CHAPTER 7

HYDROGEOLOGY

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7.1 Hydro-geological Survey

7.1.1 Purpose of Survey

The hydrogeological survey was conducted to know the geomorphology, the hydrogeology and the distribution and quantities of surface water (rivers, pond, swamps, springs etc.) in the targeted 24 communes.

7.1.2 Survey Method

The Study Team conducted the survey systematically with following procedure.

a) Before visiting each target commune, the Study Team roughly grasp the hydrogeological images (natural condition, geomorphology, geology, resource of water supply facilities, water quality of groundwater and surface water) of the Study Area using the result of review, analysis of the existing data and the remote sensing analysis.

b) Interview on the distribution of main surface water (the location and quantity), main water resources in the 24 target communes.

c) Verification of the interview results in the site and acquisition of the location data using handy GPS and simple water quality test equipments.

7.1.3 The Survey Result

The field survey conducted from 25 June 2007 to 26 July 2007. Phu Yen, Khanh Hoa and Nin Thuan provinces were in dry season, and Binh Thuan was in rainy season. The each survey result was shown in data sheets with tabular forms for identified surface waters (refer to annex). The results are summarized to from Table 7.1.1 to Table 7.1.24 by every target commune.

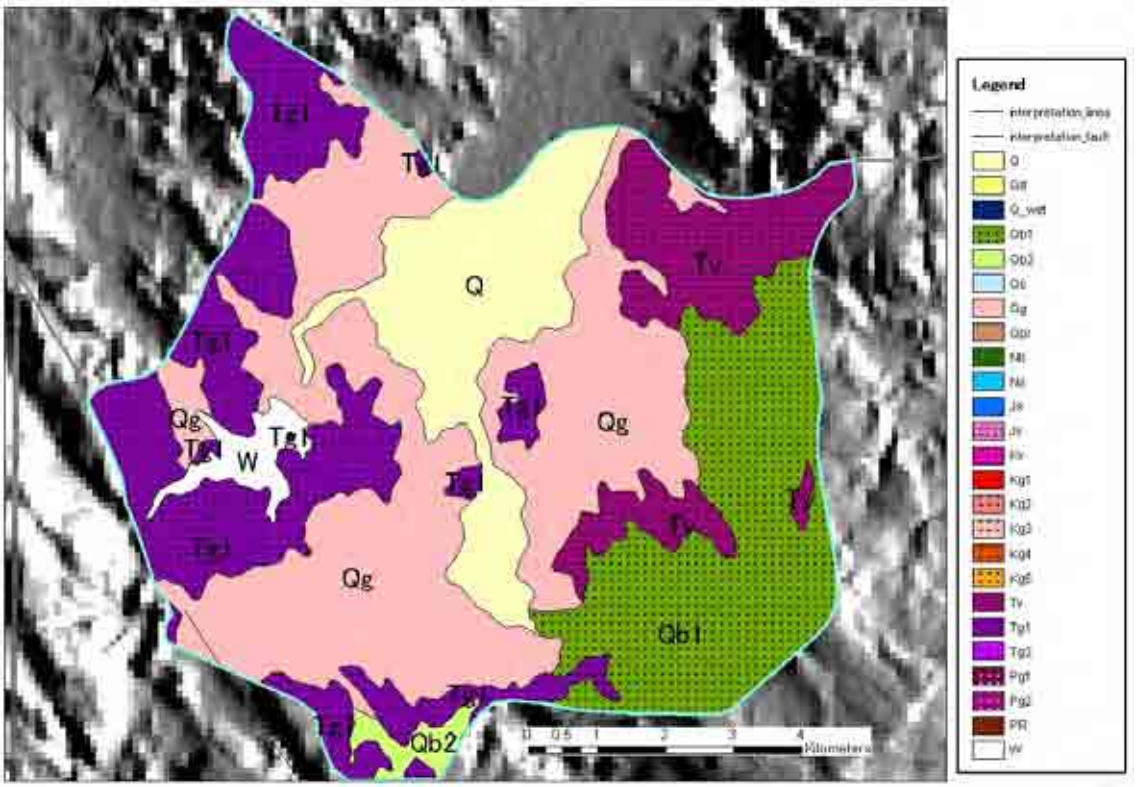
The main outputs of the survey result are as follows:

a. Four communes (P-2; An Dinh, N-2; Cong Hai, N-3; Bac Son and B-4; Tan Duc) have perennial rivers in their communes; however, the river waters are used for irrigation, not for drinking water because of agricultural chemical pollution.
b. One commune (B-3; Nghi Duc) has perennial spring in the commune: however the quantity is small, and not enough for the users.
c. Five communes (P-1;Xuan Phuoc, P-7;Suoi Bac, P-8; Son Thanh Dong, N-4; Phuoc Minh, B-6; Sung Nhon) have reservoirs or ponds for irrigation.
d. Many surface waters in the communes dry up in dry season.
e. The main resource for drinking water in the 24 target communes are dug wells during dry season. Eight communes (P-2; An Dinh, P-8; Son Thanh Dong, K-1; Cam An Bac, N-1; Nhon Hai, N-3; Bac

Son, N-4; Phuoc Minh, B-1; Muong Man, B-4; Tan Dac) buy drinking water in dry season. Two communes (K-2; Cam Hiep Nam, K-3; Cam Hai Tay) use rainwater as drinking water in rainy season.

Table 7.1.1 Geomorphology and Hydro-geological Characteristics of Xuan Phuoc Commune (P-1)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology: The commune area mainly consists of low land and low mountains. The northern part of the commune mainly consists of low land and the southern part mainly consists of mountains and its dissected valleys. The CPC is located at the foot of small mountain.

2. Geology: The mountainous area consists of plutonic rocks and igneous rocks. Sedimentary deposit is distributed in the valley plain. Main geology of this area is granitic rocks except eastern part of the commune. At eastern part basaltic rocks are distributed.

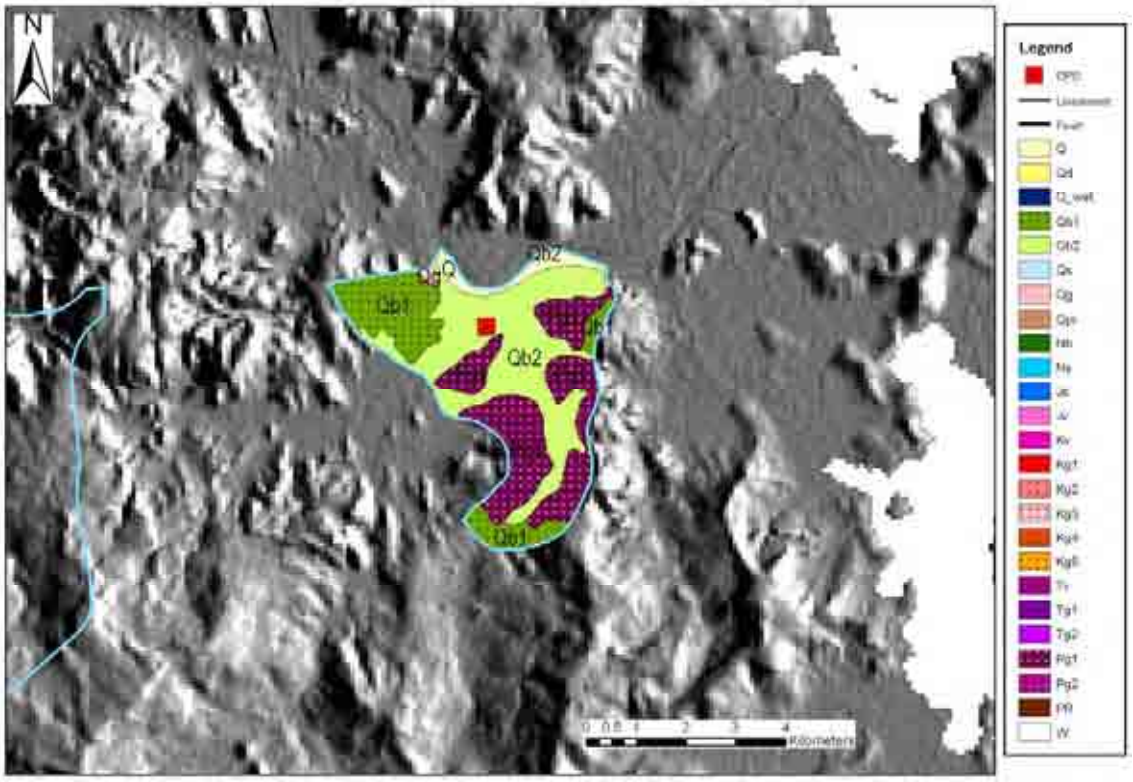
3. Condition of surface and groundwater: The water resources dry up in dry season.
3.1 Current state of surface water: Here is a tributary of "Cai" river at center of the commune and it flows from south to north. In addition, here is a reservoir "Phu Xuan" at south-western part of the commune. The base rock of the reservoir is igneous rocks.

