mountain peak exceeds 2,000m above mean sea level.

The plain area,i.e.,the Vientiane Plain, the Savannakhet Plain and the Champasak Plain are lower 500m in altitude and form a wide and a flat landform where Jurassic to Mesozoic continental sandstone and shale are widely distributed.

The Xiangkhoan Plateau(Plain of Jars) in Xiangkhoan province and the Bolaven Plateau in the southern part of Laos are wide and gently undulated plain with altitude of 1,000m to 1,300m.

The Alluvial lowland is distributed continuously along the Mekong River and forms a narrow and flat plain in Vientiane(200m high), and khong(80m high).

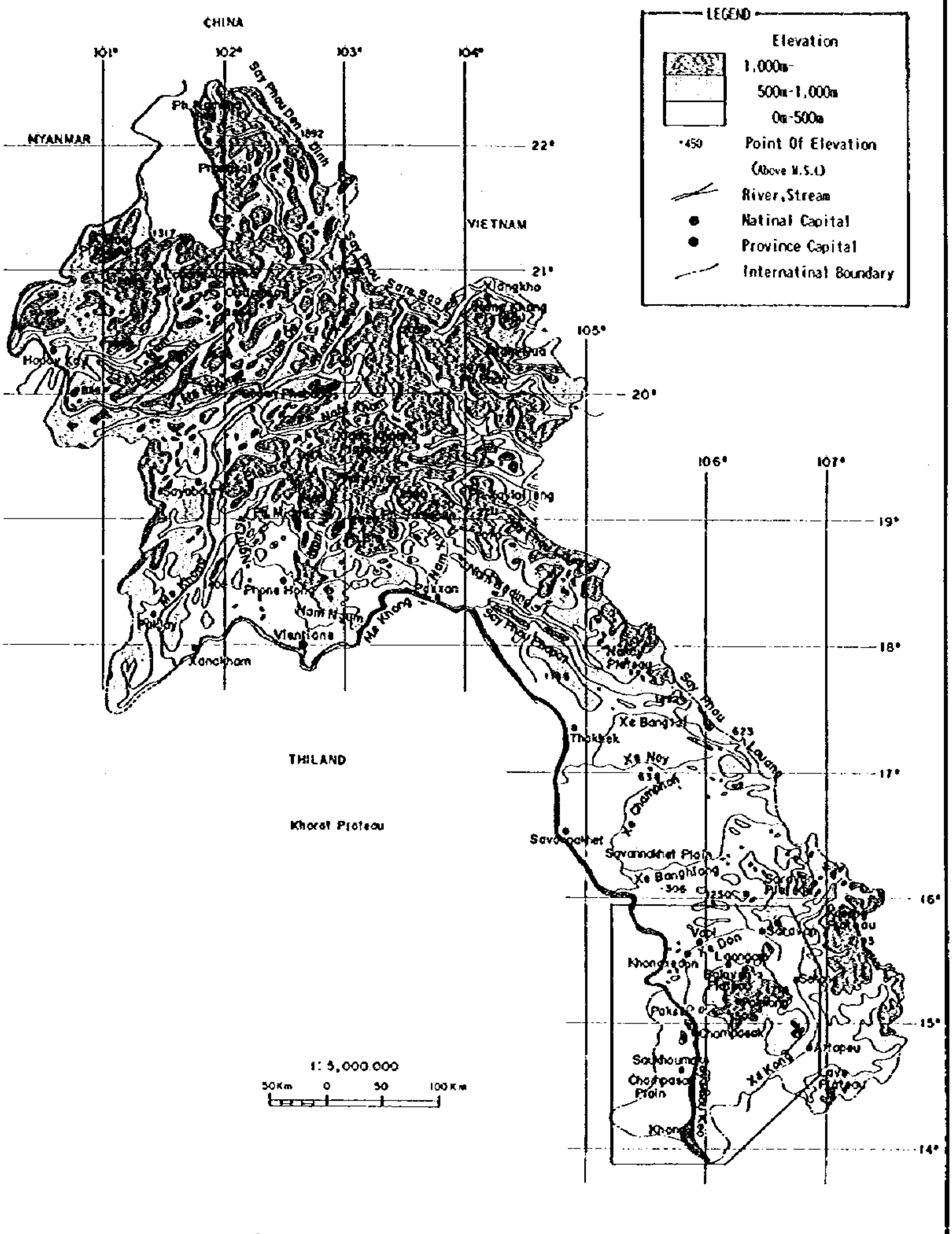


Figure 1.4	Topographic Map Of The LAO P.D.R.

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.

1.5 Geology

(1) Geology of Indochina

Lao P.D.R is located inland of the Indochina Peninsula and geological connected to Vietnam, Thailand, Cambodia and Myanmar(Figure 1.5).The Indochina Peninsula is geologically divided into Proterozoic basement rock area(Kontum Massif), strongly folded Hercynian Mountain, Indosinian Massif, slightly folded Paleozoic area, and basaltic rocks and sedimentary basins of Tertiary and Quaternary ages.

The Kontum Massif is composed of metamorphic rocks and granitic rocks and exposed in southeast of Laos to Vietnam, north of Laos, west of Cambodia and east of Thailand. This Massif is extensively distributed and forms the basement of the Indochina Peninsula.

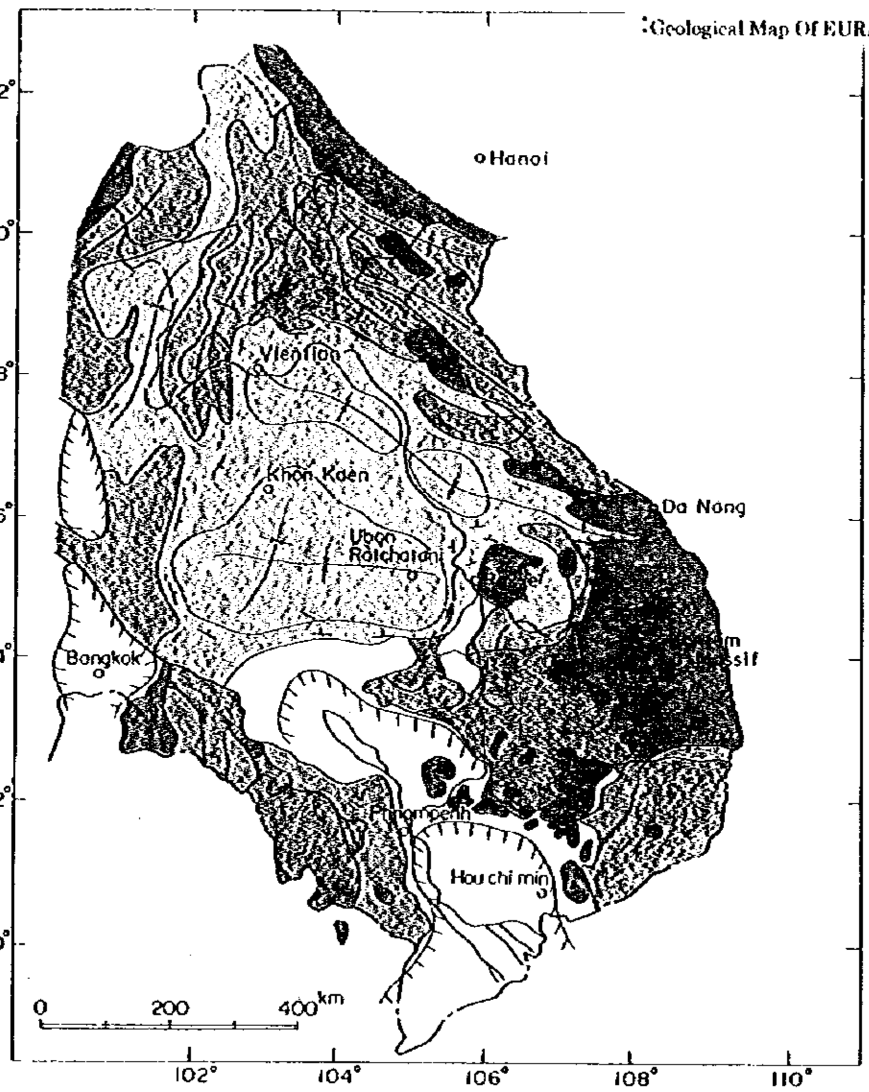
The Hercynian Mountain surrounds the exposed area of the Kontum Massif. The Hercynian Mountain became land through orogenic movement in middle to late Paleozoic age. The area forms a steep high mountain and is composed of strongly folded sandstone, slate and limestone etc.

The Hercynian Mountain is surrounded by the Indosinian Massif. The Indosinian Massif consists of strongly folded slate,sandstone and limestone. It became land through orogenic movement in Triassic age.

Slightly folded Paleozoic rock is extensively distributed in northeast of Cambodia, forming a plateau. Mesozoic sedimentary rocks are distributed widely in the central part of the Indochina Peninsula. Sedimentary rocks are composed of sandstone and red shale,were deposited in the sedimentary basins of Jurassic to Cretaceous age. Evaporite also occurs in late Cretaceous age.

Basaltic rocks of Tertiary to Quaternary ages are sporadically distributed in Bolaven Plateau in south of Laos, south of Vietnam and northeast of Cambodia, forming flat high plateau . Rocks consisting of alkali basalt lava were formed during volcanic activities in Pliocene to Pleistocene age.

Modified: Workman,D.R.(1975))
:Geological Map Of EURASIA(USSR1972)



LEGEND

Plain

Neogene-Quaternary Sedimentary Basin

Plateau

Alkali Basalt (Paleogene-Quaternary)

Paraplatform

Sandstone,Shales (Jurassic-Cretaceous)

Tuff,Slate,Sandstone,limestone (Upper Paleozoic-Triassic)

Orogen

Indosinian Massif (Upper Paleozoic-Triassic Formation) Late Triassic Fold Belt

Hercynian Massif (Mainly Paleozoic Formation) Middle-Late Paleozoic Fold Belt

Kontum Massif (Pre-Cambrian Crystalline Rocks)

Attitude

Axis Of Downwarping

Axis Of Upwarping

Figure 1.5 Simplified Geological Map Of INDOCHINA

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

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Sedimentary basins of Tertiary and Quaternary ages are located in Cambodia,the Mekhong Delta and the Central Plain of Thailand, where the sediments are composed of unconsolidated sand, gravel, clay and marl.

As mentioned above, the basement of the Indochina Peninsula is composed of Proterozoic metamorphic rocks. The land was originally formed by the orogenic movement from Paleozoic to Mesozoic age. Huge sedimentary basins were formed inland in the late Indosinian orogenic movement(Jurassic to Cretaceous period). Red shale, sandstone and evaporite were deposited in the basins.

Early Cenozoic era was the geologic time of the continent. The land was eroded, and peneplains occurred extensively. The upheaval movement became active again in the late Cenozoic age. Rivers like the Mekhong River were eroded downwards, building up the present landform. Volcanic activities also took place during this period,forming the lava plateau. Relative subsidence areas became Tertiary to Quaternary sedimentary basins,forming the lowland.

(2)Geology of Lao P.D.R

All types of geologic members mentioned above are distributed in Lao P.D.R(Figure 1.6). The stratigraphy and lithology of the formations and rocks are presented in Figure 1.7.

Proterozoic rocks

The oldest rocks in Laos are distributed sporadically in the vicinity of Vietnamese border and composed of metamorphic rocks such as migmatite and gneiss. These rocks form a part of Kontum Basement Massif. Few outcrops are also found in the border of Myanmar.

Paleozoic rocks

Lower formations(Cambrian to Devonian) surround the basement and composed of weakly metamorphic sandstone, slate, limestone and conglomerate in marine origin. Upper formations(Carboniferous to Permian) are composed of sandstone, limestone and slate in marine origin. Huge limestone block of this formation forms a unique karst topography in Kammouan province. Few coal bearing continental sediments are also found in Vientiane,Pongsaly and Saravan.

Permian and Triassic volcanic rocks

Rhyolitic and dacitic effusive volcanic rocks and intrusive rocks are distributed in Paklay-Luangpravan Belt, Sam-noua and Cambodian border. These rocks occurred accompanied with the volcanic activities of Permian to Triassic age.

Mesozoic marine sediments

Marine sediments, consisting of sandstone, slate and tuff occurring in Triassic age, are distributed in the vicinity of the volcanic rocks mentioned above. Marine Triassic sediment exposed in Xe Kong valley nearby Cambodian border is the youngest of marine origin known in Laos.

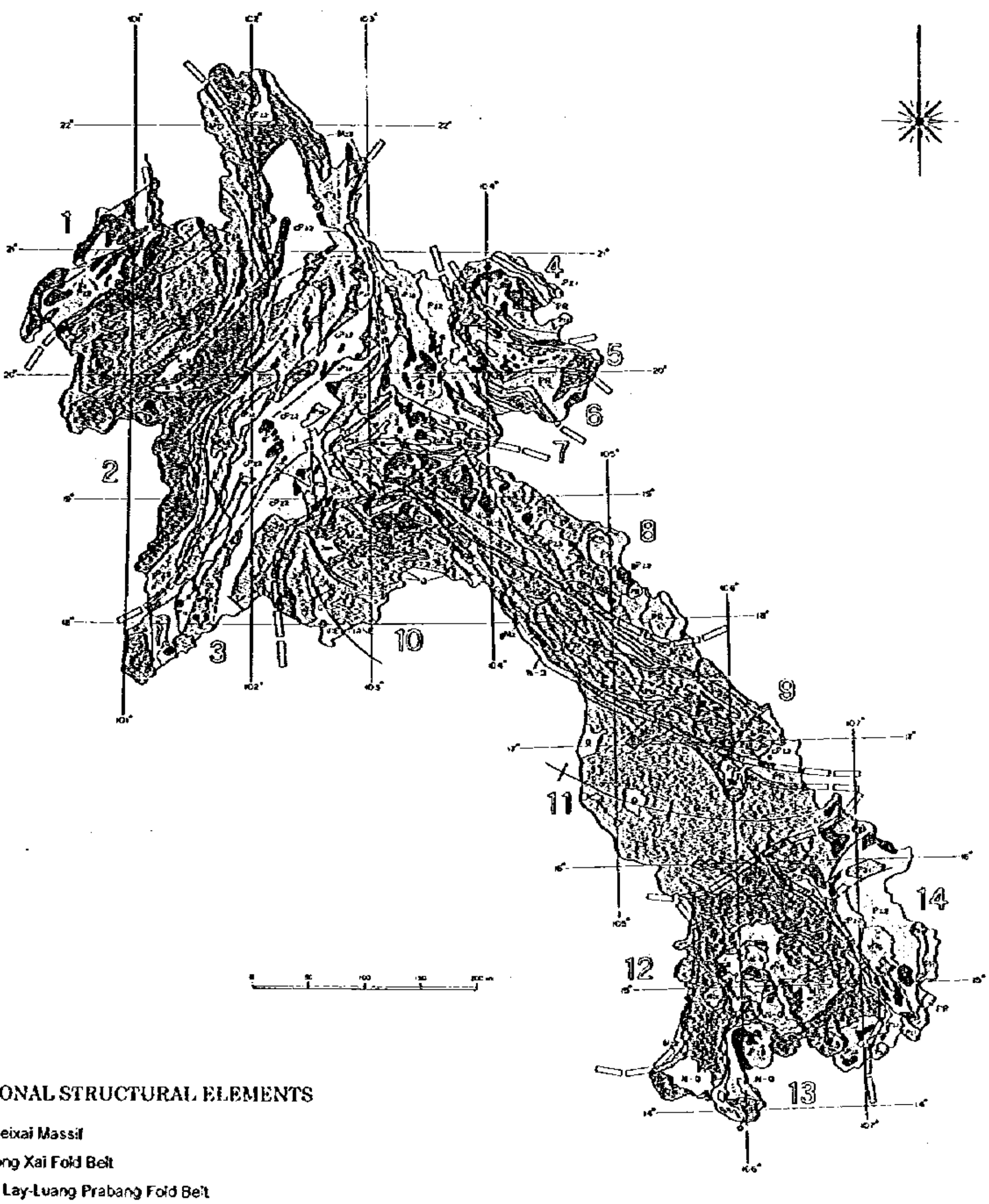
Mesozoic non-marine sediments

These sediments consist of sandstone and shale deposited in the intra-mountaim sedimentary basins which were formed during the late Indosinian orogenic movement. The Vientiane Plain, the Savannakhet Plain and the Champasak Plain are composed of these sediments. Upper member contains evaporite.

Cenozoic sediments

Paleogene sediments are not distributed in Laos. All of the area became land, and peneplains occurred widely in this age.

Neogene sediments are found in the small intra-mountain basin in northern part of Laos. The sediments consist of sandstone, mudstone,marl and lignite of freshwater origin.Terrace deposits,semi-consolidated gravel are found in small area in the Study Area.



REGIONAL STRUCTURAL ELEMENTS

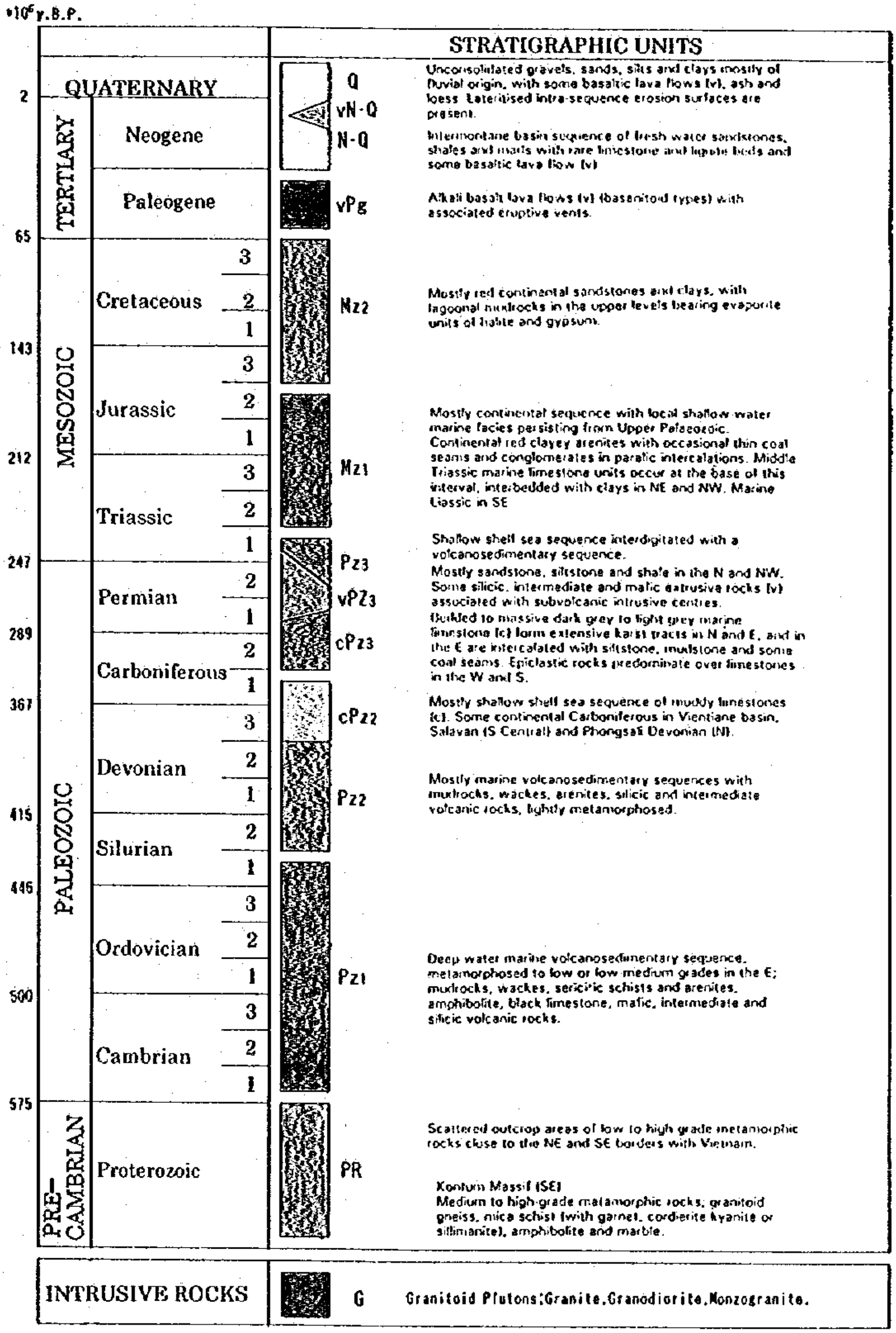
1 Houeixai Massif
2 Muong Xai Fold Belt
3 Pak Lay-Luang Prabang Fold Belt
4 Song Ma Massif
5 Xam Nua Trough(Basin)
6 Phu Hoat Massif
7 Annamitic Fold Belt
8 Rao Co Massif
9 Truongson Fold Belt
10 Vientiane Basin
11 Savannakhet Basin
12 Khorat Basin
13 Boloven Active Swell
14 kontum Massif

Modified Geological And Mineral Occurrence Map
B.G.S.(1990-91).

Figure 1.6	Simplified Geological Map Of LAO P.D R.

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

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)



Modified GEOLOGICAL AND MINERAL OCCURRENCE MAP B.G.S(1991).

Figure 1.7 Stratigraphy Of LAO P.D.R.

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

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2 Hydrogeology of the Study Area

A hydrogeological reconnaissance survey was conducted using topographical maps, aerial photographs and LANDSAT images.

2.1 Geomorphology

The study Area is divided into six physiographic areas,i.e.,mountain, low plain, high plain, basalt slope, escarpment and plateau.

Mountain

Mountain area is located in the east and south of the Study Area. In the east, it covers a part of the Annamite Mountain Range. Its altitudes from 1000m to 2000m, and it has many V-shaped valleys. The mountain area in the Cambodian border has a rather gentle slope and the altitudes range from 300m to 1300m.

Low Plain(Erosion Plain)

Low Plains are extensively distributed along the Mekong River and its tributaries, i.e., the Xe Don River and Xe Kong River. The plains are flat due to erosion, and their elevations range from 80m to 180m. Paddy fields are found in the plains. The low plains are contiguous to southern edge of the Savannakhet Plain, where the altitudes become higher.

Plateau

The Bolaven Plateau with an elevation of about 1300m is located in the central part of the Study Area. The plateau consists of basalt. The surface of the plateau is gently undulated. No deep valley is formed, but many spatter cones are found on the plateau.

Basalt Slope

Basalt Slope is a wide, gentle slope around the Bolaven Plateau. Its elevation ranges from 120m to 500m, and its sediments are composed of basalt lava and volcanic ash ejected from the Bolaven. Northwest in the Basalt Slope is being cultivated because of its fertile soil, plenty of rainfall, and accessibility to Pakse and Saravan.

Escarpment

Escarpment is located on the edge of plateau or high plain. West of the Study Area, the eastern edge of the Khorat Plateau forms a long escarpment in the north-south direction and bounds the Champasak Plain. North of the Study Area,the escarpment of the Savannakhet Plain trends in the east-west direction and divides the Champasak Plain. The elevations of these escarpments range from 400m to 500m. The escarpment with elevations of 500m to 1000m surrounds the Bolaven Plateau.

Mesa topography which was formed by deferential erosion is also found on the plateau. Most of the steep escarpments are densely covered by vegetation.

High Plain

This topography includes the "plain" in the Bolaven and the "mesa" which is isolated from the low plain. The high plain consists of alternating beds of sandstone and shale. Its mountain ridge is flat like a table. Since its elevation exceeds 1000m, and it is surrounded by escarpment, the land is not used for cultivation.

2.2 Drainage

The main rivers of the Study Area are the Mekhong River and its tributaries, namely, the Xe Don River and the Xe Kong River. The Xe Don River flows toward west, while the Xe Kong River flows towards south. These tributaries surround the Bolaven Plateau.

Inside the Study Area, the Mekhong River has a width of one to two kilometers. However, it is reticulated in the downstream and has a width of about 12km at Khong Island south of the Study Area. Rocks crop out on the river bed, but the terrace sediments consisting of sand, gravel and silt are found on the river side. Wide alluvial plain is not found along the Mekong River, except in the Nonghai Plain and Champasak Plain.

The Xe Don River originates from the Bolaven Plateau and the east mountain area. It flows westward north of the Bolaven Plateau. It then flows southward at Kongxedon and joins the Mekhong River at Pakse. Alluvial sediments are found downstream of Kongxedon.

The Xe Kong River originates from the eastern mountains and is joined by small rivers from the watershed of the Bolaven Plateau. It flows down to Cambodia.

The discharge is stable in small rivers draining the Bolaven Plateau is a huge recharge zone for surface water and groundwater. Rainfall infiltrates and flows through the basalt slope. Most streams and rivers are effluent due to groundwater discharge.

2.3 Geologic and Hydrogeologic Features

This section describes the geologic and hydrogeologic features of the Study Area based on the field reconnaissance survey and analysis of existing borehole data.

The stratigraphic classification presented in the UNICEF report(1990) was adapted basically but modified according to the results of the survey and analysis(Figure 2.2).The hydrogeological map was prepared as a result of the survey.

(1)The Paleozoic(PZ,C-P)

The Paleozoic group is distributed in the mountain areas from northeast of Saravan to east of Attapeu, with elevations ranging from 1000m to 1200m. The formation is composed of slightly folded, metamorphic tuffaceous sandstone, slate and tuff(PZ). These rocks are considered as the hydrogeologic basement due to its hard and compact occurrence.

The flysh type sediments composed of sandstone and slate are distributed in the south of Khong Island. This formation can be correlated with the upper Paleozoic age(C-P). Though it is compact and hard, the formation may be found to have few fissure water.

(2) The Mesozoic(T,J,J-K)

The Mesozoic is composed of Manggian formation, Jurassic shale beds, Champa formation and Donghen formation in ascending order. Donghen formation is distributed in the Savannakhet area and contains evaporites.

1) Manggian formation(T)

The Manggian formation crops out in the south of Pathoumphon, i.e.,on the left bank of the Mekong River and in the south and east of Attapeu. The erosion terrace along the Mekong River and the gently undulated hill are composed of this formation.

The fault(lineament) in the northwest to southeast direction and perpendicular(northeast to southwest) direction is found; however, no continuity to Jurassic formation is observed. Therefore, this formation may be correlated with the Permian to Triassic age.
This formation consists so hard rhyolitic tuff, quartz porphyry and welded tuff.

2) Jurassic shale bed(J)

This formation is distributed in the Champasak Plain with elevations of 100m to 200m. It can be correlated with the Khorat Subgroup in Thailand. Some outcrops in Saravan and Attapeu yielded fossils, indicating that this formation may be correlated with the lower Jurassic age(Workman,1977).

The lithology of this formation shows an evidence of marine sediments,i.e.,limestone and marl, in the vicinity of the basement rock. In the Champasak Plain, however, it principally consists of alternating beds of laminated sandstone with abundant muscovite and red sandy shale. Therefore, the formation is considered as continental sediments.

The formation is composed of rhythmical alternation of thin beds with thickness of 20cm to 30cm. Sandstone facies is prominent in the south of Kongxedong, but shale is abundant in Saravan. Sandstone and shale are medium hard and will jointed with 20cm to 50cm spacing.The surface is weathered along the joint. Shale is cracked dispersedly.