3.2 Current state of groundwater: The residents mainly use groundwater from dug wells. The dug wells dry up during dry season. Seventy five percent of the households have their own dug wells. Some wells have fluoride and metallic taste in the water.

Note:
The water shortage area is located on the foot of a small mountain, where the CPC stands. Groundwater aquifers will be weathered and fissure zones of igneous rocks, and porous zone of basaltic rocks.

Table 7.1.2 Geomorphology and Hydro-geological Characteristics of An Dinh Commune (P-2)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology: The commune area consists of low land and low mountains. The villages are located on a valley plain. People live on the foot of small mountain in the valley and the bottom of the valley near "Cai" river.

2. Geology: The surface geology of the low land (valley plain) is sedimentary deposit and the base rock is basalt. The mountainous area consists of basalt and plutonic rocks.

3. Condition of surface and groundwater

3.1 Current state of surface water: Tow tributaries of "Cai" river run through the commune, namely, "suoi Cay" and "Dong Su". These rivers flow from south to north.

3.2 Current state of groundwater

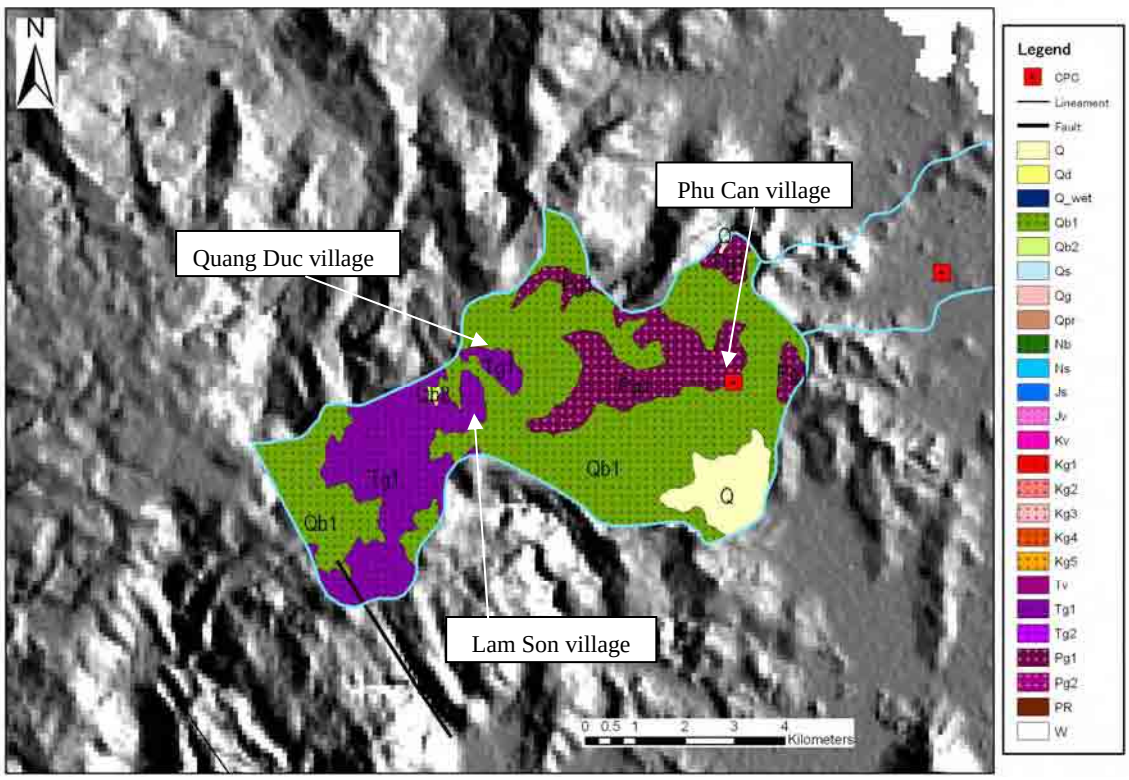
Fifty percent of the households have their own dug wells. Some wells have fluoride and metallic taste in the water.

Note:

The people in the commune are suffering flooding, because the area is located in low land and the rail way bank crossed the valley has prevented smooth flow of flooding river water. The people live in higher places for avoiding flood damage. Groundwater aquifers will be porous and fissure zones of basalt and basal conglomerate of sedimentary layers.

Table 7.1.3 Geomorphology and Hydro-geological Characteristics of An Tho Commune (P-3)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology: The commune is located in the mountainous area, and dissected narrow valleys are distributed in the lower areas. Villages are mainly located at hilly areas.

2. Geology: The area mainly consists of basaltic rocks and plutonic rocks. Base rocks crops out at the river bed. The valley located at southeast end of the commune is covered by sedimentary deposit.