The formation is folded in waves with inclinations of 5 to 20 degrees. The axis of fold is parallel to the boundary of the pre-Triassic basement,i.e., the axis trends northwest to southeast in Saravan, northeast to south west in Attapeu and west-northwest to east-southeast in the south of Kongxedon. The thickness of the formation is estimated to be about 1000m.

Groundwater exists in the weathered zone, sandstone layer and fracture associated with joint and bedding. In the vicinity of Saravan, however, porous sandstone is intercalated in the formation.
Groundwater may exist in the intergranular of the beds.

3) Champa formation(J-K)

The mountain ridge at the Thailand border, the flat table plateau on the right bank of Xe Don and Bolaven consist of Champa formation. The formation is also distributed on the mesa topography in the northwest of Saravan. The formation may be correlated with the Khorat Subgroup of the Lower Indosinian Group of Thailand.

The formation is composed of massive, well consolidated quartz sandstone and siltstone.

These rocks are anti-erosional due to their property and texture. The flat surface of the plateau and the steep cliff are the distinctive features of this formation.

The boundary between Jurassic shale beds(J) and Champa formation(J-K) is not clear, but Champa formation(J-K) can be distinguished from its abundant sandstone facies. Springs are found along the cliff, but only few villages are located in this area. Groundwater potential may be low, and groundwater exists in the fracture or weathered zone as perched water.

(3)The Tertiary(vPg,vNg)

The Tertiary consists of basalt lava flows which are distributed in the Bolaven Plateau. Basalt lava flows can be classified into three formations,i.e.,vPg,vNg and vN-Q. However, the lithologies of lava flows are the same. The age of ejection of lava is unknown, but it is later than the Mesozoic since it overlies the Mesozoic in unconformity. Volcanic activity might have continued to Quaternary age as topography of younger volcanic ejecta is well preserved.

This rock is dark gray, hard alkali basalt with columnar joint and onion structure and abundant vesicurar due to bubbling. Occurrence of basalt lava shows volcanic breccia and autobrecciated lava in many places.

vPg is distributed north and south in the Study Area,forming a gentle slope. Surface soil is erosioned. Surface slope consists of lava with abundant joints and weathered boulders.
Thickness of lava is estimated to be less than 40m, and it is underlain by Jurassic shale.

Groundwater potential of vPg is very low, but artesian groundwater can be expected in the underlying Jurassic shale beds.

vNg overlies vPg and is extensively distributed on the Bolaven Plateau, burying the space between mountain blocks. It is composed of Jurassic shales and Champa formation. Surface soil is rather thick. Considering the areal extent of vNg, it may constitute a closed underground basin, thereby groundwater is expected.

Typical outcrop of vN-Q is seen in the vicinity of Pakxong and Pakse. The formation is composed of lava flow, scoria and mudflow(Debris flow). Thickness of mudflow with boulders varies from a few meters to several tens of meters, and mudflow's surface is unconsolidated. vN-Q overlies vNg and vPg. These underlying formations groundwater, and many springs originate from these basaltic formations in the vN-Q area. However, water table is shallow and groundwater potential varies from place to place.

(4) The Quaternary(Qal,Qt,Qte,vN-Q)

The Quaternary consists of talus deposits, fan deposits(Qt),terrace deposits(Qte) and Alluvial sediments(Qal) along the river. These deposits are composed of gravel, sand, silt and clay. Qt is distributed under the cliff in Champasak and Kongxedon. Qt has thin sediments and underlain by Jurassic shales.

Qal is mainly distributed in the downstream of the Xe Don River and on the right bank of the Mekhong River with 4m to 30m thickness and consists of fine sand with gravel and silt and partly intercalating clay bed. The formation constitutes good aquifers, but groundwater table is affected by river water level.
Since groundwater level declines up to the bottom of the aquifer during dry season, groundwater potential depends on the water level and lithology.

2.4 Hydrogeologic Structure

This section describes the hydrogeologic structure of the Study Area. The hydrogeological cross-sections is presented in the Hydrogeological Map.

(1) A-A' Section

This section shows the east-west profile along Route 16 from Kongxedon to Saravan. Jurassic shale is mainly distributed in this section and overlain by thin basalt lava flows(vPg) and Alluvial sediments. Jurassic shales are folding with an axis in the northwest to southeast direction and tilting at 10 to 20 degrees.
The edge of the older basalt flow(vPg) is distributed and having a thickness of about 40m. Alluvial sediments with thickness of about 10m is distributed along the Xe Don River and its tributaries. Jurassic shales crops out on the river bed. The main aquifers are the Alluvial sediments and the sandstone layer of Jurassic shales. Jurassic shales may have confined groundwater in the syncline area and under the basalt lava flow.

(2) B-B' Section

This section shows a profile in the north-south direction at the central part of Saravan Province. The area is mainly composed of basalt slope underlain by Jurassic shale. Basalt lava flows cover the area. They consist of older vPg to younger vN-Q. Thickness of lava flow is estimated to be 40m and 260m in the vicinity of Route 16 and Route 20, respectively. Surface volcanic ash and mudflow(Debris flow) may become water table aquifers, while the formation overlying the lava flow may have confined groundwater.

(3) C-C' Section

This cross section shows the hydrogeological profile from Chong Mek at Thailand border to Pakse and Pakxong. Jurassic shale is extensively distributed, overlying the Paleozoic basement. Jurassic shale is faulted and overlain by basalt lava flow from east of Pakse. Groundwater is recharged in Bolaven and flows down towards west. Unconfined and confined groundwater exists in the mudflow(Debris flow) and lava flow of vN-Q in the basalt slope from Bolaven to Pakse, but weathered zone of Jurassic shale and sandstone formes aquifer in the west of Pakse.

(4) D-D' Section

The section shows the profile of the southwestern slope of the Bolaven Plateau. The escarpment consists of Jurassic shales, and Champa formation bounds the plateau and the basalt slope. The basalt slope extends downward from the escarpment at elevations 150m to 300m. The southern part is underlain by the Manggian formation which constitutes the basement in this area. Basalt lava is hard and constitutes aquifuge, but the underlying Jurassic formation may have confined groundwater.

(5) E-E,F-F,G-G Sections

These sections represent the west-east hydrogeological profiles which cross the Mekhong Riv. The Champasak Plain edges on the right bank of the Mekhong Riv., while either the edge of lava flow or the Triassic Manggian formation is distributed on the left bank. Alluvial sediments with thickness of 10m to 30m are distributed the Mekong Riv.The main aquifers are composed of Alluvial sediments(Qal) and the weathered zone of the Jurassic shales.Water table is shallow, and the unconfined groundwater flows down to the Mekhong River.

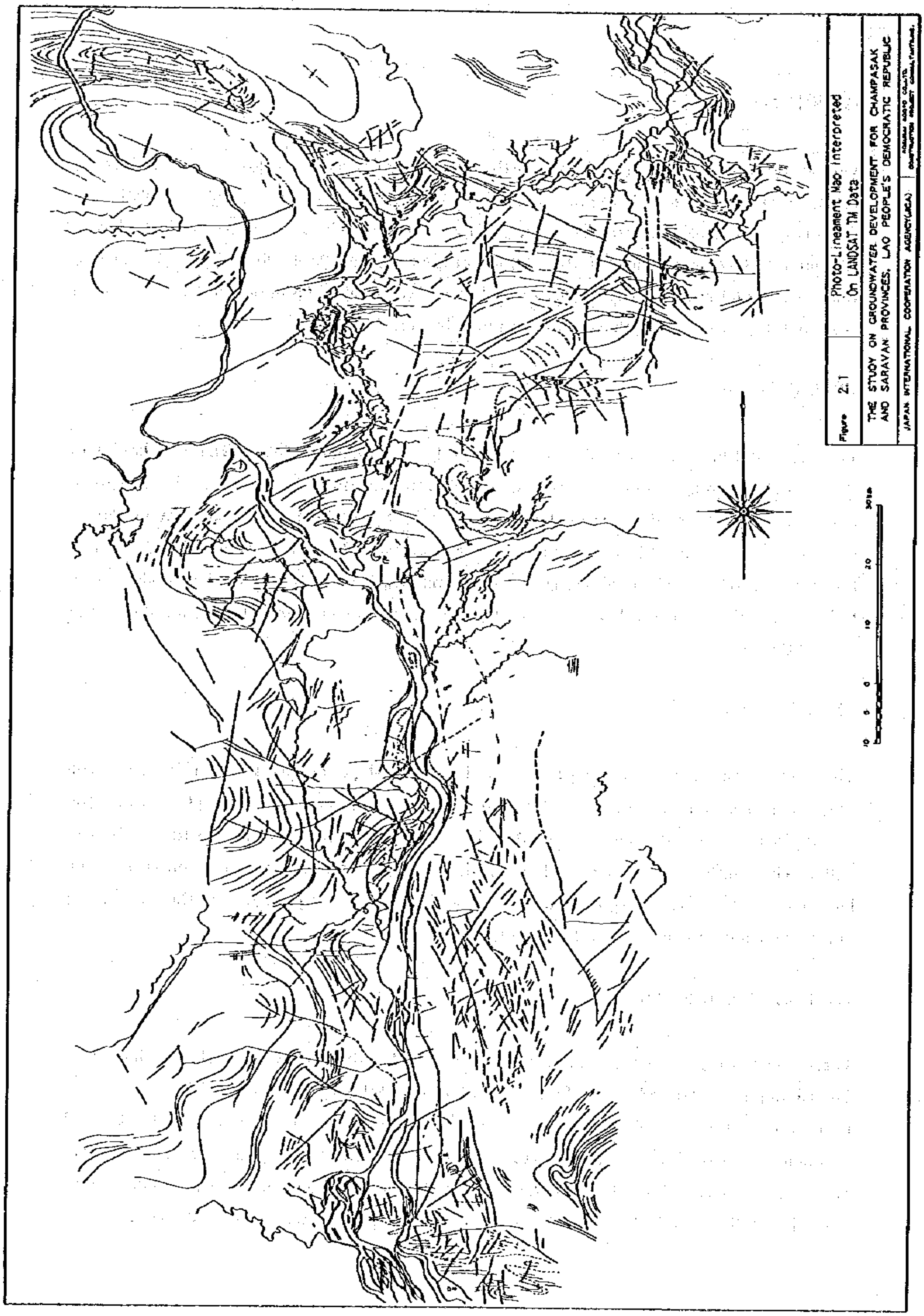


Figure 2.1 Photo-Lineament Map Interpreted On LANDSAT TM Data

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

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

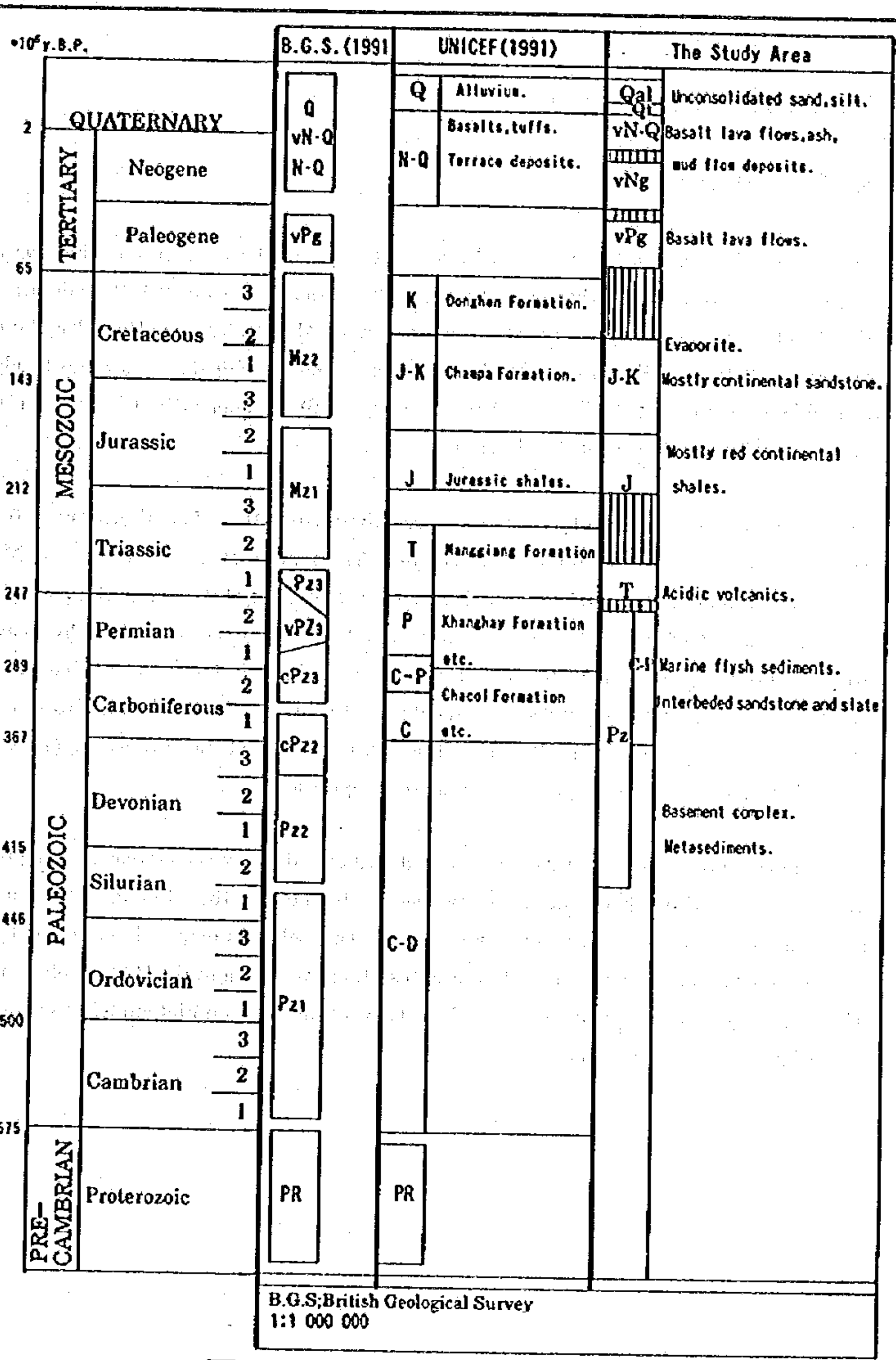


Figure 2.2 **Stratigraphy Of The Study Area**

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.

3.Hydrology of the Study Area

3.1 Precipitation

There are eighty(80) rainfall stations with at least 10 years of records in the whole country of Lao P.D.R according to Soukhathammavong(1992). As shown in Table 3.1, the rainfall data in this Study area are collected by the Department of Meteorology & Hydrology,MOAF at twenty-four(24) rainfall stations. At the same time, the rainfall data near the Study area available at six(6) rainfall stations. There are sixteen(16) stations with at least ten(10) years of records within and near this Study area.

The study area is dominated by monsoons, prevailing winds that blow alternatively from the northeast and southwest, each for about half year. The southwest monsoon begins in May and continues until September and contains high moisture because of its long path over equatorial seas. The period of the southwest monsoon, a wet season, is characterized by heavy and frequent rainfall. A remarkable characteristic of seasonal precipitation shows that more than eighty(80)% of annual precipitation occurs during the wet season from May to October as shown in Table 3.2. The rainfall during the wet season at about seventy-five(75)% of the rainfall stations exceeds ninety(90)% of annual precipitation.

Annual mean precipitation in this Study area distributes like a coaxial circle, ranging from over 3500mm at KM 42(Pakxong) in the Bolaven Plateau to less than 1600mm at Khong as shown in an isohyetal map of annual precipitation. The isohyetal map is described on the basis of the data at the twenty-two(22) rainfall stations as shown in the Hydrogeological Map. The annual rainfall is highest on the windward side of the Bolaven Plateau lying across the path of the southwest monsoon.

Table 3.1 Climatological and Rainfall Stations

ID Number	Name	Longitude Deg	Longitude Min	Latitude Deg	Latitude Min	Altitute (m)	Province	District	Type of Station	Opened Year	Observation years
224	Khongxedone	105	48.00	15	34.00	122.00	Saravan	Khongxedone	Rainfall	1963	15
225	Pakxe	105	47.00	15	7.00	101.50	Champasak	Pakxe	Cimatology	1960	35
226	Paksong	106	14.00	15	11.00	1270.00	Champasak	Paksong	Cimatology	1963	19
227	Saravan	106	26.00	15	43.00	184.00	Saravan	Saravan	Cimatology	1960	29
229	Mounlapamok	105	52.00	14	20.00	95.00	Champasak	Mounlapamok	Rainfall	1964	16
230	Khong	105	51.00	14	7.00	90.00	Champasak	Khong	Rainfall	1900	21
242	Selabam	105	50.00	15	21.20	117.00	Champasak	Sanasounboun	Rainfall	1972	20
247	Phonethong	105	31.30	15	8.00	125.00	Champasak	Phonethong	Rainfall	1979	7
255	Pathoumphone	105	56.20	14	47.40	96.00	Champasak	Pathoumphone	Rainfall	1965	16
256	Soukhouma	105	48.00	14	38.30	95.00	Champasak	Soukhouma	Rainfall	1979	15
258	Km 42 Paxsong	106	11.00	15	13.00	1160.00	Champasak	Paxsong	Cimatology	1977	17
259	Champasak	105	53.00	14	54.00	95.00	Champasak	Champasak	Rainfall	1979	12
260	Nong Hine	106	21.00	15	13.00	1280.00	Champasak	Paxsong	Rainfall	1979	15
270	Laongam	106	10.00	15	28.00	451.00	Saravan	Laongam	Rainfall	1989	6
271	Nikhom 34	106	26.00	15	11.00	1150.00	Champasak	Paxsong	Cimatology	1984	9
272	Bachiang	105	54.50	15	15.20	220.00	Champasak	Bachiang	Rainfall	1977	7
	Nam Hane	105	37.50	14	57.50		Champasak	Paxsong	Rainfall	1993	1
	Ken Sim	106	18.00	15	51.00		Saravan	Saravan	Rainfall	1993	1
	Pheng	105	33.50	15	53.50		Saravan	Lakhonepheng	Rainfall	1990	2
	Mai	106	1.00	15	14.30		Saravan	Vapi	Rainfall	1990	3
	Taoy						Saravan		Rainfall	1993	0
	Toum Lane						Saravan		Rainfall	1994	0
	Samoay						Saravan		Rainfall	1994	0
281	Paktaphane	105	30.00	15	19.00		Saravan	Lakhonepheng	Rainfall	1990	1
279	Xe Kong(Lamane)	106	43.00	15	24.00		Xe Kong		Cimatology	1988	5
268	Attapeu	107	13.00	14	45.00		Attapeu		Cimatology	1900	19
431	Khong Chiam	105	30.00	15	19.00	90.00	Thailand		Rainfall		21
433	Phibun Mangsahan	105	15.00	15	15.00	110.00	Thailand		Rainfall		21
538	Buntarik	105	15.00	14	45.00	145.00	Thailand		Rainfall		20
576	Ban Nong Mek	105	18.00	15	4.00	154.00	Thailand		Rainfall		20

Table 3.2 Monthly Precipitation in the Study Area

Unit: mm

Station	Code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ratio*
Khonexedon	224	0.0	11.5	28.5	60.8	184.4	306.1	311.4	365.4	281.5	107.1	6.7	2.3	93.4
Pakxe	225	2.2	7.3	20.8	68.6	213.9	398.6	382.1	528.2	314.5	103.2	18.2	2.8	94.2
Paksong	228	9.2	17.9	94.9	234.1	323.8	517.0	608.2	860.0	458.9	194.1	82.0	12.0	86.8
Saravan	227	4.4	4.4	38.3	71.2	157.5	305.1	336.7	456.7	277.2	114.5	16.1	0.7	92.4
Mounlapamok	229	0.3	0.0	12.5	58.0	214.7	323.3	258.5	438.7	349.5	155.7	55.2	4.2	93.0
Khong	230	2.4	4.0	22.6	70.5	185.2	296.8	244.0	314.9	274.9	131.3	32.8	4.0	91.4
Selabam	242	2.7	3.6	23.6	61.7	202.1	376.4	361.6	572.8	258.8	82.9	11.4	2.0	94.6
Phonethong	247	7.6	3.7	35.8	75.9	194.0	302.7	292.4	446.1	357.4	117.6	20.6	1.9	92.2
Pathomphone	255	1.8	3.8	12.2	78.4	223.2	394.0	442.2	524.6	295.1	111.4	14.8	8.7	94.3
Soukhouma	256	0.0	2.5	13.8	72.0	225.4	368.6	356.9	471.1	339.9	150.0	32.1	0.8	94.0
Km 42(Paksong)	258	9.3	10.5	82.2	207.6	331.2	557.7	571.6	904.1	486.1	244.5	82.4	12.0	88.5
Champasak	259	1.8	0.6	22.2	82.7	232.0	471.2	504.5	597.7	425.8	188.9	6.2	3.7	95.4
Nong Hine	260	10.1	56.3	150.2	240.0	321.8	400.6	466.2	586.0	357.7	205.0	64.9	12.2	81.4
Laongam	270	12.4	1.5	49.5	86.8	272.4	250.8	364.0	380.3	289.2	149.7	6.0	1.1	91.6
Nikhom 34	271	12.3	31.4	141.6	180.4	292.0	282.9	441.3	494.5	358.5	176.7	27.5	12.0	83.5
Bachiang	272	3.7	2.0	15.9	66.2	181.5	351.7	400.1	653.8	293.5	227.7	10.3	19.2	94.7

* : the ratio of rainfall during the wet season(May to Oct) to annual rainfall(%)

3.2 River Discharge

(1) Existing Discharge Measurement Stations

The Department of Communication MOCTPC and the Department of Meteorology & Hydrology, MOAF are the main agencies responsible for hydrologic data collection. There are four(4) regional centers including Pakxe in the country. These centers are operated by personnel of the two above-mentioned departments. Field Procedures and subsequent computations for determining discharge follow the WMO's manual on stream gauging and the United States Geological Survey's methods for water data acquisition.

There are existing twenty(20) gauging stations in the Study area as shown in the following table(Table 3.3). There are four(4) key discharge measurement stations for the Mekhong at Pakxe and for the Xe Don at Saravan, Khongxedon and Souvanna Khili. The six(6) stations of the remaining sixteen(16) gauge height stations are not collected and the six(6) stations are for gauge height only. The four(4) stations are utilized for the purpose of irrigation only during wet season.

Table 3.3 Existing stream gauging stations

River	Location	Latitude (N)	Longitude (E)	Elevation (m)	Drainage area(km^2)	Remarks
Mekhong	Pakxe	15° 07'	105° 48'	86.490	545,000	Discharge
	Ban Chan Noi	14° 19.5'	105° 53.0'	80.224	549,000	Height only
	Ban Voeunkham					Not collected
	Champasak					Not collected
	Ban Hatxaykhoun	14° 07'	105° 52.2'			Not collected
Xe Don	Saravan	15° 42.6'	106° 27'			Discharge
	Khongxedon	15° 34.5'	105° 48.9'			Discharge
	Souvanna Khili	15° 23.8'	105° 49.5'	114.381	5,760	Discharge
	Ban Nanay	15° 22.7'	105° 49.4'	117.082	6,170	Height only
	Ban Don Xe	15° 19.9'	105° 49'	93.675		Height only
	Ban Solo Cnai	15° 17.9'	105° 49.5'	87.190	6,320	Height only
Champi	Ban KM35					Height only
Nhang	Ban KM 8					Height only
Bangliang	Ban KM25	15° 58.8'	105° 50.3'	89.003		Not collected
Tomo	Ban KM10	15° 50.5'	105° 56.9'	95.059		Not collected
Khamouane	Ban Mai	15° 35.4'	105° 49.3'	89.998		Not collected
	Ban Nongte					Height & Wet season
	Ban Sukhuma					Height & Wet season
Phaling	Ban Dou					Height & Wet season
Xe	Ban Phonthong					Height & Wet season

The following table(Table 3.4) shows characteristics of discharge at the existing discharge measurement stations. The 185-day discharge or ordinary discharge is smaller than the mean value for each station. The mean discharge is larger than the 95-day discharge or high discharge for the Xe Don River.

Table 3.4 Characteristics of discharge at existing stations

River & Station	year	95-day	198-day	275-day	355-day	Max	Min	Mean
Mekong at Pakxe	1986					28,300	1,650	9,020
Ditto	1987					37,900	1,630	7,740
Ditto	1988					28,800	1,490	7,390
Ditto	1989	14,100	5,030	1,780	1,410	28,700	1,380	8,430
Ditto	1990	17,500	5,660	2,410	2,010	34,100	1,930	10,300
Xe Don at	1989	32.8	7.6	1.5	0.7	1,290	0.6	40.6
Saravan								
Ditto	1990	33.5	5.5	1.3	0.8	1,280	0.7	38.2
Xe Don at	1987					5,290	6.31	214
Souvanna khili								
Ditto	1988					1,980	3.38	87.7
Ditto	1989	134	42	14.6	4.6	3,150	4.09	159
Ditto	1990	138	33.3	15.9	6.8	2,890	4.09	144

Unit : m^3/sec

(2) Discharge Measurement Stations set up in the Study

Any discharge data is not available for small rivers of houay except for the Mekhong River and Xe Don River. Therefore, from the viewpoints of hydrology, geology and accessibility to the stations, the following stations were selected and set up as discharge measurement stations. The following table(Table 3.5) show locations of discharge measurement stations set up in the Study.

Gauge height and discharge measurements were carried out for one hydrological year at the five(5) Stations in order to make clear characteristics of river discharge especially for small rivers and estimate rating curves for conversion on gauge height into discharge. Discharge calculation was based on velocity measurements using a current meter and floats. The velocity was measured at sixty(60)% depth of stream water depth and the stream water depth was measured at the interval of 1 meter in the case of stream width of less than twenty(20) meters.

The following table shows the results of discharge measurements using a current meter at the five(5) stations.

Table 3.5 Discharge measurement stations set up in the Study

Stream	Location	Remarks
Houay Champi	Ban Nake	3 km upstream from the confluence with the Xe Don River
Houay Champi	Ban KM35	16 km downstream of Muong Pakxong
Houay Nhang	Ban Houaxe	7 km upstream from the confluence from the Mekong River
Houay Phaling	Ban Chik	4 km downstream of the existing station at Ban Dou
Houay Khamouan	Ban Soukhuma	11 km upstream from the confluence with the Mekong River

Table 3.6 Results of discharge measurements in the study

Station	Date	Dischage (m^3/sec)	Gauge Height (m)
Houay Champi at Ban Nake	20 May., 1994	9.24	0.18
	21 Nov., 1994	12.43	0.34
	23 Dec., 1994	5.36	-0.01
	27 Jan., 1995	3.59	-0.12
	24 Feb., 1995	2.61	-0.22
	16 Jul., 1995	6.83	0.01
Houay Champi at Lak 35	20 May., 1994	3	1.18
	21 Nov., 1994	2.83	1.15
	23 Dec., 1994	1.13	0.98
	27 Jan., 1995	0.632	0.87
	24 Feb., 1995	0.396	0.84
	16 Jul., 1995	2.57	1.14
Houay Nhang at Ban Houaxe	20 May., 1994	0.052	0.07
	21 Nov., 1994	0.672	0.39
	23 Dec., 1994	0.646	0.38
	27 Jan., 1995	0.524	0.33
	24 Feb., 1995	0.16	0.15
	3 Jul., 1995	0.57	0.35
Houay Phaling at Ban Chik	21 May., 1994	0.575	0.54
	10 Nov., 1994	0.072	0.31
	22 Dec., 1994	0.0027	0.25
	28 Jan., 1995	0	0.02
	23 Feb., 1995	0	-0.05
Houay Khamouan at Ban Sukhuma	21 May., 1994	8.61	0.99
	10 Nov., 1994	1.17	0.68
	22 Dec., 1994	0.299	0.46
	28 Jan., 1995	0.102	0.40
	23 Feb., 1995	0.025	0.36
	17 Jun., 1995	1.784	0.84

4 Groundwater occrrence

In order to clarify groundwater occurrence in the Study area, regional simultaneous groundwater leveling surveys were carried out at existing boreholes and dug wells as shown in the appendices. The groundwater leveling surveys were conducted once in the rainy season and two times in the dry season. At the same time, seven(7) automatic groundwater level recorders were installed for monitoring of long-term charge of groundwater levels.