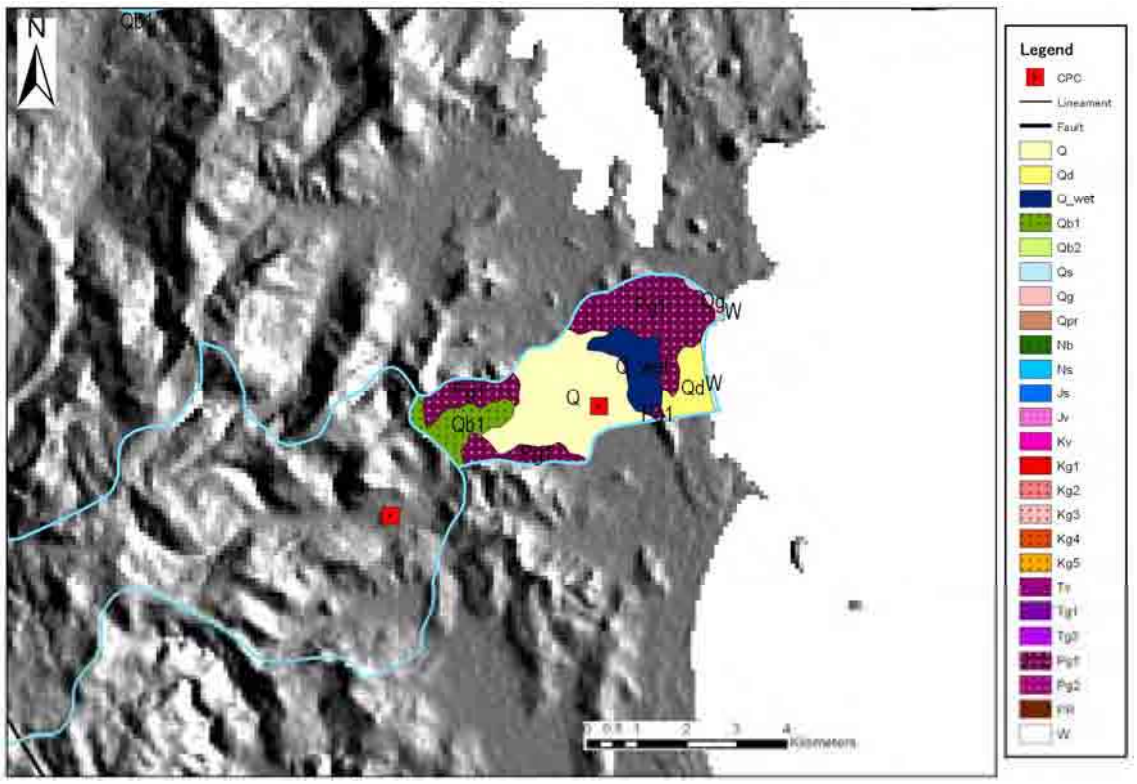
3. Condition of surface and groundwater: The water resources dry up from June to July.
3.1 Current state of surface water
River head of "suoi Lau" comes from this commune area.

3.2 Current state of groundwater
Twenty percent of the households have their own dug wells. Some wells have salinity, fluoride, high pH and odor in the water.

Note:
The people in the commune seem to use shallow groundwater in weathered rock. Phu Can village is located on gentle slope area. Quang Duc village is located on the mountain ridge. Lam Son village is located near a mountain top. Groundwater aquifers will be porous and fissure zones of basalt, weathered and fissure zones of plutonic rocks.

Table 7.1.4Geomorphology and Hydro-geological Characteristics of An My Commune (P-4)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology: The commune area mainly consists of coastal plain. The foot of mountainous area is in the western part and small mountains are distributed in north end. The main residential area is located near the sea coast. The people live on sand dune, natural levee and foot of small mountains. There is a big swamp in the center of the commune during rainy season.

2. Geology: The main geology of the commune is sedimentary deposit in the plain. The mountains mainly consist of plutonic rocks, and partially of basaltic rock that is widely distributed in adjacent area.

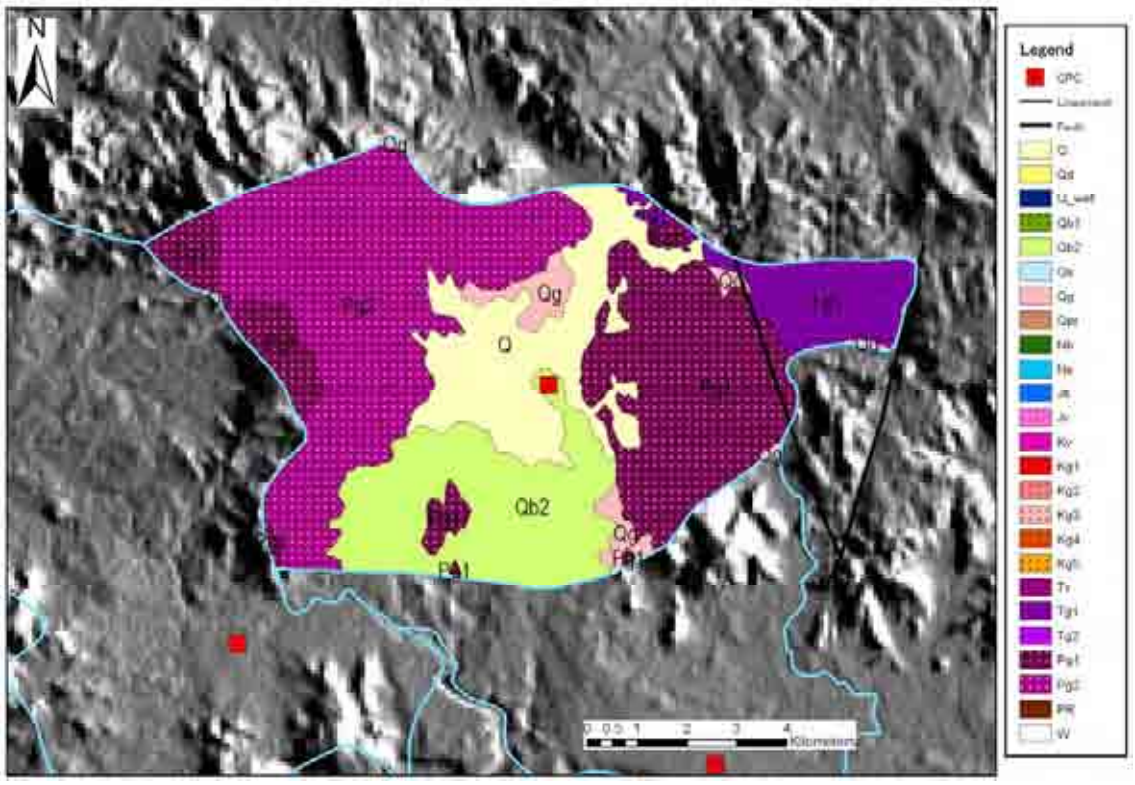
3. Condition of surface and groundwater: The water resources dry up from June to August.
3.1 Current state of surface water
A large swamp and a river flow from western part emerge during rainy season.

3.2 Current state of groundwater
Ninety percent of the households have their own dug wells. Some wells have salinity, fluoride and odor in the water.

Note:
The commune has a large swamp which emerges in every rainy season because the area is surrounded by small mountains, sand dune and sand bar so that the area has no explicit outlet of rain water. Salinity intrusion has already advanced in coastal plain. Groundwater aquifers will be fissure zone of basaltic rocks, weathered and fissure zone of plutonic rocks and sand dune.

Table 7.1.5 Geomorphology and Hydro-geological Characteristics of Son Phuoc Commune (P-5)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:
The commune is mainly located on table land with gentle slope surrounded by foothills.

2. Geology:
The table land consists of basalt and its weathered parts, and the foothills consist of plutonic rocks. Plutonic rocks are massive. Sedimentary deposit is distributed at the head of the table land.

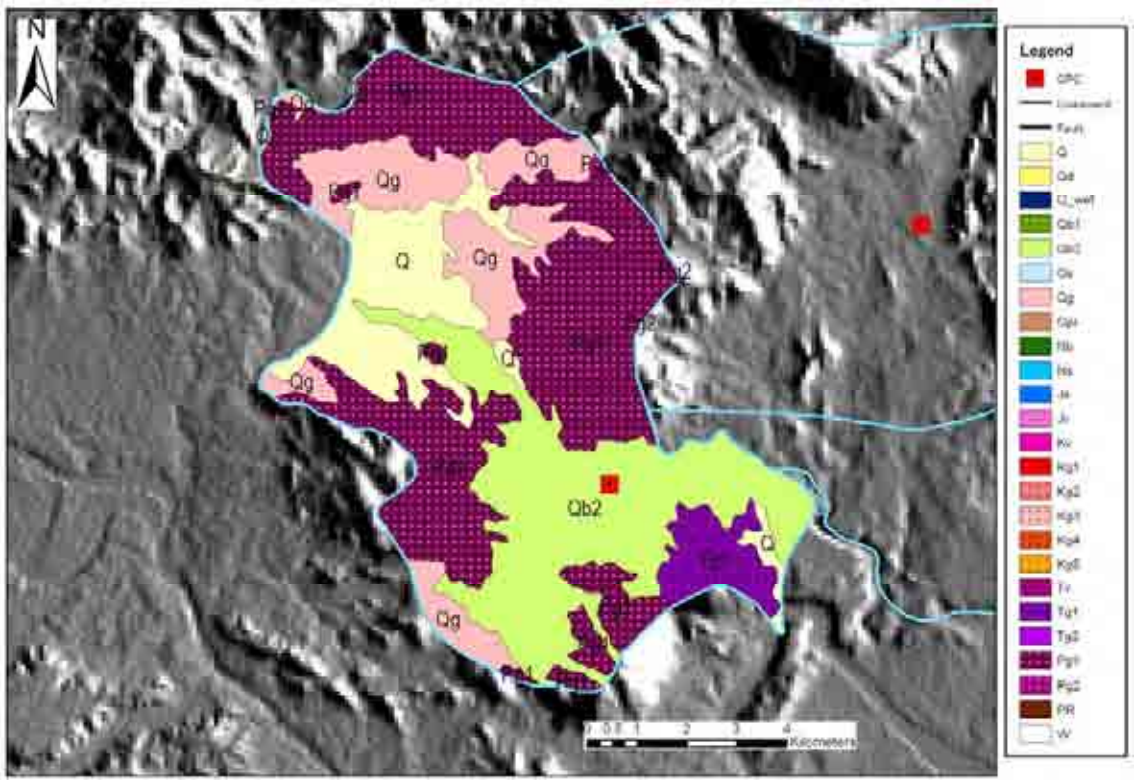
3. Condition of surface and groundwater: The water resources dry up in dry season.
3.1 Current state of surface water
Here is a trace of a stream but it is not confirmed because the season of the site survey was dry season.

3.2 Current state of groundwater
Thirty percent of the households have their own dug wells. Some wells have odor in the water.

Note:
The people have been using shallow groundwater in the weathered rock with dug wells. The commune has one spring with big yield and many springs with small yields. However those springs dry up in dry season. The groundwater aquifers will be weathered and porous zones near the boundary of basalt and massive plutonic rocks.

Table 7.1.6 Geomorphology and Hydro-geological Characteristics of Ea Cha Rang Commune (P-6)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:
The commune is mainly located on undulating table land with gentle slope surrounded by foothills and residual small mountains.

2. Geology:
The table land mainly consists of basalt and its weathered parts. The foothills and residual small mountains consist of massive plutonic rocks. Granitic rocks are distributed near the edges of the foothills.

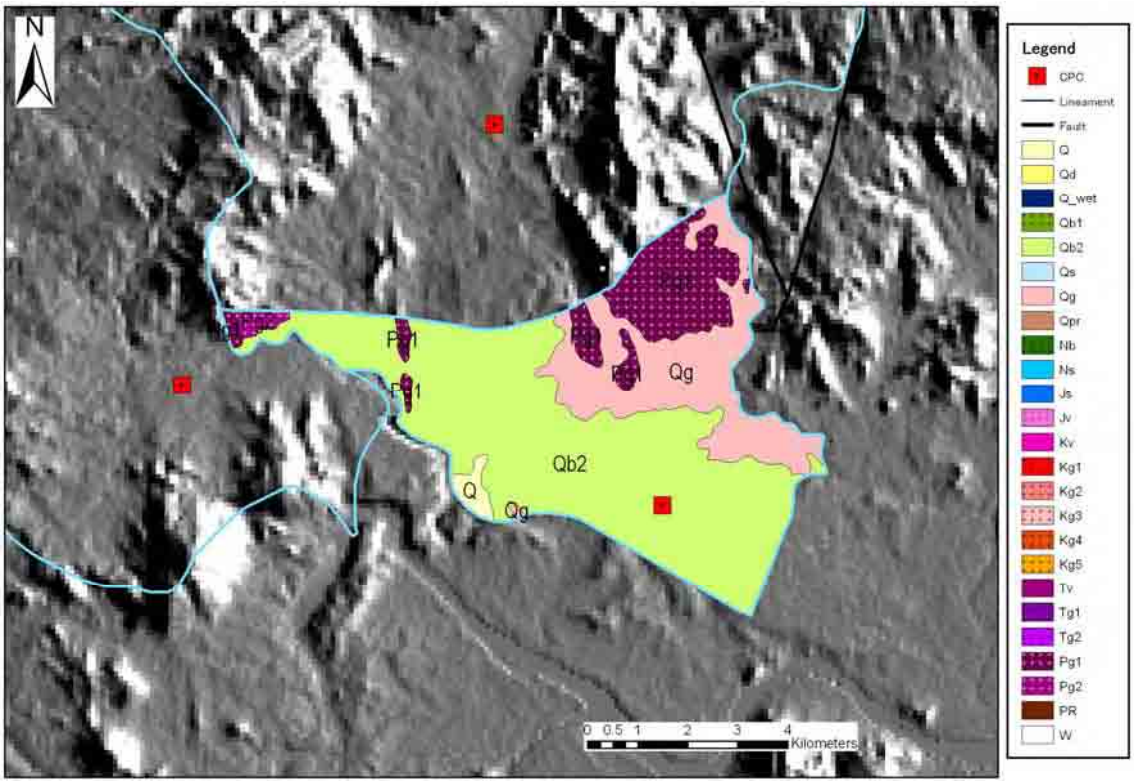
3. Condition of surface and groundwater: The water resources dry up in dry season.
3.1 Current state of surface water
Hear are no explicit surface waters.

3.2 Current state of groundwater
Eighty five percent of the households have their own dug wells. Some wells have fluoride, calcium and high pH in the water.

Note:
The people come to a spring to take drinking water with plastic bottles in dry season. The water quality of the spring is acidic. The groundwater aquifers will be weathered and porous zones near the boundary of basalt and massive plutonic rocks.

Table 7.1.7 Geomorphology and Hydro-geological Characteristics of Suoi Bac Commune (P-7)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:
The commune is mainly located on table land with gentle slope. Northeastern part of the commune consists of mountainous area.

2. Geology:
The table land mainly consists of basaltic rock and its weathered parts, and sedimentary deposit is partially distributed along a river. The mountainous area consists of plutonic rocks and granite.