4.1 Regional Groundwater Table

The results of groundwater leveling in the Study area are summarized as shown in Table 4.1.

Groundwater levels below the ground surface range 0 to 23m, about 6m in average. The mean groundwater level is the deepest in the dry season from Jan. to Feb. in 1995(the dry season II) when recharge to groundwater can be the smallest. The mean groundwater level is the shallowest in the dry season from Nov. to Dec. in 1994(the dry season I) when recharge to groundwater can be the largest.

The groundwater level of a volcanic rock(symbol Bal) is the deepest, about 10 to 12m in average.

Table 4.1 Characteristics of groundwater level

Unit : m

Hydro-geology	Wet season (May to June, 1994)			Dry season (Nov. to Dec., 1994)			Dry season (Jan. to Feb., 1995)		
	Mean,	Max,	Min,	Mean,	Max,	Min,	Mean,	Max,	Min,
Qf	6.23	11.84	0.6	4.96	9.22	1.77	6.50	14.52	2.66
Qt	4.56	6.55	0.31	4.50	5.38	3.26	5.87	6.06	5.68
Ba1	11.97	23.32	0.3	10.97	16.45	0.30	12.15	20.99	0.50
Ba2	1.78	3.76	0.7	1.97	3.78	0.89	6.08	18.58	1.54
Ba3	2.35	5.01	0.0	2.26	3.98	0.15	3.27	7.43	0.14
Eh	5.10	10.00	0.29	4.68	8.91	0.88	6.05	9.55	1.45
Ep	6.52	10.93	0.43	4.30	8.62	1.04	5.83	10.29	1.93
Et	0.23	-	-	3.83	5.61	2.05	5.68	9.34	2.50
Mean	6.11(Sample:68)			5.3(Sample:94)			6.53(Sample:100)		

The groundwater has similar flow networks, although some minor variation of groundwater levels are recognized by season. General observations of the groundwater flows in the Study area can be summarized as follows;

1)In the central part of Saravan Province, the northward flow exists in the slope of the Bolaven Plateau and the westward flow exists along the Xe Don.

2)In Lakhonpheng District of Saravan Province, there are two ground water flows from a groundwater ridge near Ban Lakhonpheng to opposite directions(northwest and southeast). The southeastern flow and two separate flows from the opposite slopes join the westward flow along the Xe Don and change the direction to the south.

3)In Bachiang District of Champasak Province, a westward flow exists in the slope of the Bolaven Plateau. There are a confined aquifer along National road No,20 and a lot of springs in the downward slope of the Bolaven Plateau.

4)In Sanasoumboun District of Champasak Province,there are two groundwater flows (westward and southeastward) and a groundwater depression near Ban Thangbeng-sivilai(C-30).

5)In Phonthong District of Champasak Province, a eastward flow from the hill of Thailand border and northward flow from the Mekhong River exist to the Nam Paling River.

6)In Champasak and Soukhuma Districts of Champasak Province, a westward flow from the Mekong River exists to the H.Khamouan River, and there is a groundwater ridge near Ban Bak(C-78).

7)In Pathoumphon District of Champasak Province, a southwestward flow from the Bolaven Plateau exists.

4.2 Groundwater Level Recordings

Groundwater level recordings were carried out at the seven(7) stations for fifteen(15) months from the April of 1994 as shown in Table 4.2 and the Groundwater Potential Map. Bars and lines in these figures present daily precipitation and groundwater level, respectively. The recordings continued for fully one hydrological year including a transition period from dry to wet, a wet period, a transition from wet to dry, and a dry period.

Except at the two stations(Ban Lak 21 and Ban Nongsim), the groundwater levels begun to rise at the middle of may and continued to rise by 3 to 4 meters to the end of September. Then, the groundwater levels begun to fall at the end of September and continued to set to the beginning of May.

At the two stations (Ban Lak 21 and Ban Nongsim) belonging to basalt area, the groundwater levels begun to rise at the middle of June and continued to rise by 11 to 13 meters to the end of October. This slow response to rise of groundwater level at the two stations can be recognized by the characteristics of a confined aquifer. The groundwater level at Ban Tong-Noy belonging to basalt area showed rather quick response to rise of groundwater level. The rather quick response can be explained by quick leakage through a rather thin basalt layer.

Table 4.2 Location of Groundwater Level Recording Stations

Location Village	district	Characteristics of Geology	Hydrogeology	Low water level (G.L. m)	Water level range (from dry to wet season)
Tong-Noy	Saravan	vPg	Ba3	5.18	3.5
Napong	Khongxedon	J	Eh	10.21	4
Nongsim	Bachiang	vN-Q	Bal	20.18	8
KM21	Bachiang	vN-Q	Bal	23.41	11
Nonghai	Phonthong	J	Ep	7.20	2
Nongphanvong	Soukhuma	Qal	Qf	11.84	4
Muang Khong	Khong	T	Et	6.55	4

5 Water Balance Analysis

In order to estimate recharge of precipitation to groundwater aquifer and to make clear a hydrological cycle in a basin, runoff analyses are carried out by the most effective runoff model, Sugawara's tank model.

5.1 Thank Model and Procedure

The tank model is composed of four tanks vertically in series as shown in the following figure:

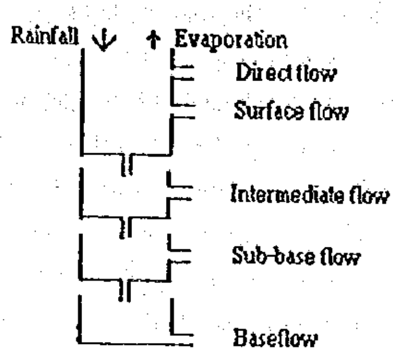


Figure 5.1 Tank model

Each tank corresponds to each runoff component. The top tank represents the ground surface and the outflow from the top tank corresponds to the surface runoff. The second tank represents the soil layer and the outflow from the second tank corresponds to the intermediate runoff. The third and fourth tanks represent groundwater layer and the outflow from these tanks corresponds to the baseflow. In order to consider the effect of initial loss, the tank model with soil moisture structure is adopted.

The characteristics of the tank model are described as follows:

1) The tank model can analyze both flood and low flow.
2) The tank model expresses non-linear relationship between rainfall and runoff. At the same time, the time lag between rainfall and runoff is automatically calculated.
3) The tank model is not necessary for complicated procedure.
4) The tank model has to find outflow coefficients of four tanks by trial and error.

5.2 Basic Meteorological Data

(1) Rainfall

The rainfall data in the Study area are collected at twenty-four(24) rainfall stations. At the same time, the rainfall data near the Study area are available at six(6) rainfall stations. There are sixteen(16) stations with at least ten(10) years of records within and near the Study area.

(2) Evaporation

The evaporation data in this Study area are collected at four(4) stations. The evaporation at the Pakxe was measured from the August of 1989 to the March of 1994 by the Class A pan which is considered to be a standard pan and pitchers are used at other three stations,KM42(Pakxong),Pakxong, and Nikhom 34. In general,actual evaporation values are approximately 50 to 70% of the values measured by the Class A pan in subtropical zones.

(3) Discharge

There are existing twenty(20) gauging stations in the Study area. Out of twenty(20) gauging stations, there are four(4) key discharge measurement stations for the Mekhong at Pakxe and for the Xe Don at Saravan, Khongxedon and Souvanna Khilli.

Of these twenty(20) gauging stations, only one(1) discharge measurement station at Pakxe is operating systematically for a long time. The station at Souvanna Khili in the Xe Don River basin has discharge data measured since 1986. At the three(3) stations, Saravan in 1989 and 1990, Khongxedon in 1989 and 1990 and Ban Don Xe in 1987 and 1988, discharge data were collected only for two years.

Any discharge data is not available for small rivers or houay except for the Mekong River and Xe Don River. Therefore, from the viewpoints of hydrology, geology and accessibility to the stations, the following five(5) stations were selected and set up as discharge measurement stations. Gauge height and discharge measurements are being carried out for the following five(5) stations. The discharge measurements were carried out using a current meter and floats.

1)Houay Champi at Ban Nake(Bachiang District)
2)Houay Champi at Ban KM 35(Bachiang District)
3)Houay Nhang at Ban Houaxe(Pakxe District)
4)Houay Phaling at Ban Chik(Phonthong District)
5)Houay Khamouan at Ban Soukhuma(Soukhuma District)

5.3 Verification of Simulated Runoff

(1) Xe Don

The drainage basin of the Xe Don River is composed of basalt slopes and erosional hills and plains of Jurassic sandstone and shale. The station at Souvanna Khili in the Xe Don River basin has discharge data measured from 1986. At the three(3) stations, Saravan in 1989 and 1990, Khongxedon in 1989 and 1990 and Ban Don Xe in 1987 and 1988, discharge data were collected only for two years. Therefore, the discharge of the Xe Don River at Souvanna Khili is selected and verified for the purpose of water balance analysis.

The daily discharge of the Xe Don at Souvanna Khili is calculated for four(4) years from 1987 to 1990. The rainfall data at the three stations (Pakxong, Selabam and Pakxe) are utilized and the evaporation data at Pakxe and Pakxong are used in the calculation.

Simulated daily, monthly and annual runoffs are verified by comparing with the observed runoffs for four(4) years from 1987 to 1990 as shown in Figure 5.2,5.3.

(2) Houai Champi

The drainage basin of the Houai Champi is composed of basalt slopes. Gauge height and discharge measurements were carried out at two stations, Ban Lak 35 and Ban Nake. The drainage basin has areas of 57.6k㎡ at Ban Lak 35 and 356.875k㎡ at Ban Nake.The station at Ban Lak 35 has gauge height data measured from 1988 and the discharge data were measured in 1989 by MCTPC. The river bottom of the Houai Champi at Lak 35 is composed of hard basalt and the cross section of the Houai Champi at Ban Lak 35 remains unchangeably. Therefore, the rating curve is calculated for the conversion of gauge height into discharge based on the discharge data in 1989 and 1994/95.

The daily discharge of the Houai Champi at Ban Lak 35 is computed for six(6) years from

1989 to 1994. The rainfall data at Pakxong are used and the evaporation data at Pakxong and Pakxe are utilized in the computation.
At Lak 35, simulated daily, monthly and annual runoffs are verified by comparing with the observed runoffs for six(6) years from 1989 to 1994 as shown in Figure 5.1.2. At Ban Nake, simulated daily, monthly and annual runoffs are verified by comparing with the observed runoffs for one and half years from 1994 .

(3) Houai Phaling

The drainage basin of the Houai Phaling is composed of erosional hills and plains of Jurassic sandstone and sandy shale. Gauge height and discharge measurements were carried out at Ban Chik with a drainage basin of 437.5km². The rating curve of the Houai Phaling at Ban Chik is calculated based on discharge measurements in 1994 and 1995.

The daily discharge of the Houai Phaling at Ban Chik is computed for one and half years from 1994. The rainfall data at Phonthong are used and the evaporation data at Pakxe are utilized in the computation.

Simulated daily, monthly and annual runoffs are verified by comparing with the observed runoffs for one and half years from 1994 .

(4) Houai Khamouan

The drainage basin of the Houai Khamouan is composed of erosional hills and plains of Jurassic sandstone and sandy shale. Gauge height and discharge measurements were carried out at Ban Soukhuma with a drainage basin of 1151.25km² at Ban Nake. The rating curve of the Houai Khamouan at Ban Soukhuma is calculated based on discharge measurements in 1994 and 1995.

The daily discharge of the Houai Khamouan at Ban Soukhuma is computed for one and half years in 1994 and 1995. The rainfall data at the two stations, Champasak and Soukhuma are used and the evaporation data at Pakxe are utilized in the computation. Simulated daily,monthly and annual runoffs are verified by comparing with the observed runoffs for one and half years from 1994 .

5.4 Water Balance

The water balance calculation in the five(5) drainage basins is summarized as shown in the following table and Figure 5.3.

Table 5.1 Water balance

mm/year

Drainage basin	Main Hydro-geology	P	E	Q	Recharge (%)	Year
Xe Don	Ba1,Ba2, Ba3,Ep, Eh	2,095	1,095	1,047	499(23.8)	1987,1989, 1990
Champi						
B.Lak 35	Ba1	3,411	774	2,438	1,219(35.7)	1989-1994
B.Nake	Ba1	3,295	988	1,996	1,296(39.9)	1994/95
Phaling	Ep,Eh	2,642	1,232	1,420	209(7.9)	1994/95
Khamouan	Ep,Eh	2,598	1,232	1,358	320(12.3)	1994/95

The recharge in basalt area of the Bolaven Plateau is estimated to exceed more than 30% of precipitation. The basalt area makes form of good groundwater aquifer.On the other hand, the recharge in the Jurassic sandstone and shale area is estimated to be about 10% of precipitation.

5.5 Basin Yield

In the Jurassic to Cretaceous Plain, discharge into the small rivers occurs in the rainy season intermittently, though the Mekhong River and Xe Don River are effluent.On the other hand, in the basalt slope, the tributaries of the Xe Don River is effluent and the storage in the basin is high.

According to water balance calculations, the recharge volume of the Study area is estimated at about 200mm/year in the Jurassic plain and about 500- 1200mm/year in the basaltic slope. This volume multiplied by the groundwater basin gives the recharge volume of the entire groundwater basin.

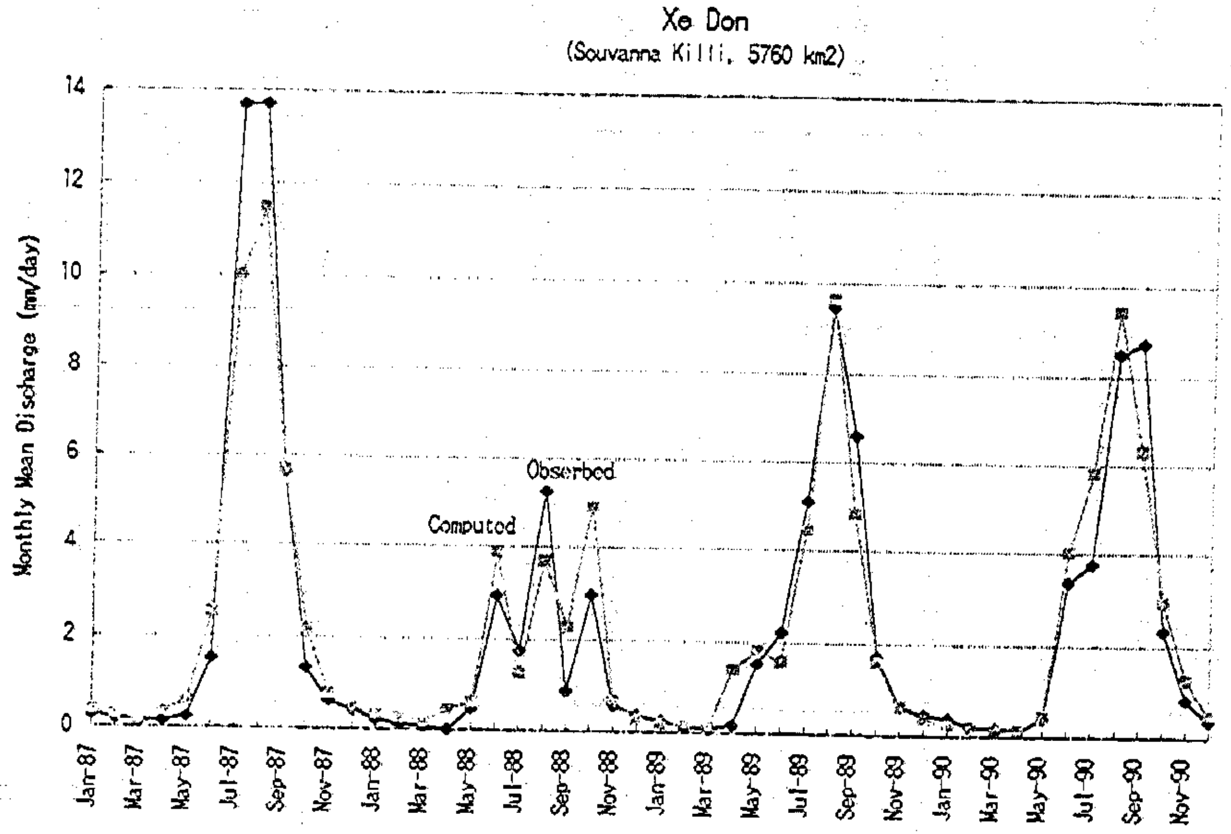


Figure 5.2 Comparison of Observed and Computed Discharges of the Xe Don River at Souvanna Khilli

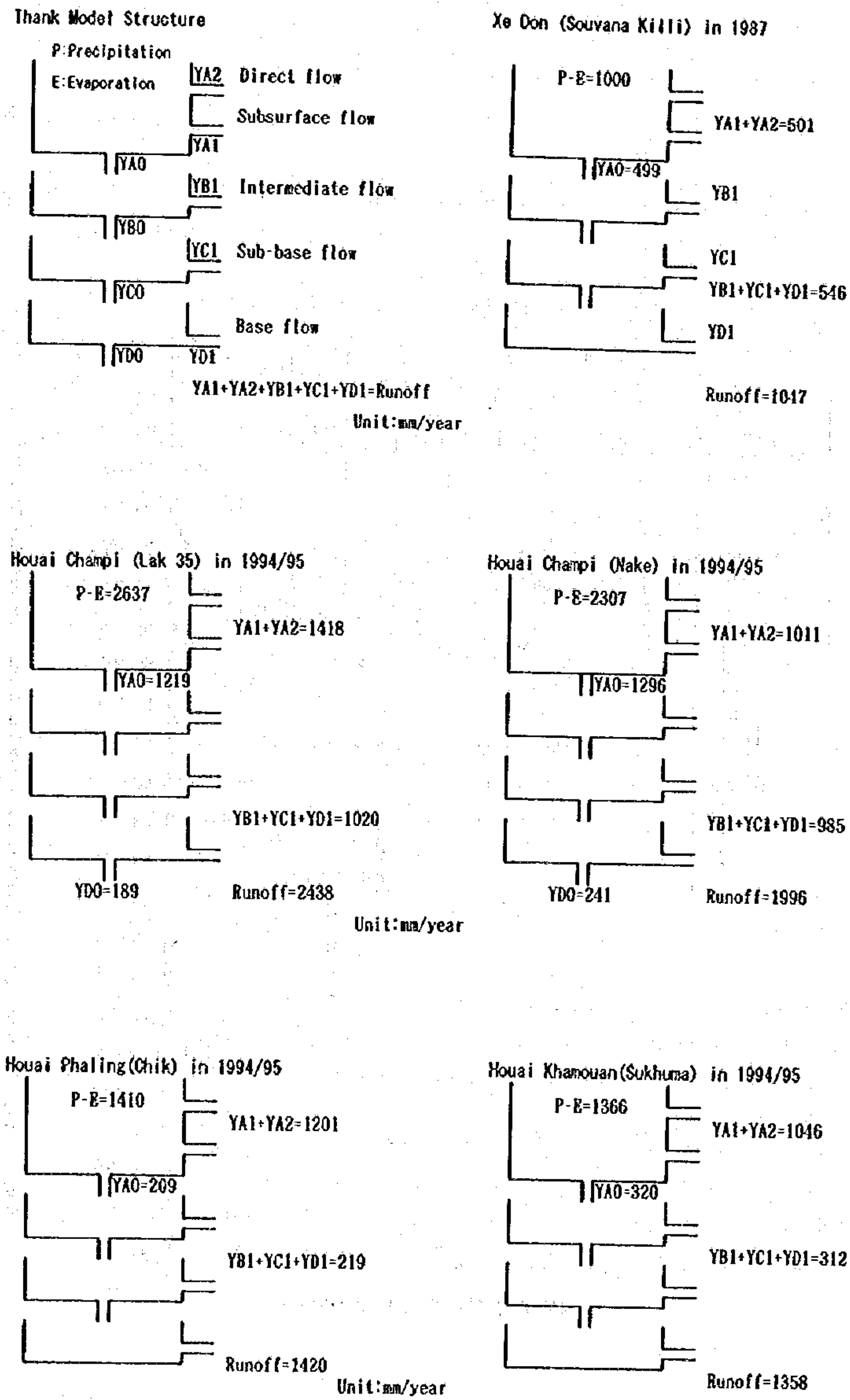


Figure 5.3 Water Balance of the Xe Don. Houai Champi, Phaling and Khamouan drainage basins

6. Hydrogeologic Units and Groundwater Potential

6.1 Potential Evaluation

The potential yield of groundwater in the study area is large. However, the condition of the groundwater is rather variable, ranging from unconfined groundwater found in alluvium and semi-confined to confined groundwater found in Jurassic shale , sandstone and Quaternary basalt.

Based on its geology and topography, the Study Area can be classified into thirteen(13) hydrogeologic units. Groundwater potential of each unit are evaluated and ranked to A,B,C and D(Table 6.1 and Table 6.2).

A:High Potential
B:Medium Potential
C:Low Potential
D:No Potential

Qf: This unit of Alluvial sediments with thickness of 4m to 30m consists of sand, gravel,silt and clay. The basement of Alluvial sediments is composed of Jurassic sandstone and red shale. The Alluvial aquifer is thin; thus, the groundwater can be taken from the underlying Jurassic formation.

Groundwater level ranges from one meter to 13m and fluctuates with respect to the river water level. Well yield shows 5 to 36 m^3/hours, the highest in the Study Area, indicating high groundwater potential(rank A). However, groundwater potential is low in the areas where groundwater level is deep since groundwater exists in Jurassic shales.

The test wells drilled at Qf were C-75 B.Nongkhe, S-24 B.Donmuang and S-50 B.Samia. Specific capacity of these wells shows 127.9, 44.6 and 14.4 m^3/day/m, respectively. Groundwater exists in Jurassic sandstone and shale.

Qt: This unit consists of talus and fan deposits. The flat erosion surface underlain by Jurassic shales is covered by thin deposition. The geologic structure is similar to Qf, but its aquifer is very thin. The shallow groundwater has low potential and seasonal fluctuation. This unit is ranked C. Groundwater table ranges 7m to 8m. Aquifer is thin and groundwater may exist in

Jurassic sandstone and sandy shale. Specific capacity is low.

Qte: This hilly unit consists of old terrace deposits. The undulated surface underlain by Jurassic shales is covered by thick layer of semi-consolidated gravel. The geologic structure is similar to Qf,Qt, but its deposits are pebble size gravel and poor matrix. Unconfined groundwater exists in the sediments. This unit is ranked B. The test well is drilled at C-16 B.Louy. Groundwater level shows 7m to 9m in dry season. Specific capacity is 16 m^3/day/m.

Bal: Basalt slope consists of vN-Q. This unit is underlain by volcanic ash and mudflow deposits(Debris flow) with boulders. The groundwater table is deep. Unconfined water or perched water exists in the sediments. The basalt lava constitutes a good semi-confined aquifer.

The test wells drilled at Bal are C-49 B.Lak 21 and S-100 B.Hountai. Groundwater level shows 22-28m in the dry season. Specific capacity is 19.7 m^3/day/m at C-49 and 2.9 m^3/day/m at S-100. This unit is ranked B to C because the distribution of basalt lava changes from place to place and because the surface sediments are not homogeneous. Groundwater level and specific capacity vary from place. However, large specific capacity may be obtained if the well drilled than 50m.

Ba2: Basalt slope consists of vNg. Thin volcanic deposits cover the surface. Unconfined or perched water exist in the sediments. The basalt lava constitutes the hydrogeologic basement, but confined groundwater exists in the lower basalt lava and brecciated lava.

The test wells were drilled at C-44 B.Thongsala and S-84 B.Beng. Groundwater level shows 13-24 m in the dry season. Specific capacity shows high value, 1,728 m^3/day/m at C-44 and, 1,900m^3/day/m at S-84. This indicates that the brecciated lava with abundant pore constitutes an excellent aquifer. Groundwater level is rather deep, however, high groundwater potential is expected. This unit is ranked A.

Ba3: Basalt slope consists of vPg. No surface deposition is found on the slope. Groundwater may exist in the fissure.
Underlying Jurassic sandstone may have confined groundwater. This unit is composed of hard rock and ranked B.

The test well was drilled at S-56 B.Chong. The formation of S-56 consists of basalt lava up to the depth of 15m. Underlying formation is composed of Jurassic sandstone and shale. The screen was positioned at Jurassic sandstone. Groundwater is confined. Specific capacity shows $19m^3$/day/m.

Ep: This unit is an erosion plain with no surface deposition. It principally consists of alternating beds of laminated sandstone with abundant muscovite and red sandy shale.
The test wells located at Ep are, C-65 B.Lak24, C-79 B.Samkhanaboua, S-38 B.Nongngong, S-64 B.Phonphai and S-75 B.Nakasao. Groundwater level ranges from 7 to 12 m. Specific capacity shows 3.3-165.3 m^3/day/m. Groundwater level is rather shallow and this unit is ranked B.

Eh: This hilly unit is more undulated than Ep. The weathered zone and Jurassic sandstone and conglomerate constitute aquifers. Groundwater table is lower than Ep because of surface undulation. The test wells drilled at Eh are C-4 B.Nongphai, C-8 B.Houaxe, S-4 B.Houaykapho and S-12 B.Nongsano. Groundwater level ranges from 9 to 20 m. Specific capacity shows 1.0-17.3 m^3/day/m. This unit is ranked B to C.

Et: The area consists of acidic volcanic rocks of the Triassic age(Et1) and Paleozoic slate and sandstone(Et2). The topography is an erosion terrace plain. Thin deposits cover the surface. Groundwater may exist in the fissure.

The test wells were drilled at C-88 B.Maisivilai and C-89 B.Nasenphan. C-88 is located on Et2 composed of Paleozoic slate. While C-89 is located on Et1 composed of acidic volcanics of Triassic age. Groundwater level ranges from 8 to 17 m in the dry season. Specific capacity shows 36.9 m3/day/m at C-88 and 4.6 m^3/day/m at C-89. This unit is ranked B to C.

P: This unit consists of gently undulated plain, and in the higher elevation, it is composed of hard formation(J-K). Groundwater may exist in the fissure. Few groundwater is replenished in this area and ranked C.

M: Mountain area consists of hard and compact rock, which constitutes the hydrogeologic basement. Groundwater cannot be expected except in the mountain valleys(ranked C to D).

6.2 Aquifer Constants

Table 6.3,6.4 presents the average aquifer constants(Transmissivity(T), Permeability(K), Storativity(S) and Specific Capacity(Sc)) obtained by the pumping tests in the test wells.