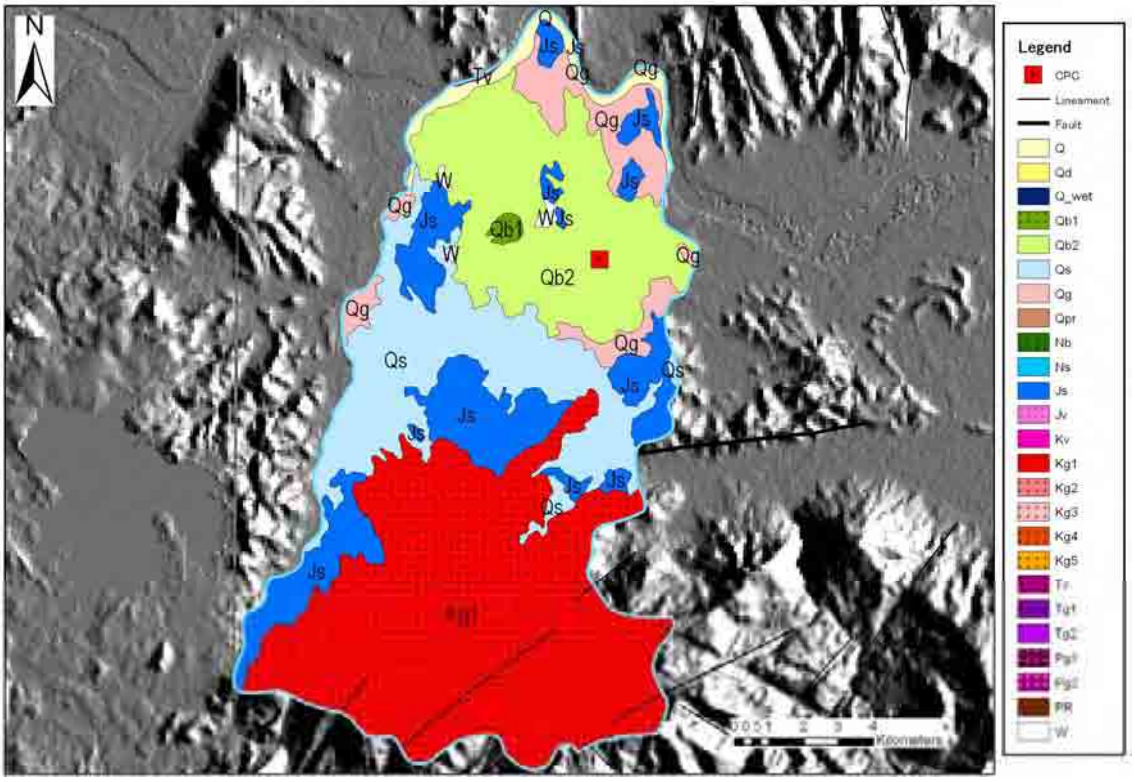
3. Condition of surface and groundwater: The water resources dry up from May to August.
3.1 Current state of surface water
Here are one pond for irrigation and "Bac" river.

3.2 Current state of groundwater
Twenty percent of the households have their own dug wells. Some wells have calcium in the water.

Note:
The groundwater aquifers will be weathered and porous zones near the boundary of basalt and massive plutonic rocks.

Table 7.1.8 Geomorphology and Hydro-geological Characteristics of Son Thanh Dong Commune (P-8)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:
One half of the commune (northern part) mainly consists of table land and some residual hills. The other half mainly consists of mountainous area.

2. Geology:
The table land mainly consists of volcanic rocks such as basalt. The residual hills mainly consist of sedimentary rocks. The mountainous area consists of plutonic rocks, and the sedimentary rocks are distributed at the edge of the mountains.

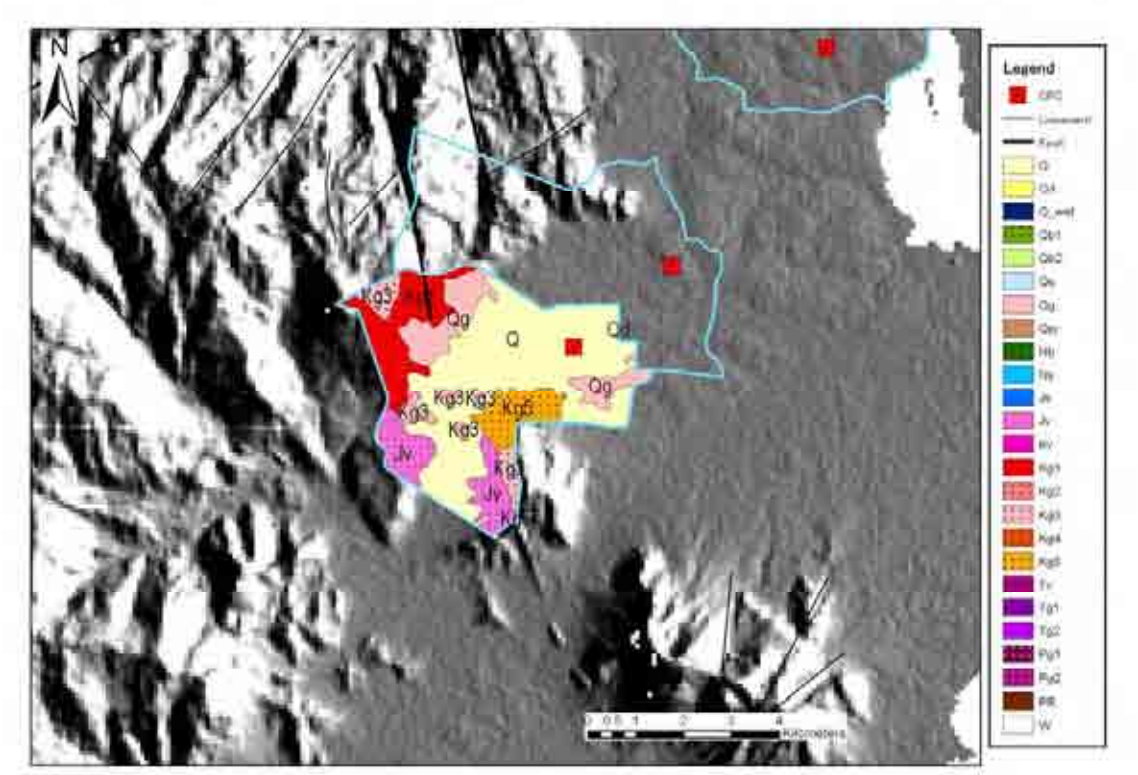
3. Condition of surface and groundwater: The water resources dry up in dry season.
3.1 Current state of surface water
Here are tow rivers and two ponds. Water of one river is utilized for hydraulic electric power generation. The other is not used. Waters of two ponds are used for irrigation.

3.2 Current state of groundwater
Fifty five percent of the households have their own dug wells. Spring water is also used for irrigation.

Note:
Water ways for irrigation is developed along the “Da Rang” river. The groundwater aquifers will be porous and weathered zones of basaltic rocks.

Table 7.1.9 Geomorphology and Hydro-geological Characteristics of Cam An Bac Commune (K-1)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The commune is located at the head of the narrow valley plain close to the foot of mountainous area. The commune is located at the highest part in its catchment's area. Hear are mountain foots at left side and residual mountain at right side.

2. Geology:

The plain is underlain by thin sedimentary deposit. The base rock is plutonic rocks. The mountains mainly consist of plutonic rock, and partially of sedimentary rocks at southern end of the commune.

3. Condition of surface and groundwater: The water resources dry up from April to September.

3.1 Current state of surface water

Here is no surface water during dry season.