(1) Transmissivity

The transmissivity changes place to place ranging from 0.8 ㎡/day to 1,500 ㎡/day(Table 6.3). It shows 1,500㎡ /day in B.Beng, 800㎡/day in B. Thongsala. Both of these villages are located on the basalt slope in the Bolaven Plateau. The lowest transmissivity was found at B.Hountai and Nongphai showing 0.8㎡/day. In B.Nongkhe and B.Phonphai, it shows 200 ㎡/day, while it ranges from 1.5 to 40㎡/day in other villages.

(2)Specific capacity

The specific capacity(Sc) is expression of the unit discharge per one meter draw down. The productivity of the aquifer and the well can be easily evaluated from the specific capacity. It was calculated by using the draw-down and the pumping rate at stable conditions during the pumping test.

The highest specific capacity was found at B.Thongsala and B.Beng ranging from 1,700 to 1,900 m^3/day/m, while the lowest was 1 m^3/day/m in B.Nongphai, 1/1,900 of the highest, showing big regional difference. Rather high values were found at B.Nongkhe and B.Phonphai showing 128 and 165 m^3/day/m respectively. The specific capacity of other test wells ranges 2.6 to 45 m^3/day/m.

(3)Aquifer constants of each hydrogeologic unit

The aquifer constants by hydrogeologic unit is presented in Table 6.2,6.3. The lithology of aquifer in each hydrogeologic unit is divided into the following 4 groups. The logarithmic average of aquifer constants of each group is summarized as follows.

1.Qf,Qt,Qte,Ep,Eh

Tertiary to Quaternary sediments and Jurassic formations consisting of sandstone, red shale and mudstone. The formation forms the basement of the plain along the Mekhong River and Xe Don River and small hill.

T: 0.78～219 ㎡/day(logarithmic average 11㎡/day)

k: 1.59E-02～3.26E-05 cm/sec

S: 0.047～0.7* *physically meaningless

Sc:1.0~165 m³/day/m

2.Ba1,Ba2,Ba3:Basalt in the Bolaven Plateau

The basalt lava, volcanic ash,loam and mud flow(Debris flow) are distributed in the north and west of the Bolaven Plateau.

T:0.74~1,500 ㎥/day(logarithmic average 72 ㎥/day)
k:7.76E-02~ 3.58E-05 cm/sec
S:0.1~0.8*
Sc:2.9~1,900 m³/day/m

The specific capacity value obtained at B.Beng and B.Thongsala ranges 1,700 to 1,900 m³/day/m. This formation intercalates two to three layers of basalt lava (autobrecciated lava, vNg). Other two wells show very small specific capacity ranging from 2.9 to 19.7 m³/day/m at B.Lak 21 and B.Hountai. The basalt in this area is strongly weathered and the weathered bed is tick. The aquifer constants varies widely place to place in the basalt zone.

3.Et1:Acidic tuff of Triassic age

This formation is distributed in the south, the left bank of the Mekhong River, of the Study Area and consists of acidic tuff(dacitic welded tuff).

T: 3.04 ㎥/day
k: 1.47E-04 cm/sec
S: 0.047
Sc: 4.6 m³/day/m

Groundwater occurs in the fracture of rocks. The specific capacity becomes higher in those area where the faults and fracture are abundant.

4.Et2:Slate and sandstone of Paleozoic age

This formation is distributed in the most southern part of the Study area. The formation is composed of hard slate and sandstone partly intercalating calcareous rocks. Groundwater occurs in the fracture.

T: 23.1 ㎡/day
k: 9.53E-04 cm/sec
S: 0.18
Sc:38 m^3/day/m

(4) Optimum Well Yield

An potion well yield(pumping rate) of the test well was evaluated by using the step draw-down test data. Taking the critical water level found on the linear relation between the pumping rate(Q) and the draw-down(S), the critical pumping rate can be determined. In addition to this, a stable water level and a time for recovery during the pumping test ware considered. An optimum well yield was calculated by multiplying the draw-down to the specific capacity(Table 6.4).

The results show that the 3,800 m^3/day of pumping is possible in B.Beng and 1,700 m^3 /day in B.Thongsala. The optimum pumping of more than 150 m^3/day is found at B.Nongkhe. B.Chong and B.Phonphai. It ranges from 9 to 140 m^3/day in other 15 villages. The lowest optimum discharge was found at B.Nongphai showing 9 m^3/day. This well may be dried up even if discharged by a hand pump.

The optimum well yield in each hydrogeologic unit is summarized as follows.

Qf,Qt,Qte:	73~380 m^3/day(average 183 m^3m3/day)
Ep,Eh:	9~165(average 59 m^3/day)
Ba1,Ba3:	20~267 m^3/day(average 138 m^3m3/day)
Ba2:	1700~3800 m^3/day
Et:	32~129 m^3/day

Table 6.1 Types of Hydrogeologic Features Based on Topography and Geology

Symbol	Topography and Geology	Aquifer	Groundwater level (Dryseason) G.L.-m	Specific Capacity Sc m^3 day m	Q(max) This Study m^3 day	Q(max) Existing(USAID) m^3 day	Groundwater Potential A(High)-D(Low)	Water Quality(Borehole) Testwell PH	Water Quality(Borehole) Testwell EC(us cm)	Water Quality(Borehole) Existing Well(30-60m) PH	Water Quality(Borehole) Existing Well(30-60m) EC(us cm)
Qf	Flood plain.Accumulation terrace. Sand.Silt and Clay.Jurassic shales	Quaternary Sand.Gravel. Jurassic Sandstone.	6-13	14-128	133-380+	120-864	A	7.1-7.4	376-767	7-8	400-600
Qt	Alluvial fan.Talus slope. Sand.Silt.Jurassic shales.	Sand. Jurassic Sandstone.	7-8	-	-	0-168	C	-	-	7-8	460-800
Qte	Accumulation terrace. Gravel.Jura-Creta.sandstone,shale.	Gravel. Jura-creta.Sandstone.	7-9	16	73	408	B	5.6	96	-	-
Ba1	Basalt slope. Mudflow Deposits.Ash.Loam.Lava flow.	N-Q Basalt Lava. Basalt lava flow.	20-35	3-20	20-127	96-2000?	B-C	5.6-5.9	55-115	6-7	10-100
Ba2	Basalt slope. Basalt lava flows.	N-Q Basalt Lava. Autobrecciated lava.	13-24	- 1700-1900	- 1728-3800+	-	A	6.4	165-230	5-7	15-200
Ba3	Basalt slope. Basalt lava flows.Jurassic shales.	Pg Basalt Lava. Jurassic sandstone.	4-12	- 19.1	267	144-216	B	7	569	6-7	41-250
Ep	Erosional plain. Jurassic red shale,sandstone.	Jurassic sandstone. sandyshale.	7-12	3-166	17-166+	0-672	B	7.0-7.3	447-627	6.5-8	300-700
Eh	Erosional Hill. Jurassic red shale.sandstone.	Jurassic sandstone. conglomerate.	9-20	1-17.3	9-34	144-200	B-C	6.7-7.1	790-4000	5-7	600-1000
Et1	Erosional terrace. Triassic Acidic welded tuff.Dacite.	Fissured aquifer.	8-15	4.6	32	-	B-C	6.8-7.3	197-430	7.2-7.7	300-600
Et2	Erosional terrace. Paleozoic slate,sandstone.	Fissured aquifer.	8-17	36.9	129	-	B	6.8	763	-	-
P	Plateau.High Plain. Jura.-Creta.sandstone.shale.	Sandstone. Locally Fissured aquifer.	Low	-	-	-	C	-	-	-	-
M	Mountains. Metasediments.Plutonic rocks.	Fissured aquifer. Sand,silt in Valley.	Low-high	-	-	-	C-D	-	-	-	-
Es	Escarpment.Ridge.	-	-	-	-	-	-	-	-	-	-

Table 6.2 (1)Groundwater Potential Evaluation and Village Classification

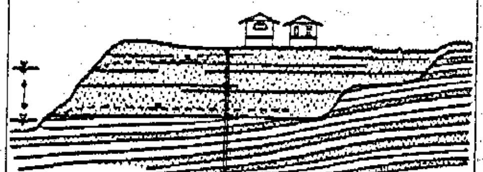
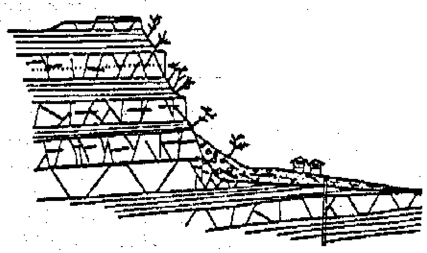
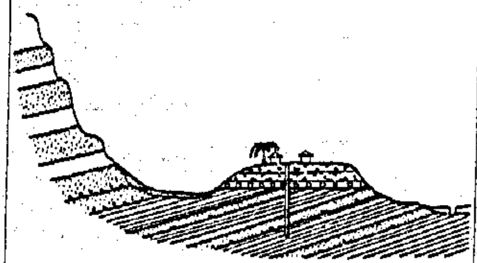
Types of Hydrogeologic Features		Province, District	Village Number ○ Test well Point
Qf Topography: Flood plain, Accumulation Terrace. Lithology: Sand, silt, clay, gravel. Geologic Time: Quaternary Aquifer: Sand, gravel Water Depth (Dry season, G. L. -m) :6-13m Well yield: (Test well) Sc=14-128m³/day/m; Qmax=133-380+m³/day (Existing well) Qmax=120-864m³/day Water Quality (Test well) PH=7.1-7.4, EC=376-767 μ s/cm (Existing well) PH=7-8, EC=400-600 μ s/cm Groundwater potential: A		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Senasomboon Bachiang Pathoomphone Sukhuma Khong	 18, 20, 22, 23, ○24, 25, 26, 29, 30, 31, 32, 33, 34, 35. 42, 43, 44, 46, 47, 48, 49, ○50 1, 5, 17, 18, 22, 23, 24, 25, 33, 34, 35, 36. ○75, 76. 80, 82, 83. 84, 85, 91, 93, 95, 97.
Qt Topography: Alluvial fan, Talus slope. Lithology: Sand, silt, clay, Sandstone, shale. Geologic Time: Quaternary, Jurassic Aquifer: Unconsolidated sand, Jurassic sandstone. Water Depth (Dry season, G. L. -m) :7-8m Well yield: (Test well) (Existing well) Qmax=0-168m³/day Water Quality (Test well) PH= — , EC= — (Existing well) PH=7-8, EC=460-800 μ s/cm Groundwater potential: C		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Senasomboon Bachiang Pathoomphone Sukhuma Khong	 21, 28. 100.
Qte Topography: Accumulation terrace Lithology: Gravel, shale, sandstone Geologic Time: Tertiary, Jura-Creta Aquifer: Gravel, Sandstone Water Depth (Dry season, G. L. -m) :7-9m Well yield: (Test well) Sc=16m³/day/m; Qmax=73m³/day (Existing well) Sc= — ; Qmax= — Water Quality (Test well) PH=6.6, EC=96 μ s/cm (Existing well) PH= — , EC= — Groundwater potential: B		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Senasomboon Bachiang Pathoomphone Sukhuma Khong	 7, 9, 10, 11, 12, 13, 14, 15, ○16
Bal Topography: Basalt slope. Lithology: Mudflow deposits, loam, ash, lava flows. Geologic Time: Neogene-Quaternary Aquifer: Lava flows Water Depth (Dry season, G. L. -m) :20-35m Well yield: (Test well) Sc=3-20m³/day/m; Qmax=20-127m³/day (Existing well) Qmax=96-2000?m³/day Water Quality (Test well) PH=5.6-5.9, EC=55-115 μ s/cm (Existing well) PH=6-7, EC=10-100 μ s/cm Groundwater potential: B-C		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Senasomboon Bachiang Pathoomphone Sukhuma Khong	 97, 98, 99, ○100 38, 39, 40, 41, 42, 45, 46, 47, 48, ○49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59. 64.

Table 6.2 (2)Groundwater Potential Evaluation and Village Classification

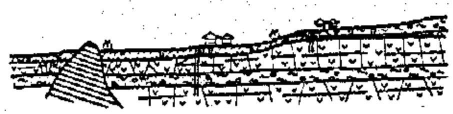
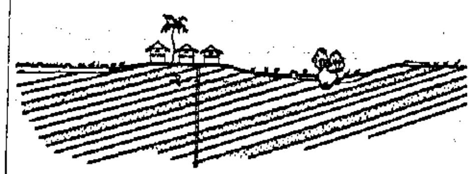
Types of Hydrogeologic Features		Province, District	Village Number ○ Test well Point
Ba2 Topography: Basalt slope. Lithology: Basalt lava flows. Geologic Time: Neogene–Quaternary Aquifer: Lava flows, autobrecciated lava. Water Depth (Dry season, G.L.–m): 13–24m Well yield: (Test well) Sc=1700–1900m³/day/m: Qmax=1728–3800+m³/day (Existing well) Qmax=—m³/day Water Quality (Test well) PH=6.4, EC=166–230 μs/cm (Existing well) PH=5–7, EC=16–200 μs/cm Groundwater potential: A		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 (84), 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 43, (44), 60, 61, 62, 63, 67, 68, 69, 70, 71, 72, 73,
Ba3 Topography: Basalt slope. Lithology: Basalt lava flow, sandstone, shale. Geologic Time: Pg–Ng basalt lava, J. sandstone. Aquifer: Basalt lava, Jurassic sandstone. Water Depth (Dry season, G.L.–m): 4–12m Well yield: (Test well) Sc=19.1m³/day/m: Qmax=267m³/day (Existing well) Qmax=144–216m³/day Water Quality (Test well) PH=7.0, EC=549 μs/cm (Existing well) PH=6–7, EC=41–250 μs/cm Groundwater potential: B		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 51, 52, 53, (56), 57, 58, 59, 61, 76, 77, 79, 80, 81, 83, 37, 66, 74,
Ep Topography: Erosional plain Lithology: Red shale, fine to medium sandstone. Geologic Time: Jurassic Aquifer: Sandstone, sandy shale. Water Depth (Dry season, G.L.–m): 7–12m Well yield: (Test well) Sc=3–166m³/day/m: Qmax=17–166+m³/day (Existing well) Qmax=0–672m³/day Water Quality (Test well) PH=7.0–7.3, EC=447–627 μs/cm (Existing well) PH=6.5–8, EC=300–700 μs/cm Groundwater potential: B		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 15, 16, 17, 27, 36, 37, 38, (39), 40, 41, 45, 54, 55, 60, 62, 63, (64), 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 76, 82, 26, 28, 29, 31, (65) 77, 78, 79, 81,
Eh Topography: Erosional hill Lithology: Red shale, sandstone, conglomerate. Geologic Time: Jurassic–Cretaceous Aquifer: Sandstone, conglomerate. Water Depth (Dry season, G.L.–m): 9–20m Well yield: (Test well) Sc=1–17.3m³/day/m: Qmax=9–73m³/day (Existing well) Qmax=144–408m³/day Water Quality (Test well) PH=6.7–7.1, EC=790–4000 μs/cm (GL–60–180m) (Existing well) PH=5–7, EC=600–1000 μs/cm Groundwater potential: B–C		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 1, 2, 3, (4), 5, 6, 7, 8, 9, 10, 11, (12), 13, 14, 19 2, 3, (4), 6, (8), 19, 20, 21, 27, 30, 32,

Table 6.2 (3)Groundwater Potential Evaluation and Village Classification

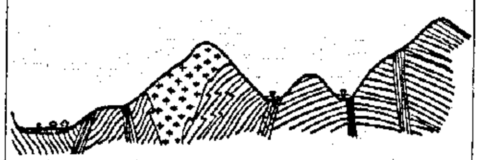
Types of Hydrogeologic Features		Province, District	Village Number ○ Test well Point
Et1, Et2 Topography: Erosional terrace Lithology: Slate, sandstone, Acidic tuff, dacite. Geologic Time: Permian-Triassic Aquifer: Fissured aquifer Water Depth (Dry season, G.L -m): 8-17m Well yield: (Test well) Sc=4.6-36.9m²/day/m; Qmax=32-129m³/day (Existing well) Qmax=—m³/day Water Quality (Test well) PH=6.8-7.3, EC=430-763 μs/cm (Existing well) PH=7.2-7.7, EC=300-600 μs/cm Groundwater potential: B-C		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 86, 87, (88), (89), 90, 92, 94, 96, 98, 99.
P Topography: Plateau, High plain Lithology: Medium-coarse sandstone, mudstone. Geologic Time: Jurassic-Cretaceous Aquifer: Sandstone, Fissured. Water Depth (Dry season, G.L -m): Deep, Shallow (perched). Well yield: Low Groundwater potential: C		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	
M Topography: Mountains Lithology: Metasediments, plutonic rocks. Geologic Time: Precambrian-Paleozoic Aquifer: Fissured aquifer, Sand in valley. Water Depth (Dry season, G.L -m): Deep shallow Well yield: Low Groundwater potential: C-D		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Laongam	

Table 6.3(1) Coefficient Of Aquifers

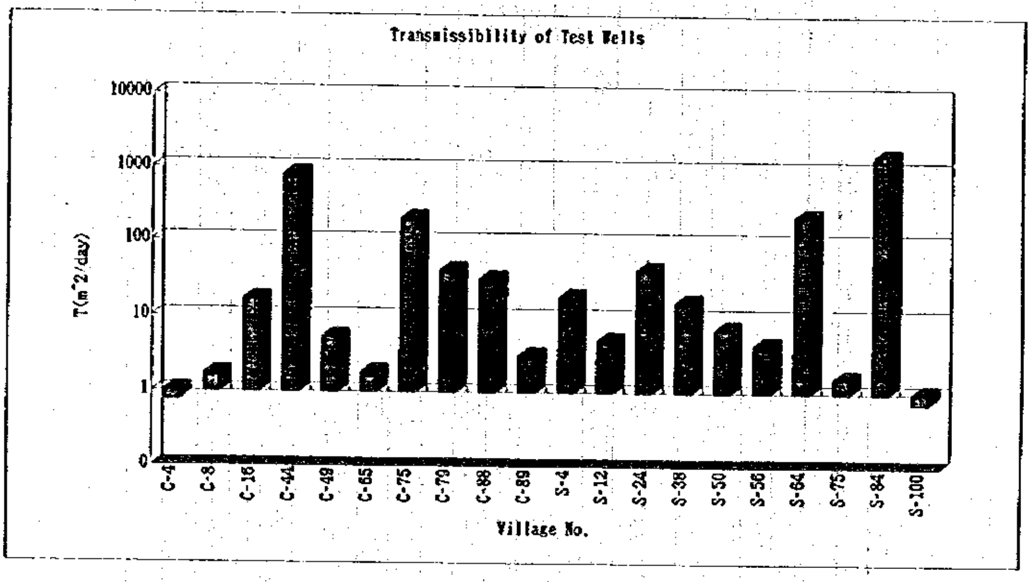
No.	Location	Average T (cm^2/s)	Average T (m^2/day)	Average K (cm/s)	S	Sc (m^3/day/m)	Geo. Type	Aquifer	Aquifer symbol
C-4	B. Nongphai	9.03E-02	7.80E-01	4.51E-05	3.42E-01	1.0	Eh	Jura. sandstone.	Js
C-8	B. Houaxe	1.95E-01	1.69E+00	3.26E-05	2.79E-01	2.6	Eh	Jura-Creta. Sandstone.	JCs
C-16	B. Louy	1.90E+00	1.64E+01	1.00E-03	*	16.2	Qte	Q-gravel. Jura. Sandstone.	Jsg
C-44	B. Thongsala	9.32E+01	8.05E+02	7.76E-02	*	1728.0	Ba2	N-Q Basalt Lava.	Ba
C-49	B. Lak21	6.09E-01	5.26E+00	5.07E-04	4.41E-01	19.7	Ba1	N-Q Basalt Lava.	Ba
C-65	B. Lak24	2.11E-01	1.82E+00	1.32E-04	7.21E-02	3.3	Ep	Jura. Sandstone.	Js
C-75	B. Nongkhe	2.32E+01	2.00E+02	1.16E-02	1.47E-01	127.9	Qf	Q Sand. Jura. SandyShale.	QsJsh
C-79	B. Samkhanaboua	4.67E+00	4.03E+01	2.33E-03	9.63E-02	30.0	Ep	Jura. Sandy Shale.	Jsh
C-88	B. Maisivilai	3.63E+00	3.14E+01	1.30E-03	1.79E-01	36.9	Et	Paleozoic Slate.	Psl
C-89	B. Nasenphan	3.52E-01	3.04E+00	1.47E-04	4.66E-02	4.6	Et	Triassic Asidic Tuff.	Tt
S-4	B. Houaykapho	2.08E+00	1.80E+01	1.04E-03	1.06E-01	17.3	Eh	Jura-Creta. Sandstone.	JCs
S-12	B. Nongsano	5.53E-01	4.78E+00	1.98E-04	2.04E-06	16.0	Eh	Jura. Sandstone.	Js
S-24	B. Donmuang	4.80E+00	4.14E+01	3.00E-03	1.75E-01	44.6	Qf	Jura. Sandstone.	Js
S-38	B. Nongngong	1.79E+00	1.54E+01	1.12E-03	2.89E-01	13.9	Ep	Jura. Sandstone.	Js
S-50	B. Samia	7.81E-01	6.74E+00	3.72E-04	4.72E-02	14.4	Qf	Q Sand. Jura. Sandstone.	QsJs
S-56	B. Chong	4.98E-01	4.30E+00	2.49E-04	2.20E-01	19.1	Ba3	N-Q Basalt. Jura. Sandstone.	BaJs
S-64	B. Phonphai	2.54E+01	2.19E+02	1.59E-02	2.02E-01	165.3	Ep	Jura. Sandstone.	Js
S-75	B. Nakasao	1.80E-01	1.56E+00	7.49E-05	2.97E-01	4.4	Ep	Jura. Sandstone.	Js
S-84	B. Beng	1.74E+02	1.50E+03	5.80E-02	2.28E-04	1900.8	Ba2	N-Q Basalt.	Ba
S-100	B. Houn-Tai	8.59E-02	7.42E-01	3.58E-05	1.16E-01	2.9	Ba1	N-Q Basalt. Loam.	Balm

Table 6.3(2) Coefficient Of Test Wells

No.	Location	1 Jacob.			2 Jaeger.			3 Hantush&Jacob.			4 Hantush t-s.			5 Recovery.	
		T1	k1	S1	T2	k2	S2	T3	k3	S3	T4	k4	S4	T5	k5
		(cm^2/s)	(cm/s)		(cm^2/s)	(cm/s)		(cm^2/s)	(cm/s)		(cm^2/s)	(cm/s)		(cm^2/s)	(cm/s)
C-4	B.Nongphai	1.80E-01	8.98E-05	2.24E-01	2.23E-01	1.12E-04	8.18E-02	1.07E-01	5.34E-05	3.42E-01	*	*	*	7.36E-02	3.68E-05
C-8	B.Houaxe	1.60E-01	2.66E-05	2.68E-01	1.62E-01	2.71E-05	2.90E-01	*	*	*	*	*	*	2.64E-01	4.40E-05
C-16	B.Louy	3.04E+00	1.60E-03	1.31E-01	2.61E+00	1.27E-03	*	3.65E-01	1.92E-04	*	*	*	*	3.44E+00	1.81E-03
C-44	B.Thongsala	*	*	*	5.54E+01	4.62E-02	*	*	*	*	*	*	*	1.31E+02	1.09E-01
C-49	B.Lak2I	2.14E+00	1.78E-03	1.95E-02	2.12E+00	1.76E-03	3.14E-02	6.72E-01	5.60E-04	4.41E-01	*	*	*	5.45E-01	4.54E-04
C-65	B.Lak24	2.35E-01	1.47E-04	8.47E-02	2.40E-01	1.50E-04	1.27E-01	*	*	*	2.55E-01	1.59E-04	7.21E-02	1.67E-01	1.04E-04
C-75	B.Nongkhe	6.50E+01	3.25E-02	*	1.52E+01	7.60E-03	2.58E-01	2.90E+00	1.45E-03	1.47E-01	*	*	*	4.35E+01	2.17E-02
C-79	B.Samkhanaboua	4.77E+00	2.39E-03	2.29E-04	5.14E+00	2.57E-03	5.00E-04	*	*	*	2.39E+00	1.19E-03	9.63E-02	6.94E+00	3.47E-03
C-88	B.Maisivilai	1.52E+00	5.43E-04	*	3.63E+00	1.30E-03	1.79E-01	8.56E-01	3.06E-04	*	*	*	*	4.49E+00	1.60E-03
C-89	B.Nasenphan	4.31E-01	1.79E-04	4.34E-02	4.24E-01	1.77E-04	4.97E-02	*	*	*	*	*	*	2.02E-01	8.43E-05
S-4	B.Houaykapho	1.87E+00	9.35E-04	3.41E-02	1.85E+00	9.25E-04	1.77E-01	*	*	*	*	*	*	2.53E+00	1.26E-03
S-12	B.Nongsano	4.02E+00	1.43E-03	1.93E-07	3.83E+00	1.37E-03	3.88E-06	1.46E-01	5.21E-05	*	*	*	*	9.60E-01	3.43E-04
S-24	B.Donmuang	4.92E+00	3.07E-03	6.49E-02	5.21E+00	3.26E-03	2.86E-01	*	*	*	*	*	*	4.26E+00	2.66E-03
S-38	B.Nongngong	6.52E-01	4.08E-04	2.35E-01	9.91E-01	6.19E-04	*	4.61E-01	2.88E-04	2.89E-01	*	*	*	3.11E+00	1.95E-03
S-50	B.Samia	7.93E-01	3.78E-04	*	9.63E-01	4.59E-04	*	1.11E-02	5.27E-06	4.72E-02	*	*	*	1.55E+00	7.38E-04
S-56	B.Chong	7.20E-01	3.60E-04	4.32E-01	8.21E-01	4.11E-04	8.10E-03	3.88E-01	1.94E-04	*	*	*	*	6.08E-01	3.04E-04
S-64	B.Phonphai	3.22E+01	2.02E-02	7.74E-05	2.48E+01	1.55E-02	4.04E-01	*	*	*	*	*	*	1.92E+01	1.20E-02
S-75	B.Nakasao	2.52E-01	1.05E-04	4.83E-01	7.03E-01	6.14E-04	9.19E-02	1.09E-01	4.53E-05	4.55E-01	3.08E-01	1.28E-04	1.38E-01	1.23E-01	5.14E-05
S-84	B.Beng	3.17E+02	1.06E-01	2.28E-04	1.41E+02	4.71E-02	*	*	*	*	*	*	*	6.30E+01	2.10E-02
S-100	B.Houn-Tai	5.18E-01	2.16E-04	5.59E-04	4.83E-01	2.01E-04	3.43E-02	8.69E-02	3.62E-05	1.16E-01	*	*	*	8.48E-02	3.53E-05

Table 6.4 Specific Capacity

No.	Location	Q	Drawdown	Sc	Q	Dd	Sc	Sc	s'(safty)	Py(optimum discharge)	
		l/min	(m)	l/min/m	cm 3/s	(cm)	cm 3/s/cm	m 3/day/m	(m)	Sc*s'	(m 3/day)
C-4	B.Nongphai	20	27.5	0.73	333.333	2750	0.12	1.0	9	9.4	9
C-8	B.Houaxe	30	16.5	1.82	500	1650	0.30	2.6	9	23.6	23
C-16	B.Louy	101.4	9	11.27	1690	900	1.88	16.2	4.5	73.0	73
C-44	B.Thongsala	120	0.1	1200.00	2000	10	200.00	1728.0	1	1728.0	1700+
C-49	B.Lak21	198	14.5	13.66	3300	1450	2.28	19.7	6.5	127.8	127
C-65	B.Lak24	30.6	13.5	2.27	510	1350	0.38	3.3	11.5	37.5	37
C-75	B.Nongkhe	198	2.23	88.79	3300	223	14.80	127.9	3	383.6	380+
C-79	B.Samkhanaboua	50	2.4	20.83	833.333	240	3.47	30.0	2.3	69.0	69
C-88	B.Maisivilai	100	3.9	25.64	1666.67	390	4.27	36.9	3.5	129.2	129
C-89	B.Nasenphan	30.6	9.5	3.22	510	950	0.54	4.6	7	32.5	32
S-4	B.Houaykapho	120	10	12.00	2000	1000	2.00	17.3	2	34.6	34
S-12	B.Nongsano	50	4.5	11.11	833.333	450	1.85	16.0	4	64.0	64
S-24	B.Donmuang	198	6.4	30.94	3300	640	5.16	44.6	3	133.7	133
S-38	B.Nongngong	132	13.7	9.64	2200	1370	1.61	13.9	8	111.0	111
S-50	B.Samia	132	13.2	10.00	2200	1320	1.67	14.4	10	144.0	144
S-56	B.Chong	198	14.95	13.24	3300	1495	2.21	19.1	14	267.0	267
S-64	B.Phonphai	132	1.15	114.78	2200	115	19.13	165.3	1	165.3	165+
S-75	B.Nakasao	40	13	3.08	666.667	1300	0.51	4.4	4	17.7	17
S-84	B.Beng	198	0.15	1320.00	3300	15	220.00	1900.8	2	3801.6	3800+
S-100	B.Houn-Tai	20	10	2.00	333.333	1000	0.33	2.9	7	20.2	20



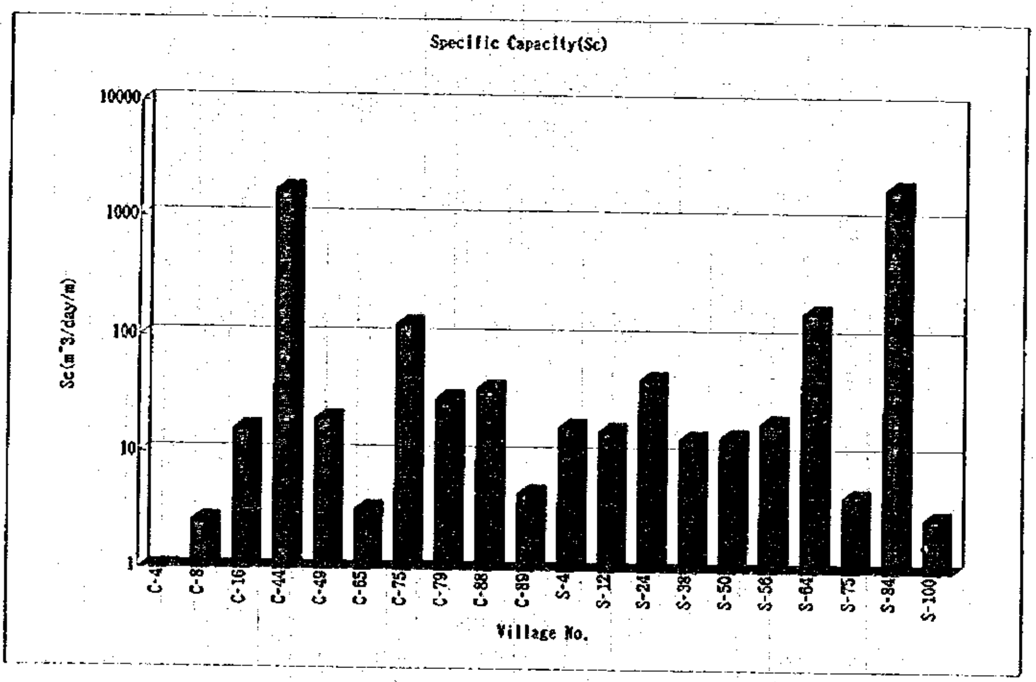
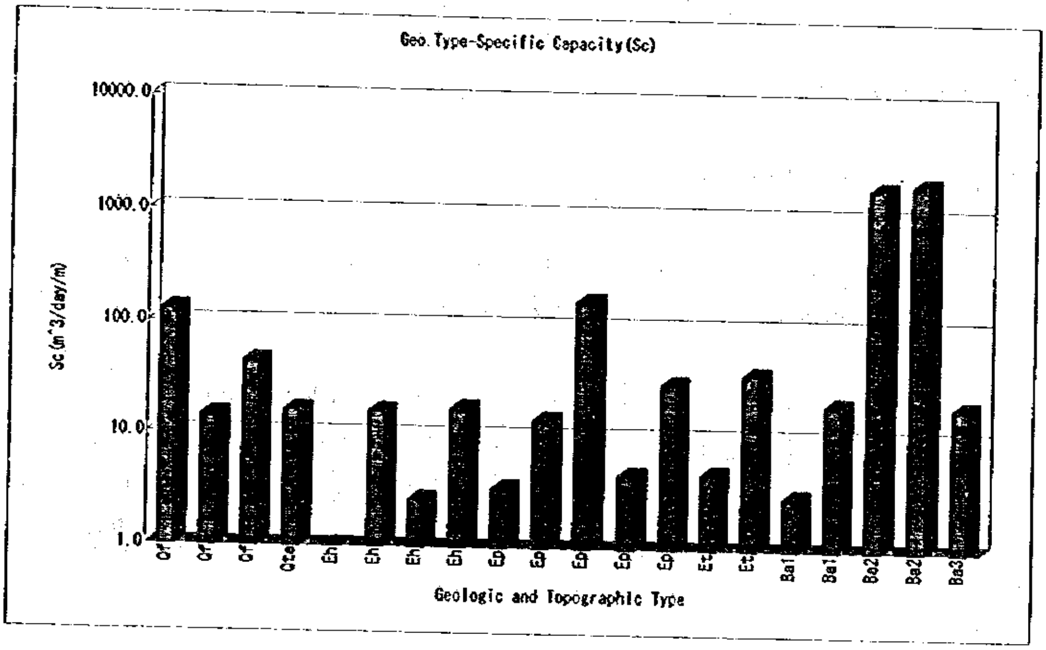


Figure 6.1	Specific Capacities of Test Wells
THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC	
JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)	KOKUSAI KOGYO CO.,LTD. CONSTRUCTION PROJECT CONSULTANTS INC.



Qf	Flood Plain
Qte	Old Terrace
Eh	Erosinal hill
Ep	Erosional plain
Et	Erosional Terrace
Ba1	Basalt slope 1
Ba2	Basalt slope 2
Ba3	Basalt slope 3

QsJsh	Q Sand.Jura.SandyShale.
QsJs	Q Sand.Jura.Sandstone.
Qg	Q Gravel.Jura.Sandstone
Js	Jura.Sandstone.
JCs	Jura-Creta.Sandstone.
Jsg	Jura.Sandstone.Conglo.
Jsh	Jura.Sandy Shale.
Tt	Triassic Asidic Tuff.
Psl	Paleozoic Slate.
Bala	N-Q Basalt,Loam.
Ba	N-Q Basalt Lava.
BaJs	N-Q Basalt,Jura.Sandstone.

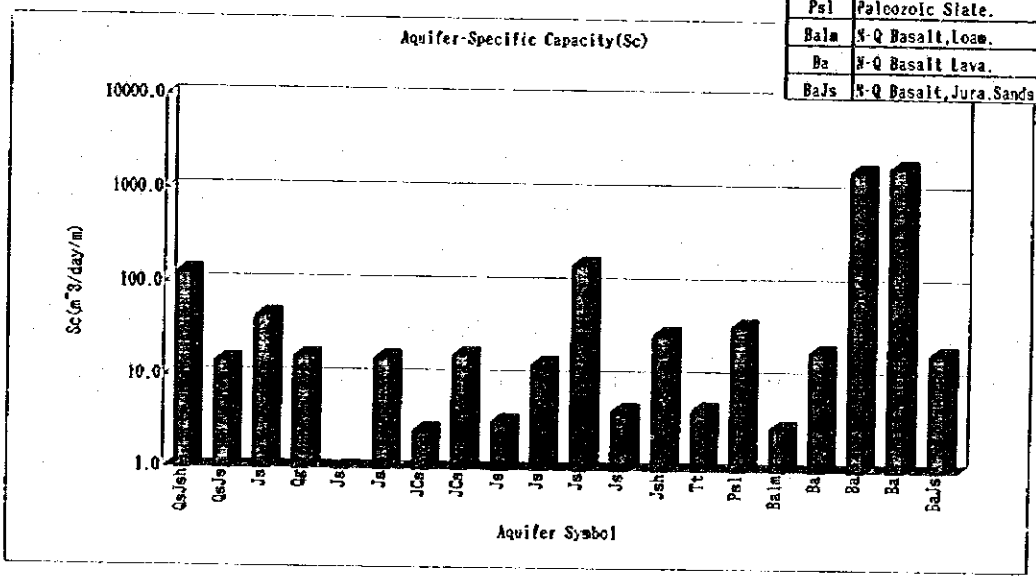


Figure 6.2	Specific Capacities of Aquifers

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.

7.Water Quality

7.1 Non-biological chemistry

Table 7.1 shows chemical data analyzed at the 80 points in the dry season for existing wells and new boreholes drilled by the JICA Study team.

In comparison with the drinking water quality standards set by WHO(Appendices), 3 chemical components(Fe, Mn and NO_3) have same problems. The concentration of iron(Fe) exceeds the WHO's guideline value of 0.3 mg/l regarding about 41% of 58 water sampled for existing wells. The Fe concentration of only 2 samples out of 20 new boreholes exceeds the WHO's guideline value.

The concentration of manganese(Mn) exceeds the WHO's guideline value of 0.1 mg/l regarding about 17% of 58 water sampled for existing wells. The Mn concentration of 10 samples 20 new boreholes exceeds the WHO's guideline value.

The concentration of nitrate(NO_3) exceeds the WHO's guideline value of 10 mg/l regarding about 10% of 58 water sampled for existing wells. There is no nitrate problem regarding 20 new boreholes.

7.2 Biological chemistry

Numbers of coliforms and bacteria do not exceed 100,000 for most of water samples regardless of river water and groundwater . The biological quality for water samples of existing wells and rivers is better in the dry season than in the wet season.

At the same time, biological chemistry is analyzed for water samples of twenty(20) boreholes drilled by the Study team. The biological quality is remarkably better than the existing water sources sampled.

Table 7.1(1) Summary of water Quality Analysis in the Dry Season (Existing wells), Nov-Dec 1994

Unit : mg/l

No.	Village	Sampled	pH	Temp C	E.C. uS/cm	Ca	Mg	Na	K	Fe	Mn	Cu	Zn	Pb	Cl	SO4	HCO3	NO3	NO2	F	PO4	NH4	I	Total Hard	SiO2	TDS	Ion Balance	Date Sampled
1	Nongdou	Dug well	6.3	26.5	98	11.0	0.4	8.5	0.4	0.28	0.00	0.01	0.04	0.00	2.0	4.0	37	0.0	0.09	0.1	0.0	0.02	0.00	29	12.0	66	1.303	94/11/28
2	Dongkalong	Dug well	4.7	27.7	37	1.9	0.0	4.6	1.6	0.30	0.00	0.03	0.12	0.00	3.2	3.0	3	10.0	0.17	0.1	0.8	0.10	0.00	5	9.9	25	0.957	94/11/20
3	Thangbangsvilai	Dug well	7.2	27.2	129	16.0	2.0	4.4	0.0	0.28	0.01	0.03	0.02	0.00	1.6	3.0	76	0.3	0.02	0.1	0.2	0.06	0.00	53	14.0	68	0.932	94/11/28
4	Bachiang	Dug well	6.3	29.2	72	8.8	2.0	2.3	0.4	0.21	0.01	0.04	0.11	0.00	0.0	2.0	35	0.0	0.02	0.1	0.0	0.02	0.01	30	32.0	50	1.175	94/11/29
5	Bachiang	H.Champi	6.9	27.5	45	4.5	1.4	2.3	0.4	*0.51	0.00	0.03	0.01	0.00	0.0	4.0	27	0.0	0.00	0.0	0.1	0.00	0.00	17	14.0	31	0.892	94/11/29
6	Oudomsouk	Dug well	5.8	28.7	38	3.8	0.6	2.3	2.0	0.24	0.05	0.02	0.24	0.00	1.2	4.0	16	0.1	0.03	0.1	0.0	0.00	0.00	12	9.1	24	0.585	94/11/29
7	Nongsai	Dug well	5.5	26.9	64	3.4	1.6	8.0	1.2	0.19	0.01	0.03	0.07	0.00	8.8	3.0	18	3.8	0.00	0.0	0.2	0.00	0.00	15	13.0	38	1.032	94/11/30
8	Nadonkhoang	Borehole	7.5	27.8	533	63.0	6.8	41.0	0.4	*0.84	0.00	0.03	0.04	0.00	17.0	7.0	328	0.4	0.00	0.1	0.1	0.00	0.01	185	36.0	326	0.920	94/11/30
9	Naxai-Noy	Dug well	6.8	25.6	185	8.0	11.0	11.0	0.8	0.10	0.00	0.02	0.03	0.00	6.0	5.0	98	3.0	0.01	0.1	0.4	0.05	0.01	66	26.0	115	0.938	94/11/30
10	Lak-25	Spring	5.8	26.5	41	2.1	2.6	2.3	0.8	0.05	0.00	0.03	0.03	0.00	0.0	2.0	20	1.2	0.05	0.1	0.0	0.00	0.00	16	15.0	28	1.137	94/12/10
11	Houaye	Dug well	5.7	27.2	37	2.1	1.9	2.3	0.4	0.07	0.01	0.03	0.03	0.00	1.2	5.0	13	0.0	0.02	0.0	0.2	0.02	0.00	13	16.0	26	1.069	94/12/01
12	Phengnei	Dug well	6.4	29.2	322	24.0	0.5	48.0	3.9	*0.60	0.00	0.03	0.03	0.00	46.0	6.0	62	*40.0	0.03	0.0	0.0	0.05	0.01	62	14.0	203	1.125	94/12/03
13	Lak-94	Dug well	5.4	28.5	138	7.2	2.4	10.0	0.8	*0.36	*0.19	0.04	0.01	0.01	31.0	5.0	12	4.0	0.00	0.1	0.1	0.02	0.01	28	15.4	81	1.114	94/12/03
14	Thangbeng	Dug well	6.2	28.2	98	13.0	0.1	7.4	0.4	*3.00	0.00	0.06	0.00	0.00	6.0	3.0	43	0.0	0.00	0.1	0.2	0.01	0.00	33	11.5	55	1.173	94/12/03
15	Namouang	Borehole	7.4	27.7	770	90.0	10.0	70.0	0.0	*0.53	*0.37	0.05	0.13	0.13	22.0	12.0	475	4.0	0.01	0.5	0.0	0.00	0.03	267	27.0	478	0.962	94/12/03
16	Nakadao	Borehole	7.2	27.7	629	93.0	3.0	28.0	0.0	0.14	0.00	0.05	0.00	0.00	6.0	4.0	423	0.3	0.05	0.2	0.0	0.05	0.01	285	32.0	403	0.850	94/12/03
17	Phanthakham	Dug well	6.2	26.5	96	6.1	0.2	12.0	0.0	*0.70	0.02	0.06	0.19	0.19	13.0	4.0	19	1.2	0.02	0.1	0.0	0.00	0.00	16	11.1	64	1.115	94/12/05
18	Mai	Dug well	5.3	28.2	42	1.4	0.6	5.3	0.0	*0.70	0.02	0.05	0.01	0.01	5.2	3.0	5.8	1.2	0.03	0.1	0.5	0.01	0.00	6	6.2	29	1.166	94/12/05
19	Sukhuma	Dug well	4.6	29.1	290	9.3	3.1	39.0	10.0	0.15	*0.20	0.06	0.06	0.06	62.0	3.0	5.8	*42.0	0.02	0.1	1.5	0.16	0.01	36	10.4	172	1.039	94/12/05
20	Nonghai	Borehole	7.5	25.6	722	95.0	8.0	58.0	0.0	*1.40	0.00	0.06	0.19	0.19	27.0	114.0	304	0.2	0.01	0.1	0.0	0.05	0.03	270	28.0	462	0.982	94/12/06
21	Dongnang	Dug well	6.0	26.7	40	1.9	1.0	4.2	0.0	*0.90	0.00	0.08	0.02	0.02	5.2	2.0	9.8	0.1	0.00	0.2	0.1	0.00	0.00	8.8	10.0	26	1.125	94/12/06
22	Nachan	Borehole	7.4	28.9	536	68.0	2.3	47.0	0.8	*0.53	0.00	0.06	0.15	0.15	32.0	4.0	288	0.0	0.01	0.1	0.3	0.10	0.01	179	28.0	354	0.993	94/12/06
23	Pathoumphone	Dug well	6.0	29.0	330	9.9	3.7	53.0	0.4	0.04	0.00	0.07	0.01	0.01	52.0	42.0	46	0.1	0.00	0.1	0.0	0.06	0.00	40	15.3	191	1.007	94/12/09
24	Nakam-Noy	Dug well	6.8	28.0	39	3.2	11.0	2.8	0.0	0.29	0.00	0.07	0.01	0.01	0.8	3.0	16	0.0	0.01	0.1	0.2	0.00	0.00	12	14.1	27	3.463	94/12/09
25	Thangbeng	Dug well	6.3	30.2	176	15.0	4.5	16.0	0.4	*0.45	0.00	0.08	0.04	0.00	12.0	4.0	363	*30.0	0.02	0.0	3.0	0.14	0.01	56	29.0	109	0.269	94/12/09
26	Nasenphan	Dug well	6.8	29.1	197	22.0	6.3	9.9	0.8	*1.20	0.00	0.09	0.36	0.00	7.2	2.0	173	0.0	0.00	0.0	1.0	0.10	0.01	81	21.0	130	0.686	94/12/08
27	Habayikhoun	Borehole	7.4	28.2	726	109.0	4.0	86.0	0.8	*0.69	0.00	0.09	0.14	0.00	12.0	6.0	72	3.9	0.03	0.4	0.2	0.06	0.02	288	42.0	414	5.091	94/12/08
28	Tapuey	Dug well	7.4	27.6	535	66.0	7.4	45.0	0.4	0.30	0.00	0.09	0.01	0.00	14.0	12.0	40	0.5	0.03	0.3	0.0	0.00	0.01	200	35.0	300	4.573	94/12/08
29	Nangkam	Dug well	5.4	28.2	57	4.2	0.1	7.4	0.0	0.19	0.00	0.09	0.18	0.00	9.0	2.0	33	0.0	0.00	0.0	0.0	0.00	0.00	11	7.5	37	0.857	94/12/07
30	Dongkalong	Dug well	7.2	28.5	729	100.0	6.4	46.0	0.4	0.09	0.00	0.08	0.02	0.00	39.0	3.0	10	0.0	0.00	0.1	0.1	0.00	0.00	276	37.0	415	5.679	94/12/07

* more than WHO's Guideline value for drinking water

Table 7.1(2) Summery of Water Quality Analysis in the Dry Season(Existing wells), Jan-Feb 1995

Unit : mg/l

No.	Village	Sampled	pH	Temp C	E.C. uS/cm	Ca	Mg	Na	K	Fe	Mn	Cu	Zn	Pb	Cl	SO4	HCO3	NO3	NO2	F	PO4	NH4	I	Total Hard	SiO2	TDS	Ion Balance	Date Sampled
31	Hinxiou	Borehole	7.2	27.8	500	64.0	0.3	48.0	0.0	0.18	0.06	0.00	0.05	0.00	0	4.0	65	0	0.01	0.2	0.1	0.00	0.00	181	40	345	4.827	95/01/25
32	Boungkha	Borehole	7.0	27.5	271	16.0	3.2	40.0	0.4	1.50	0.13	0.00	0.00	0.00	0	4.0	118	0.3	0.02	0.1	0.0	0.05	0.01	53	28	192	1.419	95/01/25
33	Thangbengawilai	Dug well	7.0	29.2	139	16.0	3.2	8.1	0.0	0.21	0.02	0.00	0.03	0.00	1.2	3.0	499	0.1	0.00	0.1	0.3	0.06	0.00	53	16	90	0.172	95/01/25
34	Bacheng	Borehole	6.2	27.6	76	5.9	2.5	6.4	0.4	0.09	0.01	0.00	0.02	0.00	0.8	2.0	341	0.2	0.00	0.1	0.0	0.02	0.01	25	27	51	0.140	95/01/27
35	Nake	H. Champi	7.0	28.3	55	2.7	3.9	1.6	0.4	0.12	0.01	0.00	0.01	0.00	0	4.0	8.6	0	0.00	0	0.6	0.06	0.00	23	14	37	2.409	95/01/27
36	Oudomsouk	Dug well	5.4	26.1	30	0.6	1.1	3.5	0.8	0.19	0.05	0.00	0.13	0.00	0	3	4.1	0	0.02	0.1	0.0	0.00	0.00	6	8.4	22	0.045	95/01/27
37	Nongsai	Dug well	5.4	26.5	58	1.1	1.8	8.1	0.8	0.03	0.01	0.00	0.02	0.00	4	4.0	8	3.2	0.07	0	0.2	0.01	0.00	10	11	37	1.668	95/01/23
38	Nadonkhoang	Borehole	7.3	26.8	528	61.0	6.1	45.0	0.4	0.32	0.05	0.03	0.03	0.00	15	6.0	319	0.2	0.13	0.1	0.1	0.02	0.01	177	40	320	0.956	95/01/23
39	Naxai-Noy	Dug well	6.6	27.8	173	12.0	6.0	13.0	0.8	0.17	0.09	0.00	0.00	0.00	6	5.0	85	2.8	0.00	0.1	0.4	0.04	0.01	56	28	116	0.988	95/01/23
40	Lak-25	Spring	5.7	26.8	47	1.6	1.9	4.8	0.8	0.02	0.01	0.00	0.01	0.00	0	2.0	20	1.2	0.02	0.1	0.1	0.01	0.00	12	14	30	1.200	95/01/27
41	Houaxe	Dug well	5.4	28.7	44	0.8	1.6	6.5	0.4	0.07	0.01	0.00	0.06	0.01	0.8	5.0	14	0.1	0.01	0	0.3	0.00	0.00	9	14	25	1.307	95/01/31
42	Phengnai	Dug well	6.7	28.5	240	12.0	2.3	40.0	1.6	3.20	0.25	0.00	0.06	0.00	32	7.0	58	18	0.03	0.1	0.1	0.02	0.01	39	15	208	1.176	95/01/23
43	Lak-94	Dug well	4.7	28.2	101	1.9	1.3	20.0	0.4	1.20	0.09	0.00	0.01	0.00	17	4.0	10	4.8	0.00	0.1	0.2	0.00	0.01	10	12	64	1.403	95/01/23
44	Thangbeng	Dug well	5.7	29.1	68	5.8	0.4	7.6	0.4	0.70	0.09	0.00	0.00	0.00	6	3.0	23	0	0.00	0.2	0.3	0.02	0.00	17	8.9	45	1.136	95/01/23
45	Namouang	Borehole	7.1	29.3	72	83.0	12.0	62.0	0.8	0.00	0.33	0.00	0.23	0.01	12	3.0	449	0.1	0.02	0.1	0.1	0.08	0.00	256	48	403	1.012	95/01/25
46	Koumkeo	Dug well	7.0	27.4	214	16.0	1.7	13.0	1.2	2.60	0.77	0.00	0.35	0.01	12	4.0	111	0.3	0.01	0	0.0	0.02	0.01	47	32	139	0.736	95/01/23
47	Bak	Dug well	6.1	26.5	147	5.6	4.4	20.0	0.8	1.40	0.22	0.00	0.02	0.00	6	2.0	27	0.1	0.01	0.1	0.0	0.00	0.00	32	26	94	2.426	95/01/24
48	Dontalat	Borehole	6.0	27.9	170	7.5	4.4	24.0	0.4	0.96	0.09	0.00	0.50	0.01	20	3.0	40	0	0.00	0.1	0.1	0.00	0.00	37	12	106	1.426	95/01/24
49	Soukhouma	Dug well	4.4	27.5	313	5.3	4.3	52.0	9.6	0.05	0.17	0.00	0.04	0.01	48	3.0	2	35	0.01	0.1	1.8	0.12	0.01	31	9.4	203	1.556	95/01/24
50	Nonghai	Borehole	7.3	27.8	514	61.0	8.7	31.0	0.0	0.10	0.01	0.00	0.05	0.00	2	84.0	283	0.3	0.00	0.2	0.3	0.03	0.03	188	33	293	0.793	95/02/03
51	Nonkoun	Borehole	7.2	28.2	585	76.0	9.0	33.0	0.0	0.31	0.15	0.02	0.02	0.00	8	3.0	333	0.1	0.02	0.1	0.1	0.00	0.01	228	29	345	1.041	95/01/28
52	Nachan	Borehole	7.3	29.1	522	53.0	8.7	42.0	0.8	0.09	0.02	0.00	0.00	0.00	28	4.0	281	0	0.00	0.1	0.2	0.08	0.00	168	34	313	0.951	95/02/03
53	Lak 29	Dug well	5.8	26.8	42	1.6	2.2	3.7	0.4	0.01	0.00	0.00	0.09	0.00	0.8	2.0	17	0	0.01	0.1	0.0	0.00	0.00	13	11	26	1.261	95/01/31
54	Tomo-Nok	Dug well	5.2	28.2	28	0.0	0.8	5.0	0.8	0.08	0.03	0.00	0.07	0.00	0	3.0	9	0	0.02	0	0.0	0.00	0.00	3	6.2	18	1.466	95/01/31
55	Thengbeng	Dug well	6.1	28.5	176	11.0	7.4	15.0	0.0	0.40	0.02	0.00	0.02	0.00	9.2	3.0	72	32	0.01	0	3.1	0.12	0.01	58	27	116	0.904	95/01/31
56	Kinak	Dug well	7.3	30.1	470	60.0	4.0	29.0	0.4	0.10	0.04	0.00	0.05	0.00	10	3.0	284	0.1	0.03	0.1	1.4	0.08	0.01	166	26	305	0.920	95/01/30
57	Don	Dug well	4.2	29.4	89	0.8	11.0	0.0	0.4	0.03	0.02	0.00	0.00	0.00	6.8	2.0	0	0.1	0.00	0.1	0.2	0.05	0.02	47	10	51	4.072	95/01/31
58	Taposy	Dug well	7.3	25.6	458	48.0	15.0	22.0	0.4	0.40	0.20	0.00	0.04	0.00	4.4	10.0	304	0.4	0.03	0.3	0.0	0.01	0.01	181	26	279	0.868	95/01/30
59	Nangkam	Dug well	4.5	26.5	59	0.8	0.7	10.0	0.0	0.10	0.01	0.00	0.13	0.00	4	3.0	3	0.1	0.01	0.1	0.0	0.00	0.00	5	6.7	37	2.373	95/01/25
60	Oongkalong	Dug well	7.2	27.7	736	79.0	17.0	52.0	2.0	0.04	0.00	0.00	0.00	0.00	48	3.0	383	0.1	0.01	0.1	0.2	0.00	0.00	267	32	426	0.995	95/01/25