3.2 Current state of groundwater

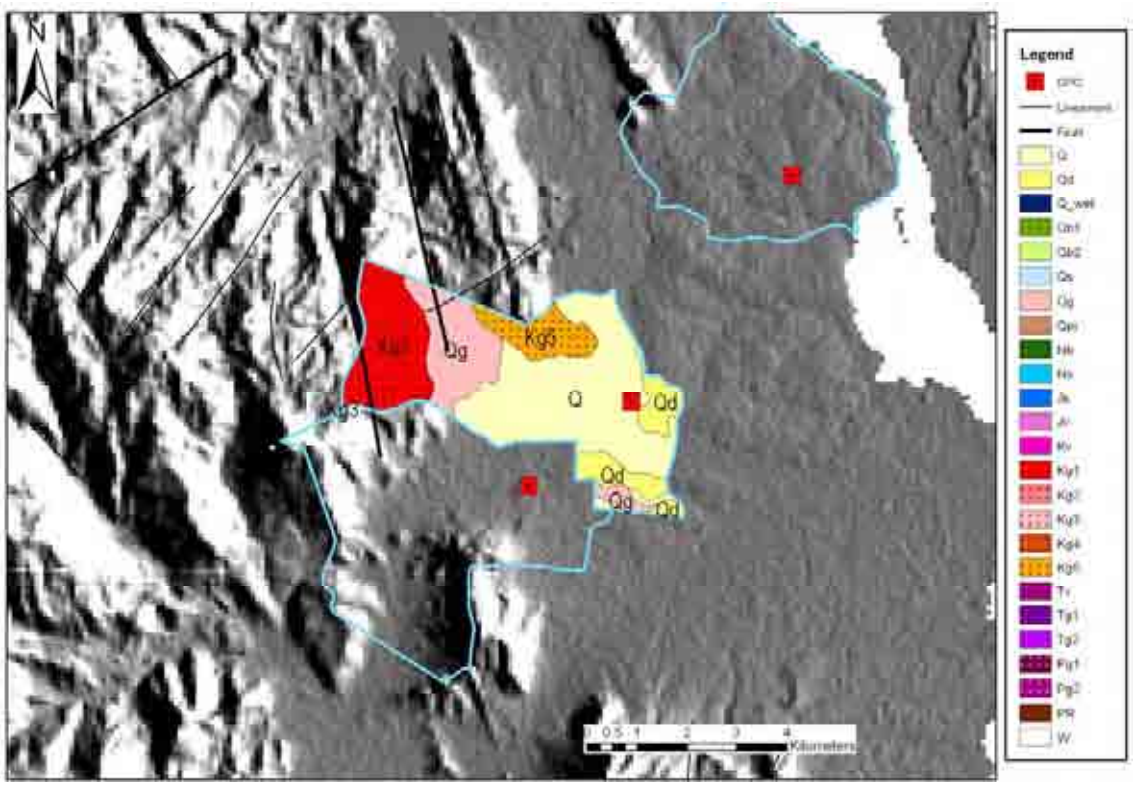
Eighty percent of the households have their own dug wells. Some wells have salinity and fluoride in the water.

Note:

The catchment area of the commune is very small. The spring water is used for only irrigation and plantation due to the high turbidity. (The spring comes out from talus deposits.) The groundwater aquifers will be weathered, fissure and fractured zones of plutonic rocks.

Table 7.1.10 Geomorphology and Hydro-geological Characteristics of Cam Hiep Nam Commune (K-2)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The commune is located on from the head of the narrow valley plain to adjacent wide flood plain. Hear are mountain foots at left side with north-south oriented lineaments. Relatively higher and well drained lowland is distributed at the south end of the commune.

2. Geology:

The plain is underlain by thin sedimentary deposit. The base rock is plutonic rocks. The mountains consist of plutonic rock.

3. Condition of surface and groundwater: The water resources dry up in dry season.

3.1 Current state of surface water

Here is a stream with name of "VinThai".

3.2 Current state of groundwater

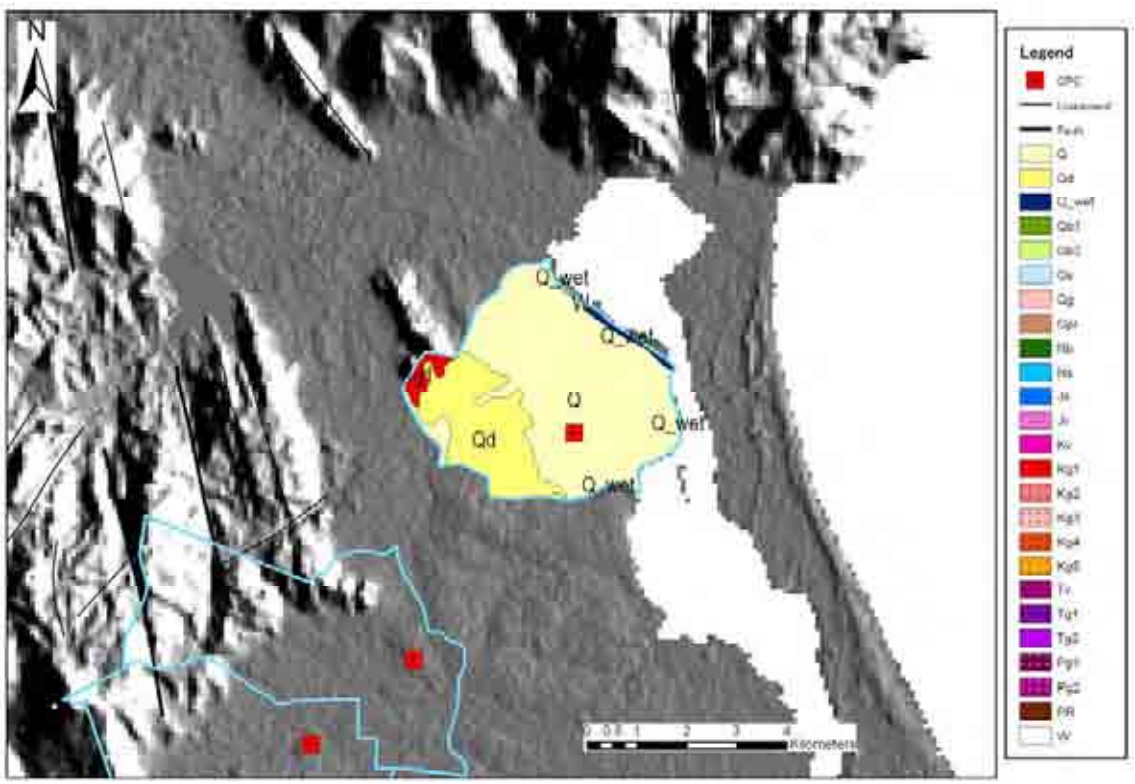
Sixty five percent of the households have their own dug wells. Some wells have fluoride and turbidity in the water.

Note:

Here are areas where the shallow groundwater has salty taste. The groundwater aquifers will be weathered, fissure and fractured zones of plutonic rocks. The weathered zone is thin.

Table 7.1.11 Geomorphology and Hydro-geological Characteristics of Cam Hai Tay Commune (K-3)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:
The commune is located on a flood plain in contact with a cove. The plain elevation near the sea is very low. Relatively higher and well drained lowland is distributed at the west part of the commune. There is a residual mountain northern outside of the commune.