* more than WHO's Guideline value for drinking water

Table 7.1(3) Summary of water Quality Analysis (Test wells), Feb 1995

Unit : mg/l

No.	Village	Sampled	pH	Temp C	E.C. uS/cm	Ca	Mg	Na	K	Fe	Mn	Cu	Zn	Pb	Cl	SO4	HCO3	NO3	NO2	F	PO4	NH4	I	Total Hard	SiO2	TDS	Ion Balance	Date Sampled
1	Nongphai	Borehole	6.8	26.2	795	84.0	22.0	53.0	1.2	0.06	*.58	0.00	4.40	0.00	17.0	4.0	497	0.0	0.00	0.2	0.2	0.10	0.01	300	32.0	452	0.960	95/02/01
2	Lour	Borehole	5.6	27.5	96	4.3	3.0	3.0	0.4	0.00	0.07	0.00	4.90	0.01	8.0	3.0	20	0.3	0.01	0.1	0.0	0.00	0.00	23	8.7	58	0.974	95/02/01
3	Thongsala	Borehole	6.4	27.3	230	18.0	12.0	12.0	0.8	0.03	0.03	0.00	4.80	0.00	0.0	4.0	140	0.2	0.02	0.1	0.3	0.00	0.01	89	18.0	133	0.979	95/02/01
4	Lak 21	Borehole	5.6	27.8	55	1.6	4.1	2.5	0.0	0.12	0.03	0.08	*6.00	0.00	0.4	3.0	28	0.1	0.00	0.0	0.0	0.05	0.00	21	13.0	35	0.991	95/01/26
5	Donmuang	Borehole	7.1	28.8	580	55.0	10.0	63.0	1.2	0.02	*0.32	0.00	0.61	0.02	0.8	7.0	391	1.6	0.01	0.2	0.8	0.30	0.02	179	44.0	236	0.982	95/02/01
6	Nongnuang	Borehole	7.0	28.8	627	74.0	15.0	44.0	2.4	0.02	0.07	0.00	0.82	0.03	9.2	5.0	330	2.4	0.04	0.1	0.2	0.22	0.01	245	45.0	358	0.995	95/02/01
7	Samia	Borehole	7.0	29.1	767	78.0	10.0	64.0	1.6	0.01	0.07	0.00	0.24	0.00	31.0	3.0	428	0.3	0.00	0.3	0.0	0.02	0.01	236	32.0	422	0.952	95/02/01
8	Chong	Borehole	7.0	28.2	569	55.0	20.0	27.0	1.2	0.10	*0.25	0.00	3.20	0.00	3.2	2.0	373	0.1	0.01	0.1	0.0	0.00	0.00	256	38.0	324	1.016	95/02/01
9	Phonphai	Borehole	7.0	25.8	593	75.0	13.0	39.0	0.8	0.04	0.01	0.00	0.47	0.01	8.8	2.0	385	0.0	0.00	0.1	0.4	0.02	0.00	240	40.0	343	0.996	95/02/01
10	Nakasao	Borehole	6.8	29.1	651	71.0	13.0	51.0	0.8	0.07	*0.41	0.02	1.40	0.00	19.0	4.0	391	0.2	0.00	0.3	0.1	0.00	0.01	230	38.0	358	0.977	95/02/01
11	Houn-Tai	Borehole	5.9	29.2	115	5.6	7.8	8.4	0.4	0.07	0.08	0.00	*7.40	0.02	0.8	2.0	60	0.3	0.02	0.0	0.0	0.05	0.01	46	32.0	76	1.155	95/02/01
12	Houma	Borehole	7.1	28.8	10000	440.0	25.0	1860.0	14.0	*0.68	*0.31	0.02	1.20	0.00	*3480	18.0	35	0.4	0.01	0.2	0.1	0.05	0.04	*1200	16.0	203	1.082	95/02/17
13	Lak 24	Borehole	7.1	28.8	488	23.0	6.9	75.0	0.8	0.05	*0.4	0.00	1.00	0.00	0.8	4.0	335	0.0	0.02	0.1	0.0	0.10	0.01	86	32.0	296	0.864	95/02/18
14	Nonsao	Borehole	7.3	27.2	447	40.0	11.0	39.0	0.8	0.00	*0.28	0.00	1.30	0.00	4.0	4.0	282	0.1	0.00	0.0	0.0	0.00	0.00	168	41.0	258	1.034	95/02/20
15	Saakhonebou	Borehole	7.4	28.1	378	33.0	13.0	25.0	1.2	0.18	0.05	0.00	0.49	0.00	2.0	3.0	447	0.1	0.00	0.1	0.2	0.00	0.00	128	28.0	218	0.518	95/02/18
16	Naisivilai	Borehole	6.8	28.2	783	100.0	33.0	19.0	2.0	0.24	*0.60	0.00	2.50	0.00	0.8	5.0	547	0.0	0.00	0.1	0.3	0.00	0.01	384	42.0	420	0.947	95/02/20
17	Naenphan	Borehole	7.3	29.2	430	43.0	13.0	28.0	0.8	*0.54	0.00	0.00	0.28	0.00	3.2	3.0	286	0.1	0.00	0.2	0.0	0.05	0.00	160	27.0	245	0.927	95/02/20
18	Houay Kapho	Borehole	6.7	28.5	790	137.0	9.3	9.2	0.4	0.11	*0.28	0.00	1.20	0.00	43.0	4.0	455	0.0	0.00	0.2	0.5	0.05	0.00	380	42.0	434	0.917	95/02/21
19	Nongnuang	Borehole	6.6	27.5	433	61.0	9.9	15.0	0.0	0.06	*0.68	0.00	2.40	0.00	7.2	3.0	289	0.0	0.00	0.1	0.1	0.00	0.00	193	27.0	284	0.971	95/02/21
20	Bong	Borehole	6.4	29.2	165	12.0	10.0	4.1	0.0	0.08	0.00	0.00	1.20	0.00	0.8	3.0	95	0.1	0.00	0.1	0.0	0.00	0.00	71	14.0	102	0.996	95/02/20

* more than WHO's Guideline value for drinking water

Table 7.2 Water Quality Analysis by the Mekong Secretariat

Sampling location : Ban Phonesikhay

Date	SWL (m)	pH	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Alk mg/l	Cl mg/l	SO4 mg/l	Fe mg/l	NO3 mg/l	PO4 mg/l	CO3 mg/l	CO2 mg/l	Mn mg/l	Si mg/l	TSS mg/l	THN mg/l	NCH mg/l	TDS mg/l
20-Jun-90	4.48	6.00	4.90	2.20	0.39	7.59	0.78	7.20	5.67	17.77	0.08	0.05	0.03	-	12.80	-	-	12.00	0.14	0.02	54.56
22-Aug-90	3.37	6.20	8.20	5.09	0.71	8.51	0.04	20.94	9.15	9.03	0.02	0.30	0.01	-	22.27	0.24	-	2.00	0.31	-	76.31
18-Oct-90	2.17	6.09	10.40	8.74	1.52	11.49	0.04	30.48	6.38	13.35	0.25	0.23	-	-	42.74	0.19	-	2.00	0.56	0.05	115.42
15-Dec-90	5.54	7.28	48.00	55.23	12.17	22.99	0.12	212.94	2.41	22.19	0.10	-	0.07	0.26	18.05	0.16	20.80	5.00	3.76	0.21	367.49
20-Feb-91	5.47	6.95	46.10	50.10	14.02	32.65	1.56	256.14	0.43	15.08	0.02	0.01	0.03	0.13	47.52	0.11	16.80	1.00	3.65	-	434.60
29-Apr-91	-	4.97	13.40	2.50	0.24	27.59	0.04	18.54	26.81	7.54	0.03	0.01	0.01	-	-	0.02	7.40	-	0.15	-	90.73
15-Jun-91	5.84	7.00	13.10	7.98	5.76	9.89	1.80	52.14	5.74	15.23	0.10	0.03	0.02	0.03	8.78	0.08	3.60	21.00	0.87	-	111.18
16-Aug-91	0.68	5.20	4.80	4.53	1.80	0.34	0.08	12.78	0.43	10.04	0.37	0.02	-	-	-	0.04	2.20	1.00	0.37	0.16	32.63
22-Oct-91	1.51	7.14	49.00	68.20	5.87	26.99	1.17	252.60	7.52	11.72	0.46	0.03	0.05	0.20	29.30	0.14	1.96	-	3.89	-	406.21
20-Dec-91	-	7.19	49.00	52.48	14.59	44.00	0.20	312.42	0.43	9.65	-	0.01	0.06	0.31	33.06	0.19	20.70	-	3.82	-	488.10
17-Feb-92	-	7.57	48.50	50.42	11.53	24.78	1.02	259.44	0.21	18.59	0.03	-	0.06	0.31	10.90	0.30	21.30	-	3.46	-	398.89
21-Apr-92	-	7.11	48.70	64.37	12.44	2.67	0.98	255.54	4.36	11.67	0.14	0.02	0.03		32.53	0.09	21.90	2.00	4.24	-	406.74

SWL : Static Water Level

Sampling location : Ban Lak 15

Date	SWL (m)	pH	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Alk mg/l	Cl mg/l	SO4 mg/l	Fe mg/l	NO3 mg/l	PO4 mg/l	CO3 mg/l	CO2 mg/l	Mn mg/l	Si mg/l	TSS mg/l	THN mg/l	NCH mg/l	TDS mg/l
16-Aug-91	0.37	7.01	56.20	64.65	25.86	1.33	0.31	275.04	0.60	48.51	0.21	0.01	0.03	0.17	44.09	0.16	18.10	36.00	5.35	0.77	479.07
22-Oct-91	0.43	7.08	9.10	17.33	0.43	0.53	0.12	37.20	1.17	12.01	0.24	0.01	0.01	0.02	6.26	0.06	15.51	-	0.90	0.28	90.90
20-Dec-91	0.50	7.47	0.70	0.60	0.17	0.64	0.04	1.20	0.25	1.44	-	0.01	0.02	-	0.11	0.04	2.00	-	0.04	0.01	6.52
17-Feb-92	-	5.80	1.50	2.53	0.05	0.41	0.08	0.90	1.81	4.27	0.21	0.01	-	-	-	0.03	2.30	-	0.13	-	12.61
21-Apr-92	0.80	5.75	2.20	2.32	1.06	0.62	0.23	8.64	1.56	1.54	0.17	0.01	-	-	-	0.02	2.00	1.00	0.20	0.06	18.17

SWL : Static Water Level

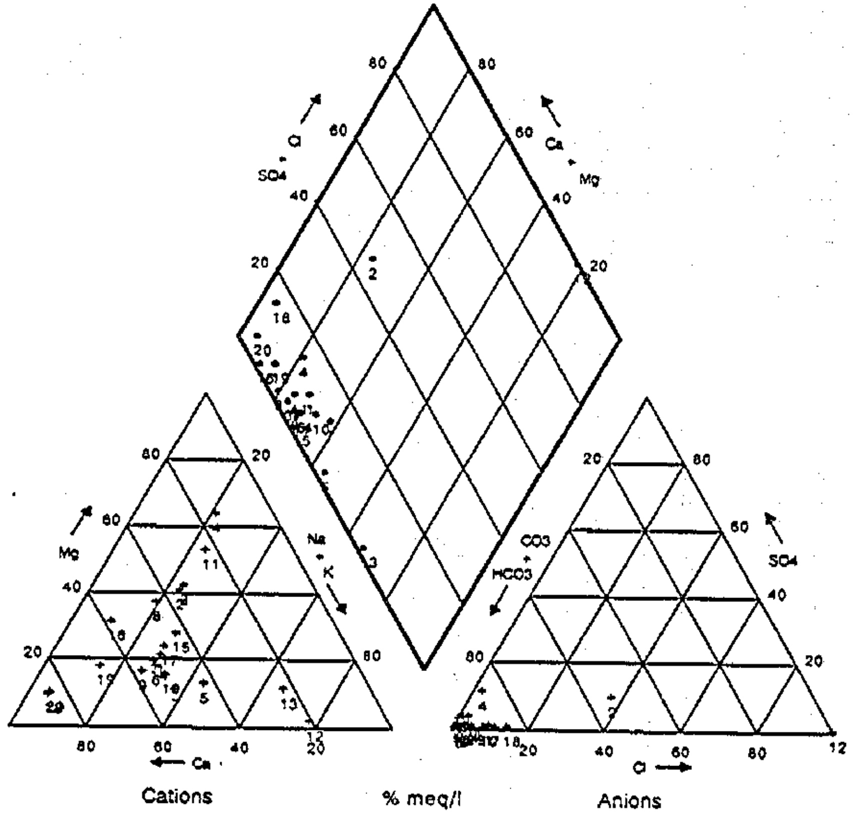


Figure 7.1 Tri-linear Diagram of water quality analysis for Test wells (Feb 1995)

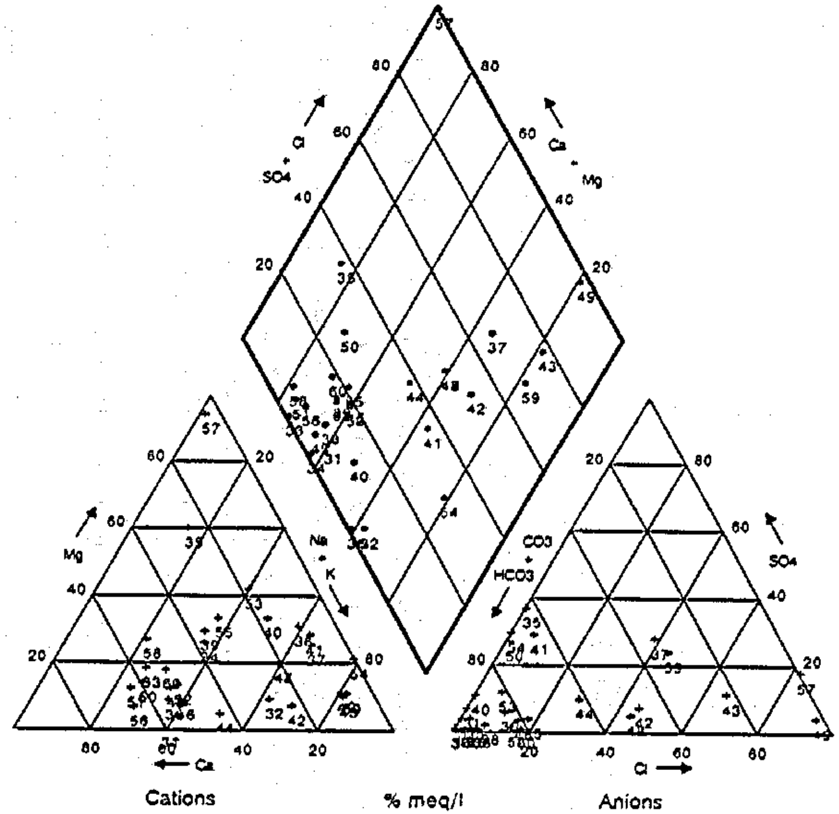


Figure 7.2 Tri-liner Diagram of water quality analysis for Existing wells (Feb 1995)

REFERENCES

British Geological Survey Department of Geology and Mines(1991) Geological andMineral Occurrence Map 1:1 000 000,Mineral Exploration and Development Plan.
British Geological Survey Department of Geology and Mines(1990) MAP OF MINERALIZED ZONES(NON-FUEL) 1:2 500 000.
Mekong Committee Secretariat with the Assistance of the French Government and of the ESCAP/UNDP Regional Remote Sensing Program(1988) BOLOVEN PLATEAU AGRO-ECOLOGICAL MAP 1:100 000
Ministry of Geology of The USSR(1972) GEOLOGICAL MAP OF EURASIA1:5 000 000.
Mekong Committee Secretariat, Lower Mekong Hydrologic Year Book.
Service Geographique National(1991) CARTE ADMINISTRATIVE 1:1 750 000.
Service Geographique National(1993) CARTE PHYSIQUE ECONOMIQUE 1:1 750 000.
UNICEF(Aug.1991) Rural Water Supply and Sanitation in the LAO P.D.R.,A Framework for a New Decade ,Main Report.
UNITED NATIONS(1990) Atlas of Mineral Resources of The ESCAP Region Vol.7,Economic and Social Commission for ASIA and The PACIFIC 1990.
Workman,D.R.(1975) Tectonic evolution of Indochina,J.Geol.Soc.Thailand,1.
Workman,D.R.(1975) Geological Structure of the Indochina Peninsula,for the Regional Conference on the geology and Mineral Resources of South Asia,Jakarta.
Workman,D.R.(1977) Geology of Laos,Cambodia,South Viet-Nam and the Eastern Part of Thailand ,Overseas Geology and Mineral Resources No.50,Institute of Geological Sciences,London.
Topographical Maps(1986) 1:500 000,1:200 000,1:100 000,
Aerial Photographs(1981-82) 1:30,000
LANDSAT TM(Feb.19,1994) Path126-Row49,50.

APPENDICES

Table Resistivity 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 Quaternary	Basalt lava	800--2000		
	Basalt Breccia	100--500		*
	Weathered Ba(dry).	100--700		*
	Weathered Basalt	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		*fissured.
Carboniferous to Permian	Slate,Sandstone	900--1500		
	Weathered.	20---30		*fissured.

Groundwater leveling in Phase II of the Study, Jan. to Feb. 1995

Village	Village No	District	Date observed	Hydro-geology	Elevation (m)	Diameter (m)	Depth (m)	Well top to G/S (m)	Well top to W/L (m)	Elevation of W/L (m)	E/C (uS/cm)	PH	Water temperature(C)	Turbidity	Type of well	Handpump or ring	Working
Nongphai	C-4	Sanasoumboun	25-Jan	Et	115.0	0.152	50.00	0.65	8.42	107.23					Borehole	India Mark III	
Nongphai	C-4	Sanasoumboun	01-Feb	Et	115.0	0.152	50.00				804	6.8	28.9		Borehole	India Mark III	
Nongphai	C-4	Sanasoumboun	02-Mar	Et	115.0	0.152	50.00				740	6.8	29.2		Borehole	India Mark III	
Nongdou	C-7	Sanasoumboun	25-Jan	Eh	146.0	1.5	10.96	0.42	8.21	138.21	50	5.4	27.2	A	Dug well	Concrete	Wat
Houaxe	C-8	Sanasoumboun	25-Jan	Qf	120.0	0.152	182.00	0.70	15.22	105.48					Borehole	India Mark III	
Houaxe	C-8	Sanasoumboun	25-Jan	Qf	120.0	0.152	182.00				10080	7.9	32.3		Borehole	India Mark III	
Houaxe	C-8	Sanasoumboun	02-Mar	Qf	120.0	0.152	182.00				4000	7.3	30.5		Borehole	India Mark III	
Dong	C-10	Sanasoumboun	31-Jan	Eh	135.0	3.0	0.60	0.10	0.00	135.10	40	3.9	24.6	A	Dug well		
Nongkham	C-12	Sanasoumboun	31-Jan	Eh	151.0	1.0	8.76	0.85	7.85	144.00	45	4.1	28.3	A	Dug well	Concrete	
Louy	C-16	Sanasoumboun	25-Jan	Eh	150.0	0.152	48.00	0.65	7.69	142.96					Borehole	India Mark III	
Louy	C-16	Sanasoumboun	01-Feb	Eh	150.0	0.152	48.00				74	5.1	28.7		Borehole	India Mark III	
Louy	C-16	Sanasoumboun	02-Mar	Eh	150.0	0.152	48.00				155	5.8	29.0		Borehole	India Mark III	
Donkalong	C-27	Sanasoumboun	25-Jan	Eh	114.0	1.2	7.29	0.31	5.33	108.98	30	5.4	27.2	B	Dug well	Wood	
Nakeo		Sanasoumboun	25-Jan	Qf	103.0	0.152	29.70	0.30	4.38	98.92					Borehole	Dempster	No
Nalong	C-28	Sanasoumboun	25-Jan	Ep	105.0	1.0	5.77	0.85	6.89	98.96	320	7.1	28.4	C	Dug well	Concrete	
Thangbengsivilai	C-30	Sanasoumboun	25-Jan	Eh	105.0	2.0	9.90	0.93	9.79	96.14	125	7.2	27.0	A	Dug well	Concrete	Wat
Saphay Phonkeo		Sanasoumboun	25-Jan	Qf	100.0	0.152	11.00	0.10	10.99	89.11					Borehole	Dempster	No School
Boungkha	C-24	Sanasoumboun	25-Jan	Qf	106.0	0.064					260	6.5	28.9	A	Borehole	Lucky	
Donkalong		Pakxe	25-Jan	Ep	114.0	1.1	6.47	0.83	4.62	110.21	650	7.0	27.2	A	Dug well	Wood	
Khoktaphan		Pakxe	25-Jan	Ep	100.0	0.152	24.11	0.67	9.58	91.09					Borehole	India Mark III	No
Thaoudam		Pakxe	31-Jan	Qf	96.0	2.0	4.25	0.00	4.20	91.80	75	6.5	22.6	B	Dug well		
Nahek		Pakxe	31-Jan	Ba1	96.0	0.152	39.75	0.25	5.18	91.07					Borehole	Dempster	No Wat
Houaxe		Pakxe	31-Jan	Ba1	160.0	1.5	1.95	0.00	0.50	159.50	30	4.9	25.5	A	Dug well		
Houaylusi		Pakxe	31-Jan	Ba1	175.0	1.0	6.37	0.00	4.41	170.59	30	4.9	27.5	A	Dug well	Wood	
Lak 19	C-62	Pathoumphon	31-Jan	Ba2	120.0	1.3	3.60	0.45	2.29	118.16	20	5.4	25.9	A	Dug well	Concrete	
Lak-24	C-65	Pathoumphon	31-Jan	Ba3	100.0	0.152	50.00	0.54	7.97	92.57					Borehole	India Mark III	
Lak-24	C-65	Pathoumphon	18-Feb	Ba3	100.0	0.152	50.00				485	7.0	29.1		Borehole	India Mark III	
Lak-24	C-65	Pathoumphon	23-Feb	Ba3	100.0	0.152	50.00				460	6.5	27.6		Borehole	India Mark III	
Lak 29	C-67	Pathoumphon	31-Jan	Ba2	105.0	1.4	9.85	0.70	9.03	96.67	30	5.2	27.2	A	Dug well	Concrete	
Thangbeng		Pathoumphon	31-Jan	Ba2	105.4	1.4	7.03	0.60	5.39	100.61	50	5.8	25.8	B	Dug well	Concrete	
Tomo-nok	C-71	Pathoumphon	31-Jan	Ba2	102.0	1.5	2.75	0.30	1.84	100.46	20	5.0	25.8	A	Dug well	Concrete	
Tao-Tai	C-72	Pathoumphon	31-Jan	Ba2	102.0	1.0	4.45	0.25	2.86	99.39	35	4.9	26.4	A	Dug well		
Nakam-Noy	C-73	Pathoumphon	31-Jan	Ba2	97.0	2.0	4.12	0.50	2.20	95.30	65	5.6	25.0	A	Dug well	Wood	
Thahou		Pathoumphon	31-Jan	Ba3	100.0	1.0	4.35	0.00	1.97	98.03	85	5.6	25.2	B	Dug well		
Thangbeng	C-74	Pathoumphon	31-Jan	Ba3	100.0	0.8	3.70	0.50	3.06	97.44	160	5.7	26.8	B	Dug well		
Nongke	C-75	Pathoumphon	31-Jan	Qf	95.0	1.0	9.10	0.80	5.16	90.64	50	4.5	27.6	A	Dug well	Brick	
Nongke	C-75	Pathoumphon	31-Jan	Qf	95.0	0.152	50.00	0.51	3.92	91.59					Borehole	India Mark III	

Table 3.3.5-3(2/4) Groundwater leveling in Phase II of the Study, Jan. to Feb. 1995

Village	Village No	District	Date observed	Hydro-geology	Elevation (m)	Diameter (m)	Depth (m)	Well top to G/S (m)	Well top to W/L (m)	Elevation of W/L (m)	E/C (uS/cm)	PH	Water temperature(C)	Turbidity	Type of well	Handpump or ring	Working	
Nongke	C-75	Pathoumphon	20-Feb	Qf	95.0	0.152	50.00				440	6.9	27.2		Borehole	India Mark III		
Pathoumphone		Pathoumphon	31-Jan	Qf	94.0	1.5	7.76	0.83	6.43	88.40	300	4.8	26.2	A	Dug well	Brick		
Khong Chom Thong		Khong	30-Jan	Qt	88.0	0.152	29.07	0.25	6.31	81.94					Borehole	Dempster	No	Wat
Nasenphan	C-89	Khong	30-Jan	Et	88.0	1.0	5.64	0.44	5.18	83.26	200	7.1	25.2	B	Dug well			
Nasenphan	C-89	Khong	30-Jan	Et	88.0	0.152	50.00	0.53	5.82	82.71					Borehole	India Mark III		
Nasenphan	C-89	Khong	20-Feb	Et	88.0	0.152	50.00				420	7.0	29.0		Borehole	India Mark III		
Maisivilai	C-88	Khong	30-Jan	Et	85.0	0.152	50.00	0.41	9.75	75.66					Borehole	India Mark III		
Maisivilai	C-88	Khong	20-Feb	Et	85.0	0.152	50.00				740	6.5	29.1		Borehole	India Mark III		
Nasomheng	C-92	Khong	30-Jan	Et	88.0	1.6	6.50	0.60	3.10	85.50	155	5.8	25.3	B	Dug well	Concrete		
Hatxaykhoun	C-94	Khong	30-Jan	Et	88.0	2.0	6.49	0.63	6.34	82.29	540	7.4	26.3	A	Dug well	Concrete		
Khinak	C-98	Khong	30-Jan	Qf	86.0	3.0	8.22	1.05	8.84	78.21	470	7.2	25.7	B	Dug well	Concrete		
Tapusy	C-100	Khong	30-Jan	Et	88.0	1.5	5.85	0.75	5.84	82.91	460	6.9	27.2	B	Dug well	Concrete		
Naveng	C-87	Khong	30-Jan	Et	95.0	1.0	7.85	0.20	5.19	90.01	420	7.0	27.9	A	Dug well	Wood		
Muangsen-Nua		Khong	30-Jan	Qt	88.0	1.5	6.55	0.63	6.31	82.32	400	6.5	26.5	C	Dug well	Concrete		Wat
Nongboua		Phonthong	04-Feb	Qf	106.0	1.5	6.30	0.00	3.85	102.15	75	5.2	23.2	B	Dug well	Wood		
Nachan		Phonthong	04-Feb	Ep	102.0	0.152	11.15	0.10	7.02	95.08	480	7.0	26.9	A	Borehole	Dempster	No	Wat
Dou		Phonthong	04-Feb	Ep	96.0	0.152	24.13	0.17	6.96	89.21					Borehole	Dempster	No	
Nonghai		Phonthong	04-Feb	Ep	96.0	0.152					480	7.1	28.0	B	Borehole	Tara		Wat
Nonkhoun		Phonthong	28-Jan	Qf	114.0	0.152		1.00	7.93	107.07	560	6.9	29.0	A	Borehole	India Mark III	No	
Dongnang		Phonthong	04-Feb	Ep	95.0	2.0	4.65	0.75	2.68	93.07	30	5.8	24.7	B	Dug well	Wood		
Langtao		Phonthong	04-Feb	Eh	130.0	1.5	5.03	0.00	4.70	125.30	140	6.9	23.00	C	Dug well			
Nonghai		Phonthong	24-Jan	Ep	96.0	0.152	15.36	1.26	7.59	89.67					Borehole	Dempster	No	Wat
Nonghai		Phonthong	28-Jan	Ep	96.0	0.152	15.36	1.26	7.61	89.65					Borehole	Dempster	No	Wat
Nonghai		Phonthong	04-Feb	Ep	96.0	0.152	15.36	1.26	7.68	89.58					Borehole	Dempster	No	Wat
Phanthakham		Champasak	24-Jan	Qf	93.0	1.4	5.38	0.88	4.34	89.54	30	5.2	26.4	A	Dug well	Concrete		Wat
Dontalatt		Champasak	24-Jan	Ep	88.0	1.7	6.94	0.60	4.65	83.95	140	5.4	28.2	B	Dug well	Concrete		Wat
Donmak-ek		Champasak	24-Jan	Ep	94.0	2.0	4.40	0.65	2.95	91.70	25	5.4	26.1	C	Dug well			
Mai		Champasak	24-Jan	Qf	93.0	1.4	4.70	0.40	3.06	90.34	30	4.9	25.6	A	Dug well			
Thomchan		Champasak	24-Jan	Ep	88.0	0.152	30.00	0.30	5.51	82.79					Borehole	Dempster	No	
Thomchan		Champasak	24-Jan	Ep	89.0			0.00	4.28	84.72	140	4.4	27.1	B	Dug well			Wat
Bak	C-78	Soukhouma	24-Jan	Ep	93.0	1.9	5.87	0.00	5.72	87.28	150	5.7	26.2	B	Dug well			
Samkhanaboua	C-79	Soukhouma	24-Jan	Ep	96.0	0.152	45.00	0.56	8.10	88.46					Borehole	India Mark III		
Samkhanaboua	C-79	Soukhouma	18-Feb	Ep	96.0	0.152	45.00				382	7.5	30.3		Borehole	India Mark III		
Samkhanaboua	C-79	Soukhouma	23-Feb	Ep	96.0	0.152	45.00				380	7.0	29.1		Borehole	India Mark III		
Nongphanvong		Soukhouma	24-Jan	Qf	86.0	0.152	30.00	1.20	11.14	76.06					Borehole	Dempster	No	
Soukhouma		Soukhouma	24-Jan	Qf	87.0	2.0	8.77	0.93	7.30	80.63	280	3.9	26.8	A	Dug well	Concrete		Wat
Lak 21	C-49	Bachiang	21-Jan	Bal	442.0	0.152	59.00	1.23	17.42	425.81					Borehole	Dempster	No	School

Table 3.3.5-3(3/4) Groundwater leveling in Phase II of the Study, Jan. to Feb. 1995

Village	Village No	District	Date observed	Hydro-geology	Eleva-tion (m)	Dia-meter (m)	Depth (m)	Well top to G/S (m)	Well top to W/L (m)	Elevation of W/L (m)	E/C (uS/cm)	PH	Water tempera-ture(C)	Turbi-dity	Type of well	Handpump or ring	Working	
Lak 21	C-49	Bachiang	27-Jan	Ba1	442.0	0.152	59.00	1.23	17.74	425.49					Borehole	Dempster	No	School
Lak 21	C-49	Bachiang	27-Jan	Ba1	443.0	0.152	60.00	0.60	15.79	427.81					Borehole	India Mark III		
Lak 21	C-49	Bachiang	28-Jan	Ba1	443.0	0.152	60.00				43	5.7	25.6		Borehole	India Mark III		
Lak 21	C-49	Bachiang	24-Feb	Ba1	443.0	0.152	60.00				50	5.0	25.1		Borehole	India Mark III		
Lak 21	C-49	Bachiang	02-Mar	Ba1	443.0	0.152	60.00				80	6.0	25.7		Borehole	India Mark III		
Lak 25	C-52	Bachiang	27-Jan	Ba1	560.0						30	5.2	26.0	A	Spring			
Oudomsouk	C-47	Bachiang	21-Jan	Ba1	325.0	1.8	20.69	0.50	15.70	309.80	30	5.3	25.0	A	Dug well	Concrete		Church
Oudomsouk	C-47	Bachiang	27-Jan	Ba1	325.0	1.8	20.69	0.50	15.92	309.58	20	4.7	26.5	A	Dug well	Concrete		Church
Moungkhai	C-45	Bachiang	21-Jan	Ba1	315.0	2.0	20.98	0.43	18.35	297.08	30	4.8	26.4	A	Dug well	Concrete		
Nongsim		Bachiang	21-Jan	Ba1	245.0	0.152	60.00	1.16	15.51	230.65					Borehole	Dempster	No	School
Nongsim		Bachiang	27-Jan	Ba1	245.0	0.152	60.00	1.16	15.77	230.39					Borehole	Dempster	No	School
Bachiang	C-38	Bachiang	21-Jan	Ba1	225.0	1.2	8.18	0.60	7.51	218.09	90	6.0	27.6	A	Dug well	Tara		Hospita
Bachiang	C-38	Bachiang	27-Jan	Ba1	225.0	1.2	8.18	0.60	7.58	218.02	55	5.6	27.6	A	Dug well	Tara		Hospita
Nongsai	C-37	Bachiang	27-Jan	Ba3	176.0	1.7	4.60	0.00	4.05	171.95	280	7.0	23.0	B	Dug well	Wood		Wat
Thongsala	C-44	Bachiang	23-Jan	Ba2	220.0	0.152	43.00	0.65	9.65	211.00					Borehole	India Mark III		
Thongsala	C-44	Bachiang	01-Feb	Ba2	220.0	0.152	43.00				222	6.3	24.3		Borehole	India Mark III		
Thongsala	C-44	Bachiang	23-Feb	Ba2	220.0	0.152	43.00				190	5.8	25.0		Borehole	India Mark III		
Thongsala	C-44	Bachiang	02-Mar	Ba2	220.0	0.152	43.00				220	6.3	25.6		Borehole	India Mark III		
Houn-Tai	S-100	Laongam	23-Jan	Ba1	520.0	0.152	54.00	0.60	21.59									
Houn-Tai	S-100	Laongam	01-Feb	Ba1	520.0	0.152	54.00				98	5.9						
Houn-Tai	S-100	Laongam	23-Feb	Ba1	520.0	0.152	54.00				100	5.4						
Houn-Tai	S-100	Laongam	02-Mar	Ba1	520.0	0.152	54.00				110	5.6						
Phao-gnai	S-77	Saravan	21-Jan	Ba3	205.0	1.5	3.15	0.65	2.18	203.47	320	6.4	25.1	A	Dug well	Concrete		
Soung	S-78	Saravan	21-Jan	Ba3	205.0	1.5	3.50	0.00	3.42	201.58	420	6.2	25.6	A	Dug well			
Nakasao	S-75	Saravan	21-Jan	Ep	194.0	4.7	7.56	0.58	3.62	190.96					Borehole	Lucky	No	
Nakasao	S-75	Saravan	23-Jan	Ep	194.0	0.152	53.00	0.60	5.09	189.51					Borehole	India Mar III		
Nakasao	S-75	Saravan	01-Feb	Ep	194.0	0.152	53.00				673	6.5	27.6		Borehole	India Mar III		
Nakasao	S-75	Saravan	02-Mar	Ep	194.0	0.152	53.00				530	6.4	27.6		Borehole	India Mar III		
Naxai-Noy	S-81	Saravan	21-Jan	Ba3	235.0	1.3	3.65	0.52	3.16	232.36	140	6.2	24.6	A	Dug well	Concrete		
Naxai-Noy	S-81	Saravan	21-Jan	Ba3	230.0	3.0	2.35	0.65	1.78	228.87	170	6.2	22.8	A	Dug well	Wood		
Beng	S-84	Laongam	23-Jan	Ba2	308.0	0.152	66.00	0.80	19.38	289.42					Borehole	India Mar III		
Beng	S-84	Laongam	02-Mar	Ba2	308.0	0.152	66.00				160	5.9	26.8		Borehole	India Mar III		
Saravan		Saravan	21-Jan	Ep	184.0	1.2	8.53	0.10	7.35	176.75					Dug well	Concrete		Wat Kh
Phonphai	S-64	Saravan	23-Jan	Ep	180.0	0.152	50.00	0.65	10.94	169.71					Borehole	India Mar III		
Phonphai	S-64	Saravan	01-Feb	Ep	180.0	0.152	50.00				657	6.9	29.2		Borehole	India Mar III		
Phonphai	S-64	Saravan	23-Feb	Ep	180.0	0.152	50.00				550	6.8	25.2		Borehole	India Mar III		
Phonphai	S-64	Saravan	02-Mar	Ep	180.0	0.152	50.00				580	6.7	29.2		Borehole	India Mar III		

3 Guidelines of water quality for drinking use

The guidelines for drinking water most accepted are set out by the World Health Organization(1984) as shown in Tables 3.1 and 3.2. The basic requirements for drinking water are as follows;

-Free from disease causing microscopic organisms
-No compounds that affect human health
-Fairly clear (low turbidity and little color)
-Not saline
-No compounds that cause offensive taste or smell
-No compounds that cause corrosion of supply system
-No compounds that cause strain of clothes washed

It is practically impossible to establish rigid water standards for chemical quality. The permissible level for each ion may be a function of water availability and socio-economic factors.

Table 3.1 Aesthetic quality

Constituent	Unit	Guideline value	Remarks
Aluminum	mg/l	0.2	
Chloride	mg/l	250	
Chlorobenzenes and chlorophenols	--	no guideline value set	these compounds may affect taste and odour
colour	true colour units (TCU)	15	
copper	mg/l	1.0	
detergents	--	no guideline value set	there should not be any foaming or taste and odour problems
hardness	mg/l (as $CaCO_3$)	500	
hydrogen sulfide	--	not detectable by consumers	
iron	mg/l	0.3	
manganese	mg/l	0.1	
oxygen-dissolved	--	no guideline value set	
pH	--	6.5-8.5	
sodium	mg/l	200	
solids-total dissolved	mg/l	1000	
sulfate	mg/l	400	
taste and odour	--	inoffensive to most consumers	
temperature	--	no guideline value set	
turbidity	nephelometric turbidity units (NTU)	5	preferably <1 for disinfection efficiency
zinc	mg/l	5.0	

Source : WHO(1984)

Table 3.2 Inorganic constituents of health significance

Constituent	Unit	Guideline value
arsenic	mg/l	0.05
asbestos	--	no guideline value set
barium	--	no guideline value set
beryllium	--	no guideline value set
cadmium	mg/l	0.005
chromium	mg/l	0.05
cyanide	mg/l	0.1
fluoride	mg/l	1.5
hardness	--	no health-related guideline value set
lead	mg/l	0.05
mercury	mg/l	0.001
nickel	--	no guideline value set
nitrate	mg/l (N)	10
nitrite	--	no guideline value set
selenium	mg/l	0.01
silver	--	no guideline value set
sodium	--	no guideline value set

* : natural or deliberately added; local or climatic conditions may necessitate adaptation
Source : WHO(1984)

Well Design Of Test Wells

No.	Location	Elevation (m)	Drill. Method	Drill. Depth (m)	Water Level (G.L-m)*	Well Depth (m)	Casing Dia. (mm)	Casing Pipe	Screen (G.L.-m) (m)	Screen Total (m)	Screen Open. Area (%)	Geo. Type	Aquifer	Pump Type	Bellows Pump (G.L.-m)	Date Completed
C-4	B.Nongphai	115	Top-300,D.H	50	12	49	150	P.V.C.	11-31	20	6.7	Eh	Jura,sandstone	India M3	33	Feb '95
C-8	B.Houaxe	120	Top-500,D.H	182	19	180	150,100	Steel	66-72,90-96,108-132,156-180	60	15	Eh	Jura,-Creta,Sandstone	*	84	Feb '95
C-16	B.Louy	150	Top-300,D.H	48	10	48	150	P.V.C.	6-10,14-22,38-46	19	6.7	Qte	Gravel,Jura,Sandstone	India M3	27	Feb '95
C-44	B.Thongsala	220	Top-300,D.H	43	13	25	150	P.V.C.	11-23,	12	6.7	Ba2	N-Q Basalt	India M3	21	Feb '95
C-49	B.Lak-21	442	Top-300,D.H	60	22	45	150	P.V.C.	23-35	12	6.7	Ba1	N-Q Basalt	India M3	36	Feb '95
C-65	B.Lak-24	100	Top-500,D.H	50	10	49	150	P.V.C.	11-15,19-23,39-47	16	6.7	Ep	Jura,Sandstone	India M3	30	Feb '95
C-75	B.Nongkhe	95	Top-500,D.H	50	7.5	50	150	P.V.C.	16-20,28-36,40-48	20	6.7	Qf	Q-Sand,Jura,SandyShale	India M3	24	Feb '95
C-79	B.Samkhanaboua	96	Top-300,D.H	45	10	43	150	P.V.C.	9-13,17-29,37-41	20	6.7	Ep	Jura,Sandy Shale	India M3	30	Feb '95
C-88	B.Maisivilai	85	Top-500,D.H	50	16	50	150	P.V.C.	20-48	28	6.7	Et2	Paleozoic Slate	India M3	33	Feb '95
C-89	B.Nasenphan	88	Top-500,D.H	50	7.4	50	150	P.V.C.	16-20,28-48	24	6.7	Et1	Triassic Acidic Tuff	India M3	30	Feb '95
S-4	B.Houaykapho	160	Top-300,D.H	45	13	42	150	P.V.C.	12-28,36-40	20	6.7	Eh	Jura,-Creta,Sandstone	India M3	27	Feb '95
S-12	B.Nongsano	160	Top-300,D.H	50	9	50	150	P.V.C.	12-20,24-28,32-48	28	6.7	Eh	Jura,Sandstone	India M3	30	Feb '95
S-24	B.Donmuang	130	Top-500,D.H	50	13	50	150	P.V.C.	28-44	16	6.7	Qf	Q-Sand,Jura,Sandstone	India M3	24	Feb '95
S-38	B.Nongngong	140	Top-500,D.H	50	10	49	150	P.V.C.	23-35,39-43	16	6.7	Ep	Jura,Sandstone	India M3	24	Feb '95
S-50	B.Samia	145	Top-500,D.H	50	10	49.5	150	P.V.C.	22.5-43.5	21	6.7	Qf	Q-Sand,Jura,Sandstone	India M3	27	Feb '95
S-56	B.Chong	170	Top-500,D.H	50	7.5	49	150	P.V.C.	15-23,31-43	20	6.7	Ba3	N-Q Basalt,Jura,Sandston	India M3	27	Feb '95
S-64	B.Phonphai	190	Top-500,D.H	50	12.2	50	150	P.V.C.	20-24,32-44	16	6.7	Ep	Jura,Sandstone	India M3	30	Feb '95
S-75	B.Nakasao	194	Top-500,D.H	53	7	50	150	P.V.C.	12-16,28-48	24	6.7	Ep	Jura,Sandstone	India M3	27	Feb '95
S-84	B.Beng	308	Top-500,D.H	66	24.4	60	150	Steel	18-48	30	15	Ba2	N-Q Basalt	**	51	Feb '95
S-100	B.Houn-Tai	520	Top-500,D.H	54	28.6	52	150	P.V.C.	9-21,34-46	24	6.7	Ba1	N-Q Basalt,Loam	India M3	42	Feb '95

D.H.=Down the Hole Hammer *=Dryseason(Presumed)
R.T.=Rotary Tricon. Bit.

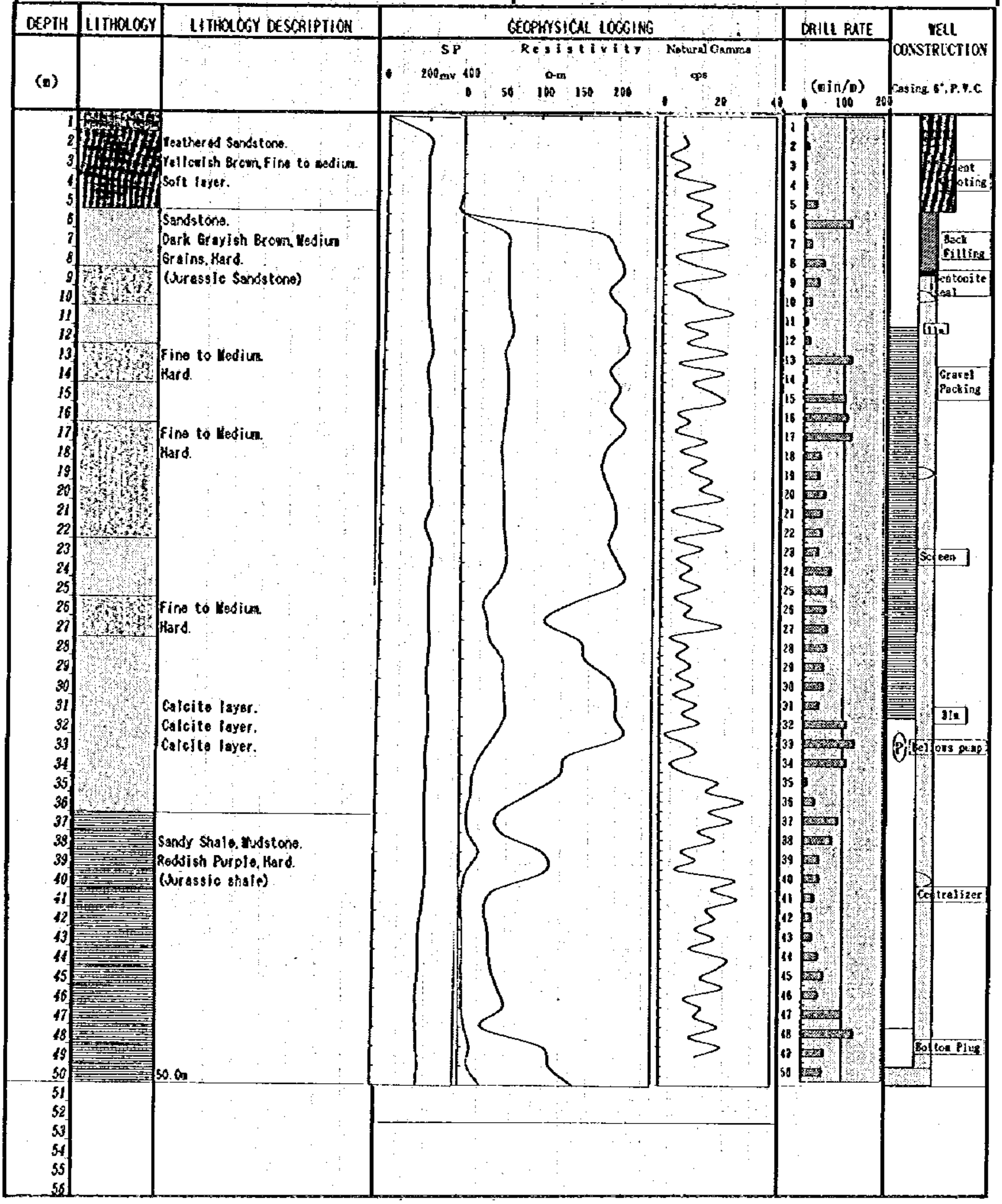
* GRUNDFOS SP5A-21,H=82m,2.2kw,5m^3/h,2830R/min
** GRUNDFOS SP14A-10,H=48m,3.7kw,14m^3/h,2830R/min

LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA- 01 /20

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

LOCATION	BAN	NONGPHAI	FIELD BOOK NO.	C-4
	PROVINCE	CHAMPASAK	TOTAL DEPTH(m)	50.0
DRILLING COMPANY		SIAM TONE Co.,LTD.	GROUND SURFACE ELEVATION(m)	115
RIG TYPE & NUMBER		TOP-300	DATE BEGUN	23/12/'94
DRILLING METHOD		Direct Rotary circulation Down The Hole Hammer(D.H.H)	DATE COMPLETED	26/12/'94
FIELD PARTY		UTAIRAAT	STATIC WATER LEVEL(B.L.S) After Boring	
GEOLOGIST		S.OHMORI		

STATIC WATER LEVEL (B.L.S) After Boring			
Depth(m)	8.66	8.32	7.67
Time			
Date	30/12/'94	4/01/'94	23/01/'94

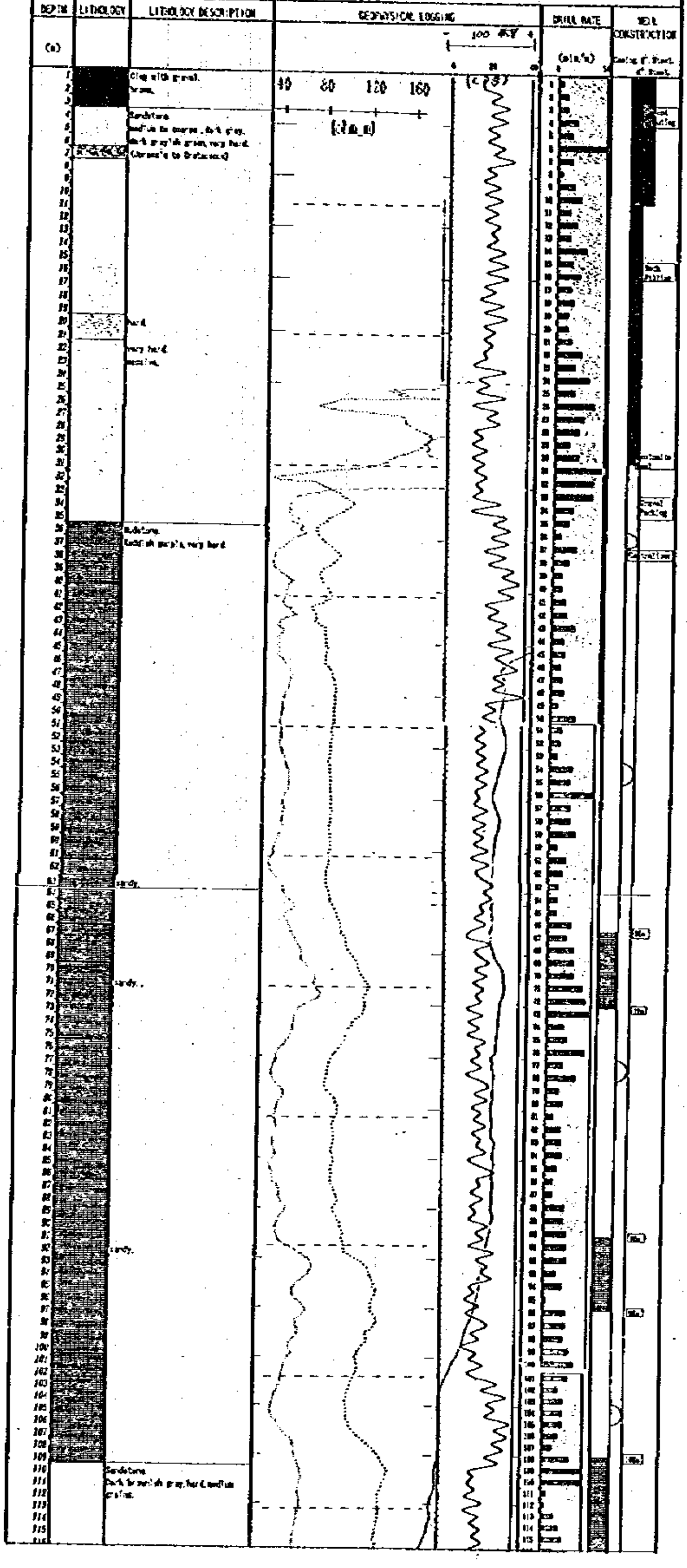


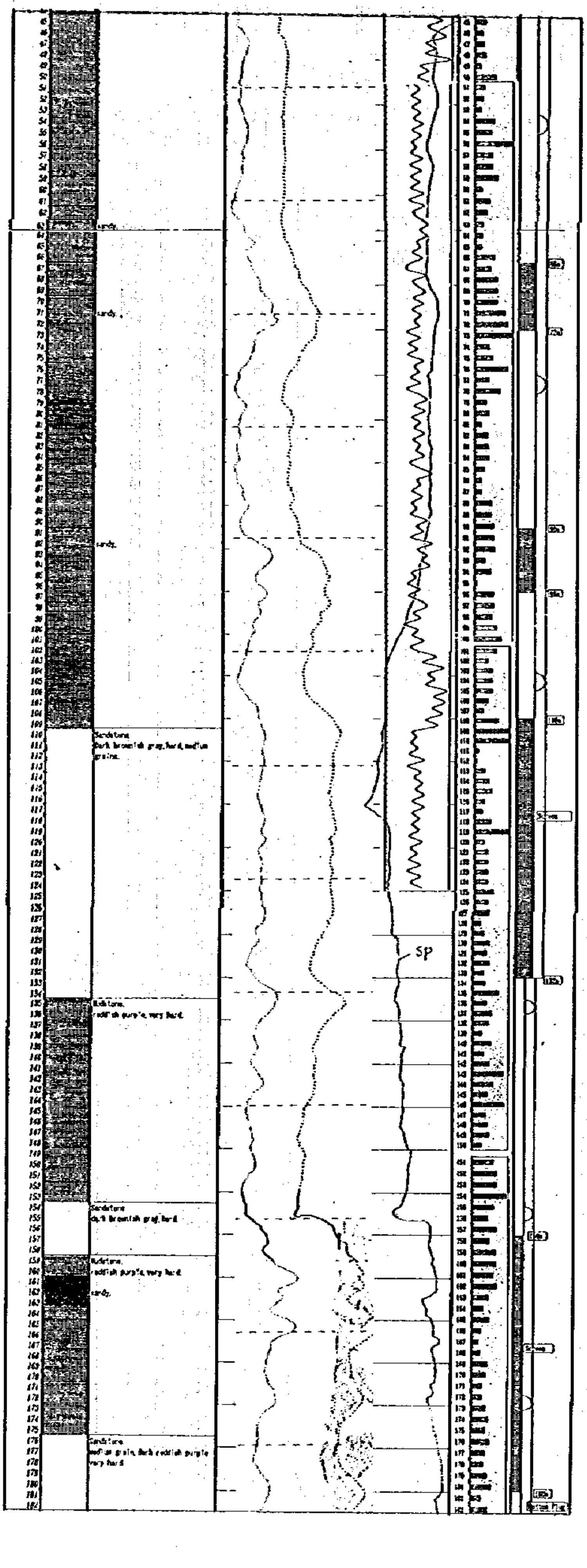
LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA- 02 /20

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

LOCATION	BAN	ROGANE	FIELD BOOK NO.	C-8
	PROVINCE	CHAMPASAK	TOTAL DEPTH(m)	102.0
DRILLING COMPANY		STAR TONE Co., LTD.	GROUND SURFACE ELEVATION(m)	120
RIG TYPE & NUMBER		TOP-300	DATE BEGUN	23/12/'94
DRILLING METHOD		Direct Rotary circulation Down The Hole Hammer (D.H.H)	DATE COMPLETED	08/01/'94
FIELD PARTY		MEKHAT	STATIC WATER LEVEL (G.L.-m) After Boring	
GEOLOGIST		S.OHORI		