2. Geology:
The surface of the flood plain consists of sandy sediment. The base rock is plutonic rock.

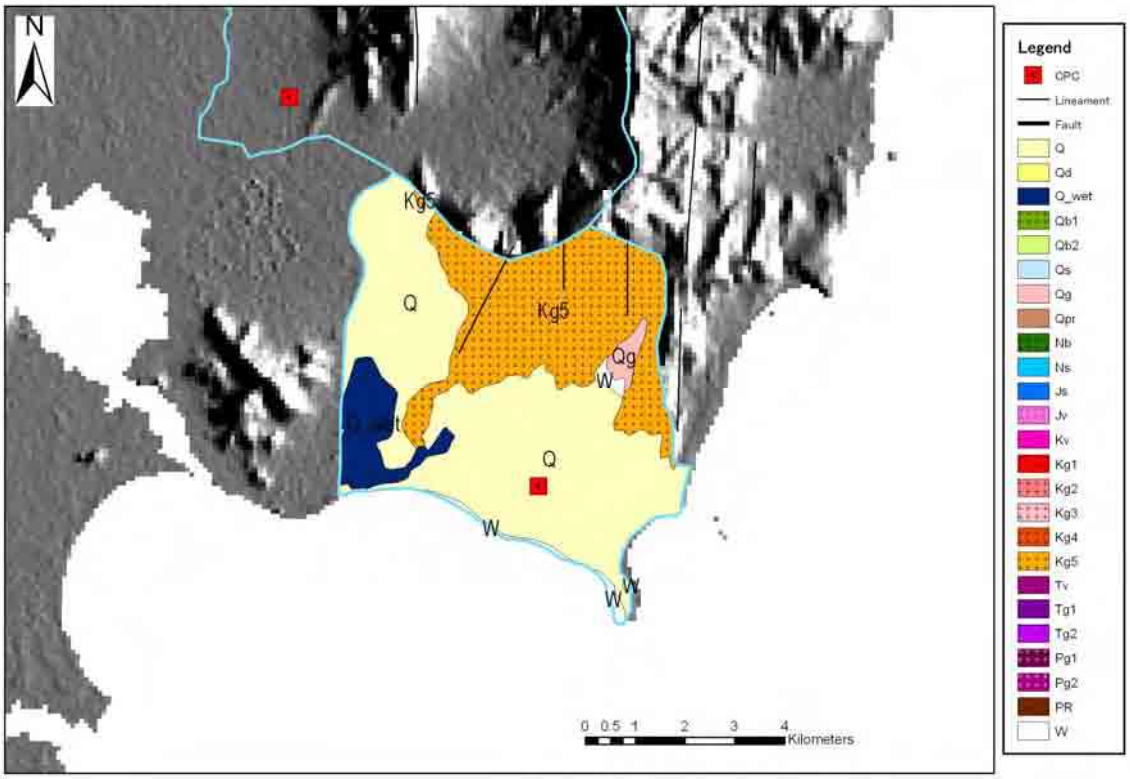
3. Condition of surface and groundwater: The water resources dry up in dry season.
3.1 Current state of surface water
Here is no surface water in the commune.

3.2 Current state of groundwater
Seventy percent of the households have their own dug wells. Some wells have salinity and fluoride in the water.

Note:
The depths of dug wells are roughly eight to 14 m. Dug wells near the sea produce groundwater with salinity. The groundwater aquifers will be weathered and fissure zones of plutonic rocks.

Table 7.1.12 Geomorphology and Hydro-geological Characteristics of Nhon Hai Commune (N-1)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The residential area of the commune is distributed on flood plain within 1.2 to 1.3 km long from coastal line. The north part of the commune is a mountainous area with two valleys

2. Geology:

The mountains consist of plutonic rocks, and sedimentary deposit is distributed at low land.

3. Condition of surface and groundwater

3.1 Current state of surface water

Here is a river, and a reservoir for irrigation is at the upstream of the river, just at the boundary of mountainous area and plain land.

3.2 Current state of groundwater

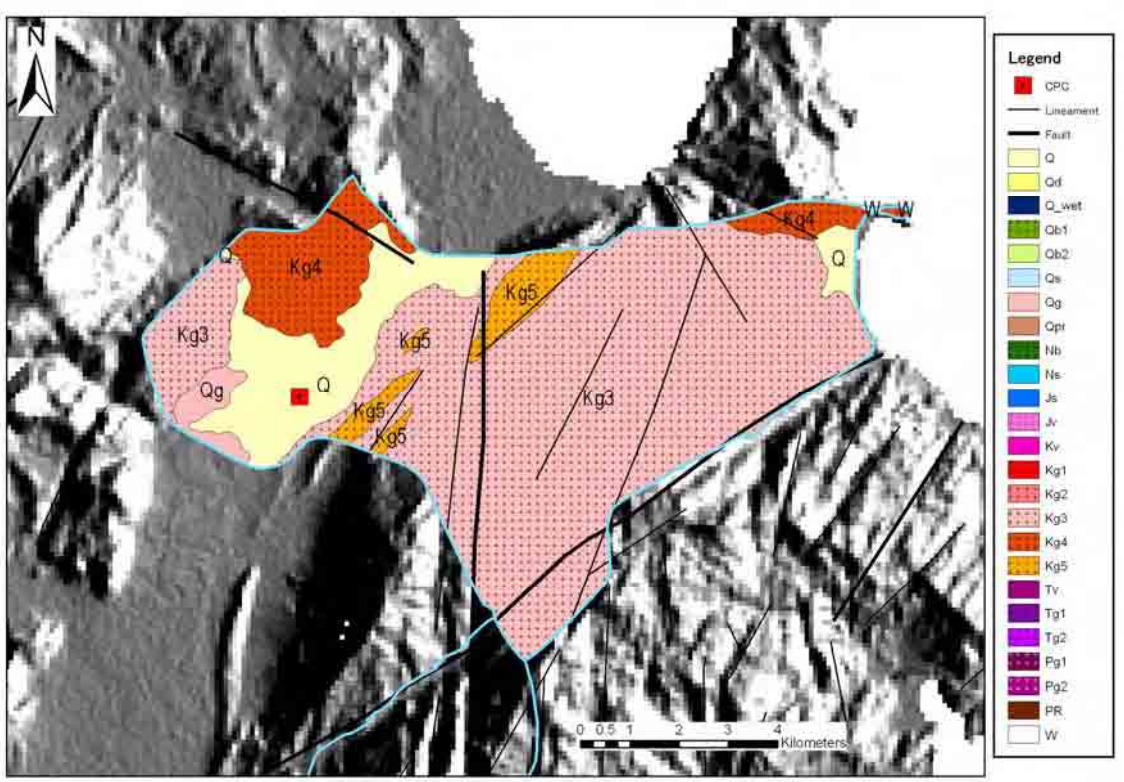
Almost all dug wells in the commune produce saline groundwater. The people don't use them for drinking water. However dug wells with more than 1.5 km far from the coast line can produce drinking water with no salinity.

Note:

The reservoir for irrigation was constructed in 1998 with financial resource of Ninh Thuan province. Most of the people purchase their drinking water from neighbor commune. The groundwater aquifers will be sedimentary deposit and weathered zone of plutonic rocks.

Table 7.1.13 Geomorphology and Hydro-geological Characteristics of Cong Hai Commune (N-2)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The greater area in the commune is in mountainous area. The people live in seven villages. Six of them are on flood plain along the highway No.1 or a river.

2. Geology:

The mountains consist of plutonic rock with lineaments. Sedimentary deposit is distributed in low land. Fault fracture zone may exist at left side of valley.

3. Condition of surface and groundwater

3.1 Current state of surface water

Tow rivers converge at the point near CPC. These river waters are muddy, but people use these river waters for drinking.