Depth(m)	18.43	15.47	14.32
Time			
Date	25/01/'95	4/01/'95	23/01/'95




sandy.
sandy.
sandy.
Sandstone
Dark brownish gray, hard, medium grains.
SP
sandy.
Sandstone
very hard

LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA- 03 /20

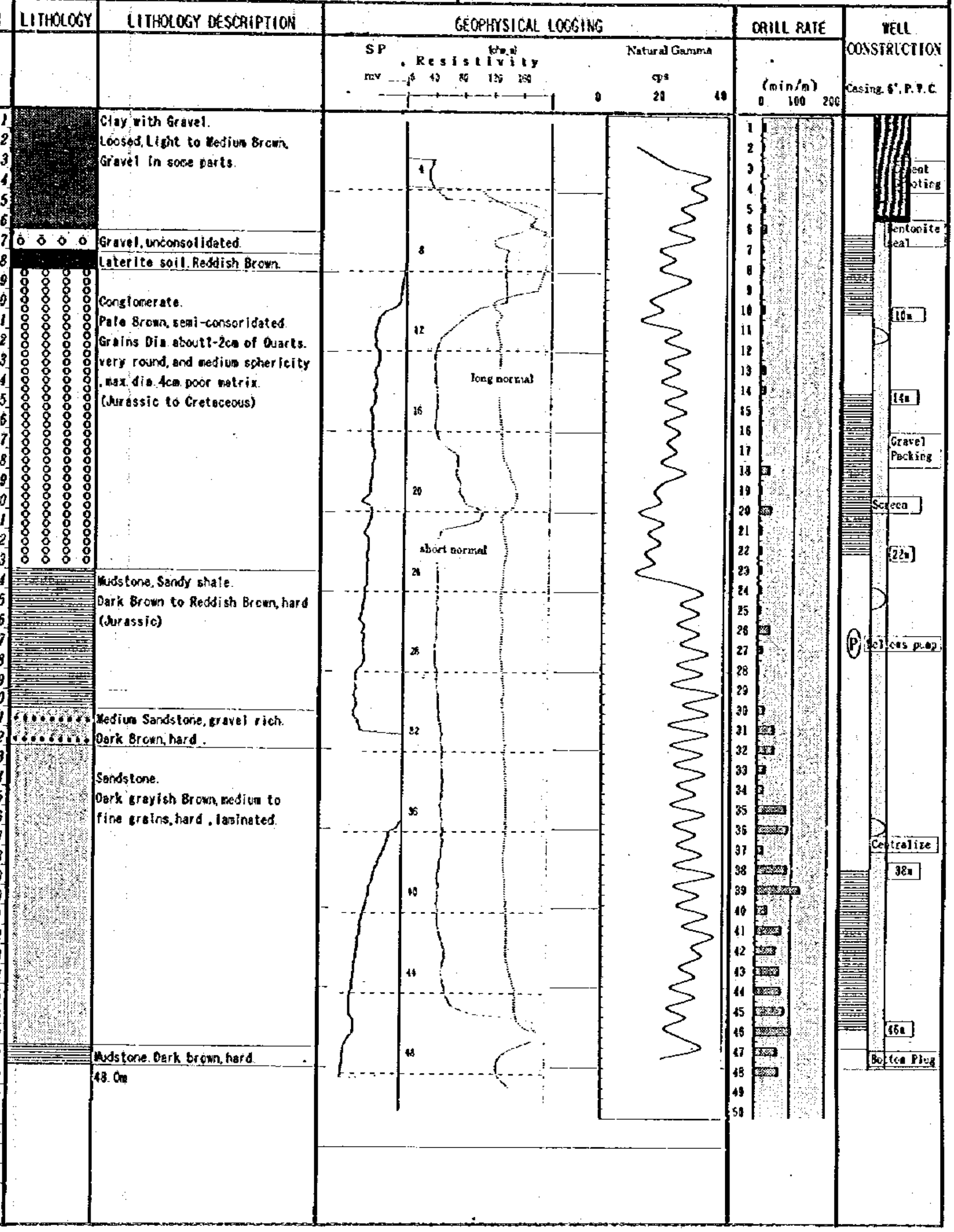
PROJECT NAME : THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES , LAO PEOPLE'S DEMOCRATIC REPUBLIC

LOCATION	BAN	LOUY	FIELD BOOK NO.	C-16
	PROVINCE	CHAMPASAK	TOTAL DEPTH(m)	48
DRILLING COMPANY		SIAM TONE Co.,LTD.	GROUND SURFACE ELEVATION(m)	150
RIG TYPE & NUMBER		TOP-300	DATE BEGUN	19/12/'94
DRILLING METHOD		Direct Rotary circulation Down The Hole Hammer(D.H.M)	DATE COMPLETED	22/12/'94
FIELD PARTY		UTAIRAAT		
GEOLOGIST		S.OHMORI		

STATIC WATER LEVEL(B.L.S) After Boring

Depth(m)	6.69	6.6	6.92
Time			
Date	23/12/'94	04/01/'95	23/01/'95

DEPTH (m)	LITHOLOGY DESCRIPTION
1–6	Clay with Gravel. Loosed, Light to Medium Brown, Gravel in some parts.
7	Gravel, unconsolidated.
8	Laterite soil, Reddish Brown.
9–23	Conglomerate. Pale Brown, semi-consoridated. Grains Dia about1-2cm of Quarts. very round, and medium sphericity , max. dia. 4cm. poor matrix. (Jurassic to Cretaceous)
24–30	Mudstone, Sandy shale. Dark Brown to Reddish Brown, hard (Jurassic)
31–32	Medium Sandstone, gravel rich. Dark Brown, hard .
33–47	Sandstone. Dark grayish Brown, medium to fine grains, hard , laminated.
48	Mudstone. Dark brown, hard. 48.0m



LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA- 04 /20

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

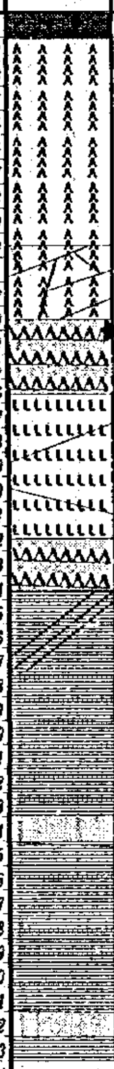
LOCATION	BAN	THONGSALA	FIELD BOOK NO.	C-44
	PROVINCE	CHAMPASAK	TOTAL DEPTH(m)	43.0
DRILLING COMPANY		SIAM TONE Co.,LTD.	GROUND SURFACE ELEVATION(m)	220
RIG TYPE & NUMBER		TOP-300	DATE BEGUN	18/11/'94
DRILLING METHOD		Direct Rotary circulation Down The Hole Hammer(D.H.H)	DATE COMPLETED	20/11/'94
FIELD PARTY		UTAIRAAT	STATIC WATER LEVEL(B.L.S) After Boring	
GEOLOGIST		S.OHMORI		

STATIC WATER LEVEL (B.L.S) After Boring			
Depth(m)	7.18	8.21	8.8
Time			
Date	21/11/'94	22/12/'94	4/01/'95

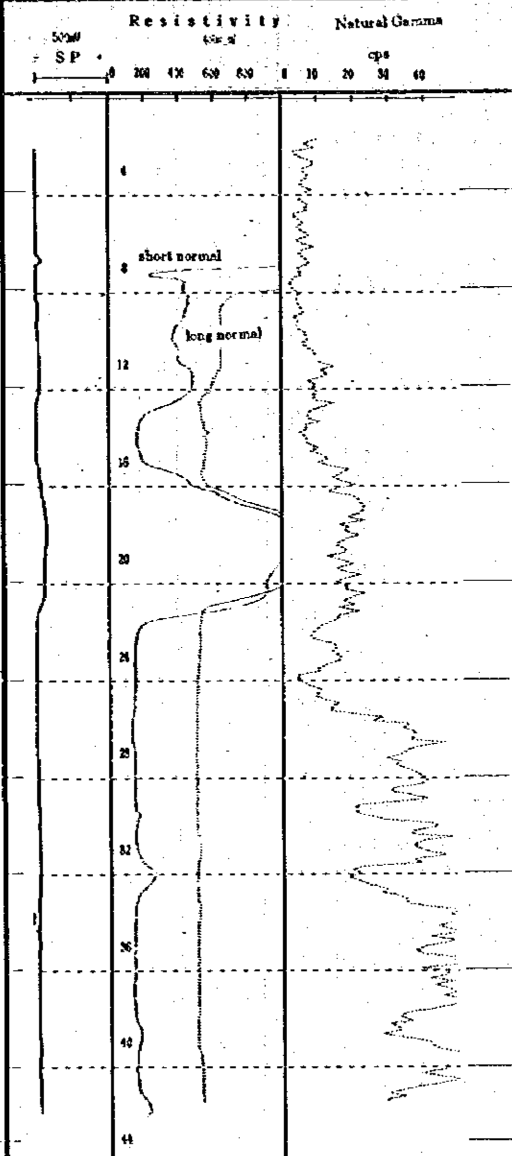
DEPTH (m)	LITHOLOGY DESCRIPTION
1	Weathered Basalt. Brown, Porous.
3–5	Basalt, lava flow. low weathered, Dark gray to bluish gray, hard. (Paleogene to Quaternary.)
11	Fractured
13–15	[I] Basalt. Auto-brecciated lava, high porous
17–19	Basalt. Low Weathered, Lava flow gray colored.
23	Basalt. Auto-brecciated lava
25–27	Mudstone. Weathered clayey layer, reddish purple collared. (Jurassic).
29–34	Sandy shale. Reddish purple color, hard rock. Sandstone, Mudstone, shale, interbeded. (Jurassic rock) Sandy. mica rich.
42–43	Sandy. very fine to fine, purple. shale.
44	43.0m

DEPTH (m): 1–56

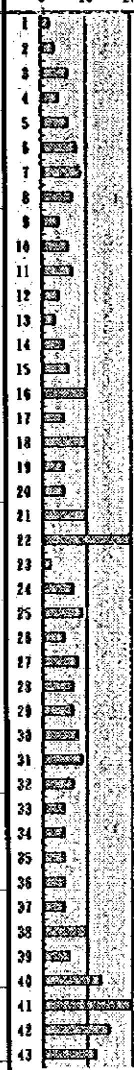
LITHOLOGY



GEOPHYSICAL LOGGING

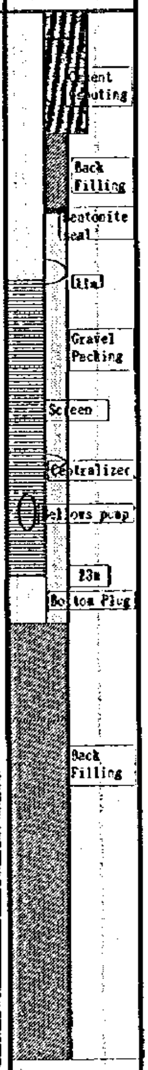


DRILL RATE (min./m)



WELL CONSTRUCTION

Casing 6", P.V.C.



LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA- 05 /20

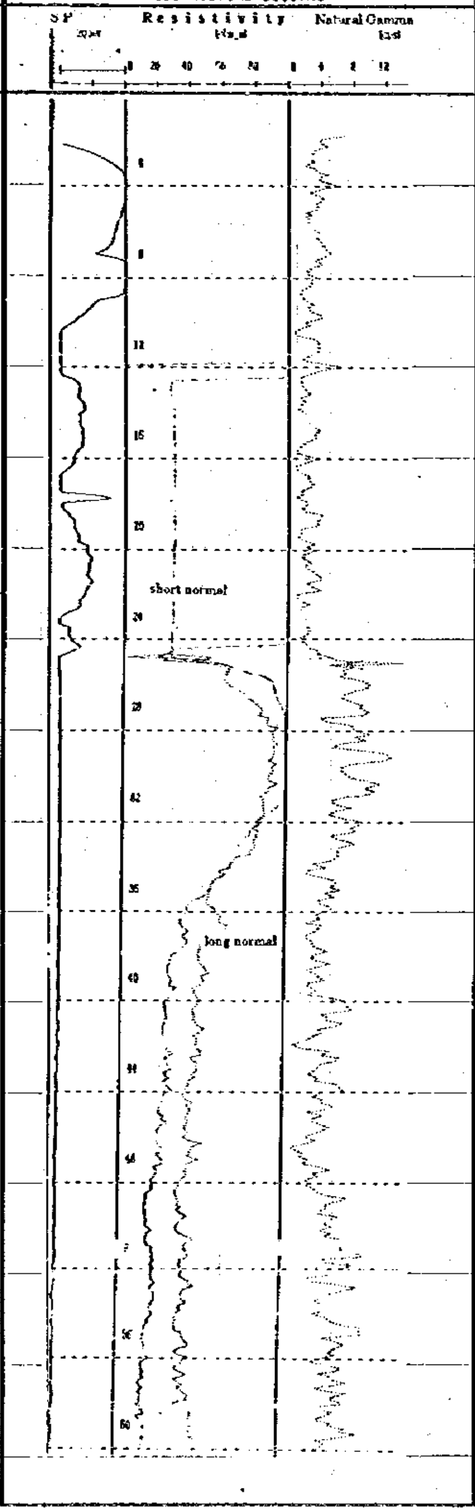
PROJECT NAME : THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES ,LAO PEOPLE'S DEMOCRATIC REPUBLIC

LOCATION BAN	LAK-21	FIELD BOOK NO.	C-49
PROVINCE	CHAMPASAK	TOTAL DEPTH(m)	60.0
DRILLING COMPANY	SIAM TONE Co.,LTD.	GROUND SURFACE ELEVATION(m)	442
RIG TYPE & NUMBER	TOP-300	DATE BEGUN	15/11/'94
DRILLING METHOD	Direct Rotary circulation Down The Hole Hammer(D.H.M)	DATE COMPLETED	17/11/'94
FIELD PARTY	UTAIRAAT	STATIC WATER LEVEL(B.L.S) After Boring	
GEOLOGIST	S.OHMORI		

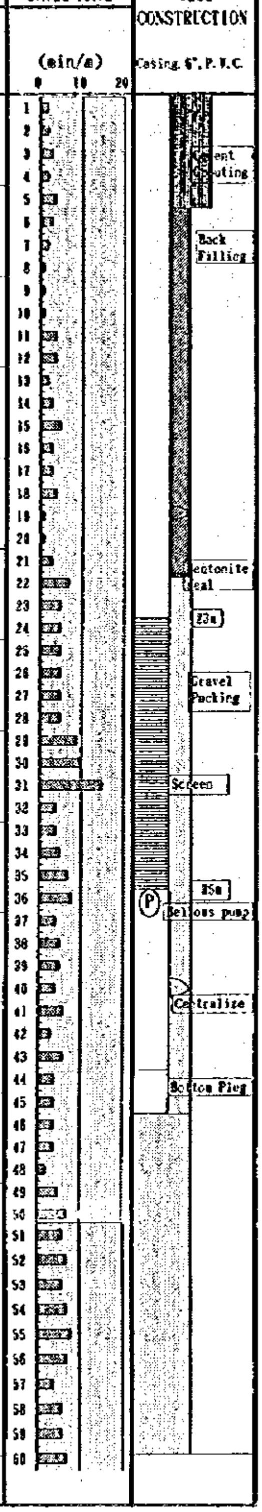
STATIC WATER LEVEL			
Depth(m)	11.29	12.8	14.68
Time			
Date	17/11/'94	5/12/'94	8/01/'94

DEPTH (m)	LITHOLOGY DESCRIPTION
1–13	Weathered Clay. Weathered Basaltic mud flow. Clay, Silt with Gravel. Dark brown color, high plasticity. (Neogene to Quaternary)
13–22	High Weathered Basalt Lava. Blackish brown color, low strength.
22–35	High to Medium weathered Basalt. Dark brown color, low strength in some parts.
35–60	High to Medium weathered basalt, or mud flow deposits with basalt boulder in some parts. dark brown to brown color.
60	60.0m

GEOPHYSICAL LOGGING



DRILL RATE / WELL CONSTRUCTION



LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA-06/20

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

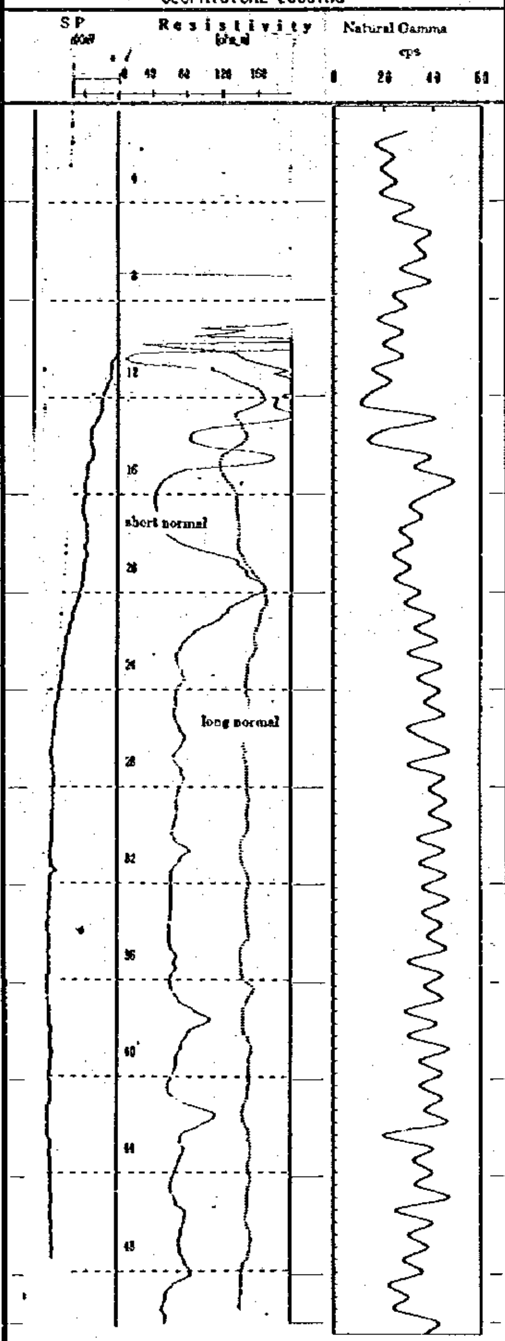
LOCATION	BAN	LAK-24	FIELD BOOK NO.	C-65
	PROVINCE	CHAMPASAK	TOTAL DEPTH(m)	50.0
DRILLING COMPANY		SIAM TONE Co.,LTD.	GROUND SURFACE ELEVATION(m)	100
RIG TYPE & NUMBER		TOP-500	DATE BEGUN	09/01/'95
DRILLING METHOD		Direct Rotary circulation Down The Hole Hammer(D.H.H)	DATE COMPLETED	10/01/'95
FIELD PARTY		UTAIRAAT		
GEOLOGIST		S.OHMORI		

STATIC WATER LEVEL(B.L.S) After Boring

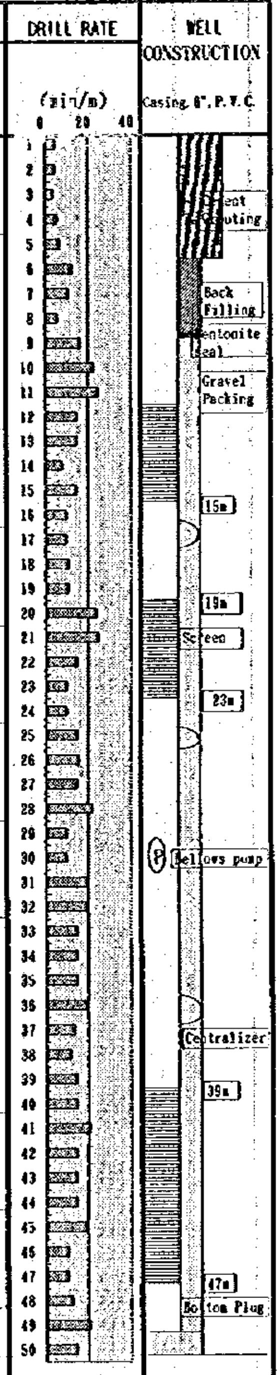
Depth(m)	7.12	7.35	7.43
Time			
Date	14/01/'95	19/01/'95	31/01/'95

DEPTH (m)	LITHOLOGY DESCRIPTION
1–2	Clay. soft, yellowish brown.
3–8	Laterite. Reddish brown
9–23	Sandstone. Dark brown, medium grains. (Jurassic)
24–44	Mudstone, Sandy shale. Reddish purple, hard.
31	Sandy.
38	Sandy.
42	Sandy.
45–50	Sandstone. Fine to Medium grains. Dark gray, hard.
50	50.0m

GEOPHYSICAL LOGGING



DRILL RATE / WELL CONSTRUCTION



LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA- 07 /20

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

LOCATION	BAN	NONGKHE	FIELD BOOK NO.	C-75
	PROVINCE	CHAMPASAK	TOTAL DEPTH(m)	50.0
DRILLING COMPANY		SIAM TONE Co.,LTD.	GROUND SURFACE ELEVATION(m)	95
RIG TYPE & NUMBER		TOP-500	DATE BEGUN	11/01/'95
DRILLING METHOD		Direct Rotary circulation	DATE COMPLETED	12/01/'95
		Down The Hole Hammer(D.H.H)		
FIELD PARTY		UTAIRAAT		
GEOLOGIST		S.OHMORI		

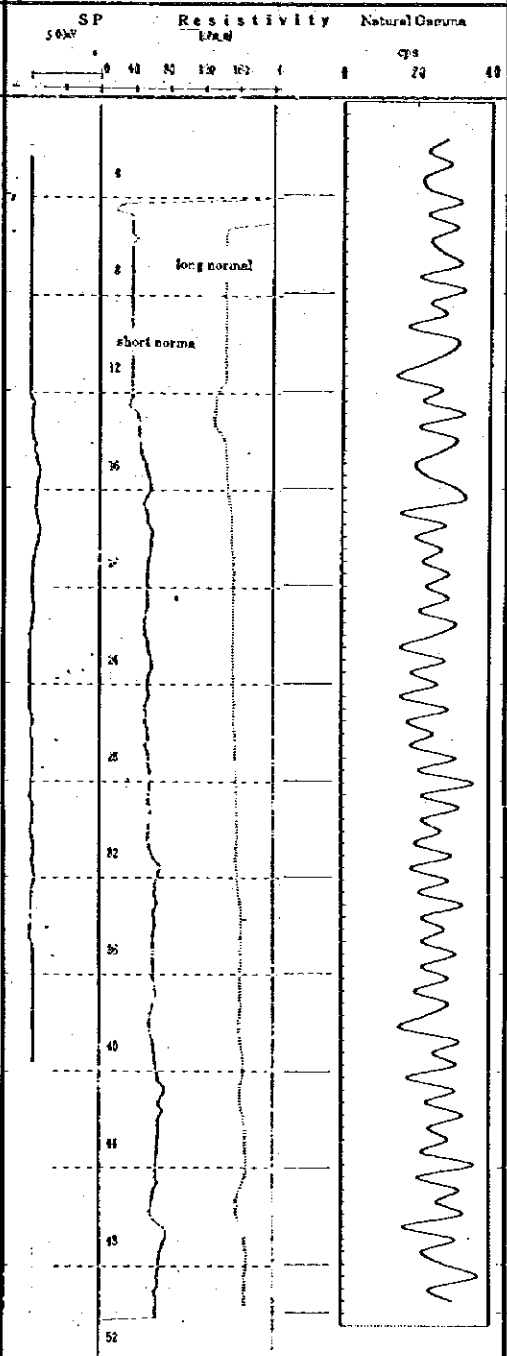
STATIC WATER LEVEL(B.L.S) After Boring				
	Depth(m)	5.12	3.2	3.41
	Time			
	Date	14/01/'95	19/01/'95	31/01/'95

DEPTH (m)	LITHOLOGY DESCRIPTION
1	Sandy clay.
2	soft to semi-consolidated.
3	Yellowish to reddish brown,
4	high plasticity.
5	Terrace deposits.
6	(Quaternary)
12	Hard shale.
13	Dark reddish purple.
14	(Jurassic)
30	Sandy shale.
31	Reddish brown to grayish brown,
32	very hard, high fissility.
37	calcareous.
38	Sandy.
42	Sandy.
50	50.0m

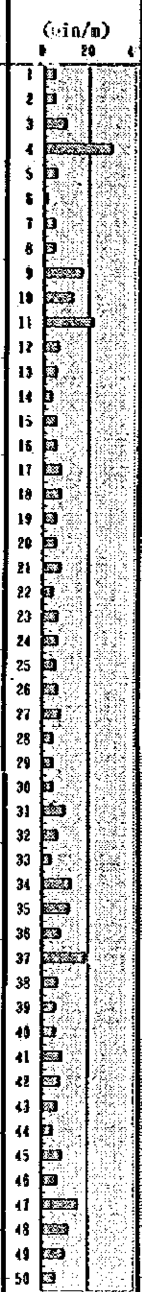
Depth scale: 1–56 m.

LITHOLOGY

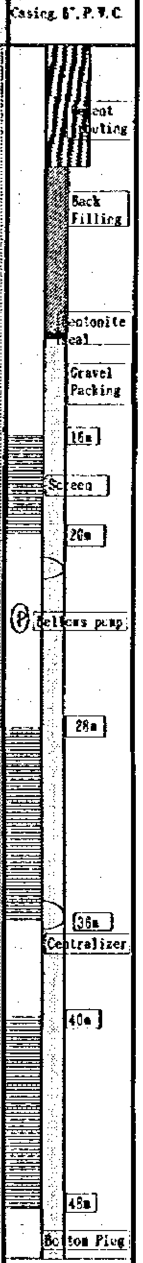
GEOPHYSICAL LOGGING



DRILL RATE



WELL CONSTRUCTION



LOG FORMAT	FIELD BOREHOLE LOG	BOREHOLE NUMBER JICA- 08 /20

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

LOCATION	BAN	SAMCHANABOUA
	PROVINCE	CHAMPASAK
DRILLING COMPANY		SIAM TONE Co., LTD.
RIG TYPE & NUMBER		TOP-300
DRILLING METHOD		Direct Rotary circulation Down The Hole Hammer (D.H.M)
FIELD PARTY		UTAIRAAT
GEOLOGIST		S.OHMORI

FIELD BOOK NO.	C 79
TOTAL DEPTH(m)	45.0
GROUND SURFACE ELEVATION(m)	96
DATE BEGUN	15/01/'95
DATE COMPLETED	17/01/'95

STATIC WATER LEVEL (B.L.S) After Boring

Depth(m)	7.5	7.63	7.8
Time			
Date	19/01/'95	25/01/'95	31/01/'95

DEPTH (m)	LITHOLOGY	LITHOLOGY DESCRIPTION
1–7		Sandy clay. Yellowish brown to gray, soft, high plasticity. eolian deposits. (Quaternary)
8–12		Sandstone. High weathered fine to very fine sandstone brown to dark grayish brown. (Jurassic)
13–40		Hard shale. Dark reddish purple. sandstone interbeded in some parts, hard. (Jurassic)
41–45		Sandy shale. Dark grayish green , very hard, high fissibility. 45.0m

Depth scale: 1–56 m