3.2 Current state of groundwater

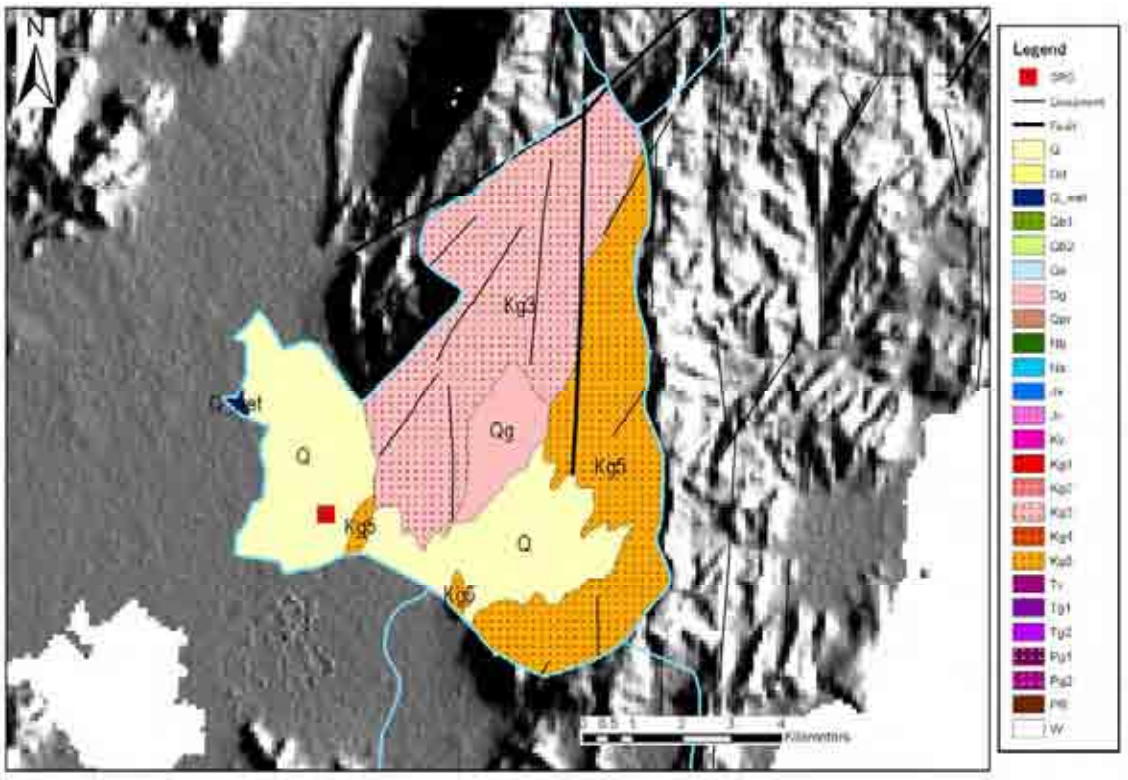
There are many dug wells in the commune. Dug wells distributed in two residential areas have saline groundwater with strong metal taste. Yields and water quality of groundwater drawn from dug wells vary significantly from place to place.

Note:

A big dam is three kilometers away from CPC to the northwest. The dam was constructed by MARD recently. The groundwater aquifer will be sedimentary deposit and weathered zone of plutonic rocks.

Table 7.1.14 Geomorphology and Hydro-geological Characteristics of Bac Son Commune (N-3)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:
The greater area in the commune is mountainous area. The people live in three residential areas. Two of them are on low land at the west side of the mountains, and the other one is in a valley at south side of the mountains.

2. Geology:
The mountains consist of plutonic rock. Sedimentary deposit is distributed in low land.

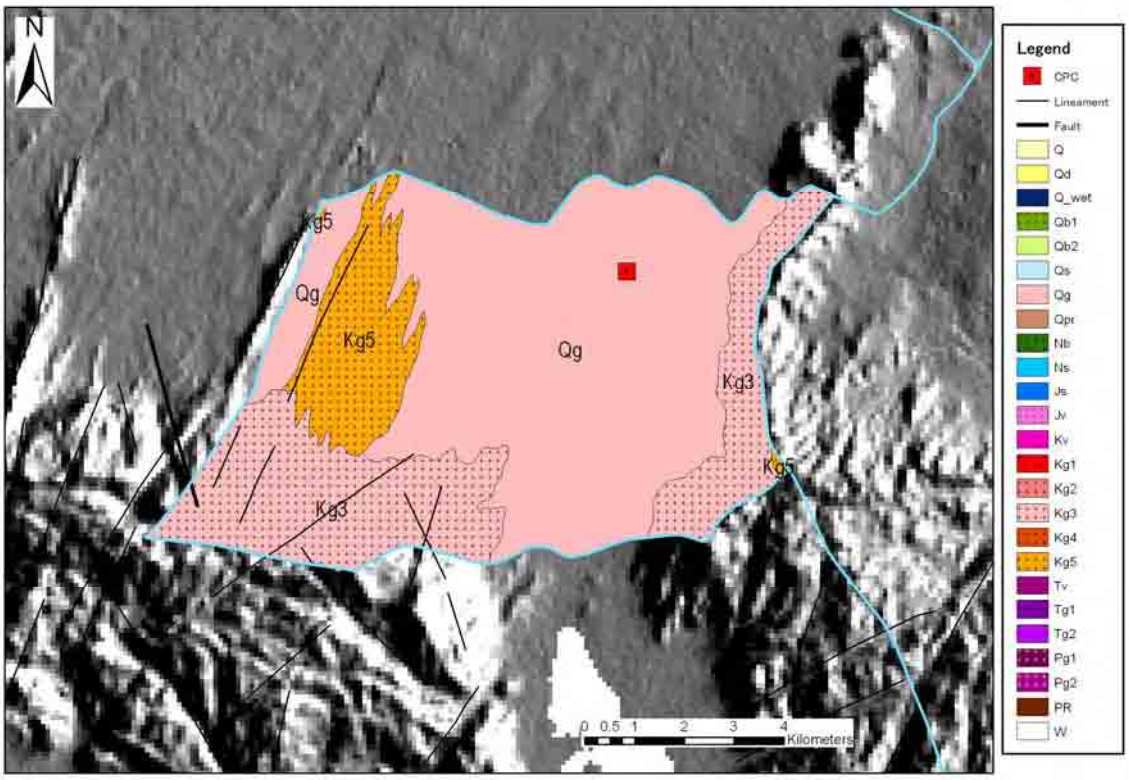
3. Condition of surface and groundwater
3.1 Current state of surface water
Here is a reservoir with one to two meters height of bank. The reservoir is tow kilometers away from "Xom Bnag" village to the north. The water supplies to the village and are used for drinking with about 2o public taps.

3.2 Current state of groundwater
Dug wells in a village at southwest end of the commune have saline groundwater. On the other hands, dug wells in a village at west side of the commune have no saline groundwater.

Note:
Two villages at west side of the commune have received house connection water supply from a reservoir belongs to neighbor commune. The reservoir is six kilometer away from the CPC to the north-northeast. However, they have to purchase drinking water during dry season because of shortage of the storage volume. The groundwater aquifer will be fissured zone of plutonic rocks.

Table 7.1.15 Geomorphology and Hydro-geological Characteristics of Phuoc Minh Commune (N-4)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

Greater part of the commune is on low land. Mountains are distributed at south end and east end of the commune. Almost all houses are along the Highway No.1 oriented NNE – SSE.

2. Geology:

The plain is underlain by thin sedimentary deposit. The base rock is plutonic rocks. The mountains consist of plutonic rock (granite).

3. Condition of surface and groundwater

3.1 Current state of surface water

Almost all surface waters converge in the commune and flow toward the south. A stream at the northwest end of the commune has water only during rainy season and the water flow into the north.

3.2 Current state of groundwater

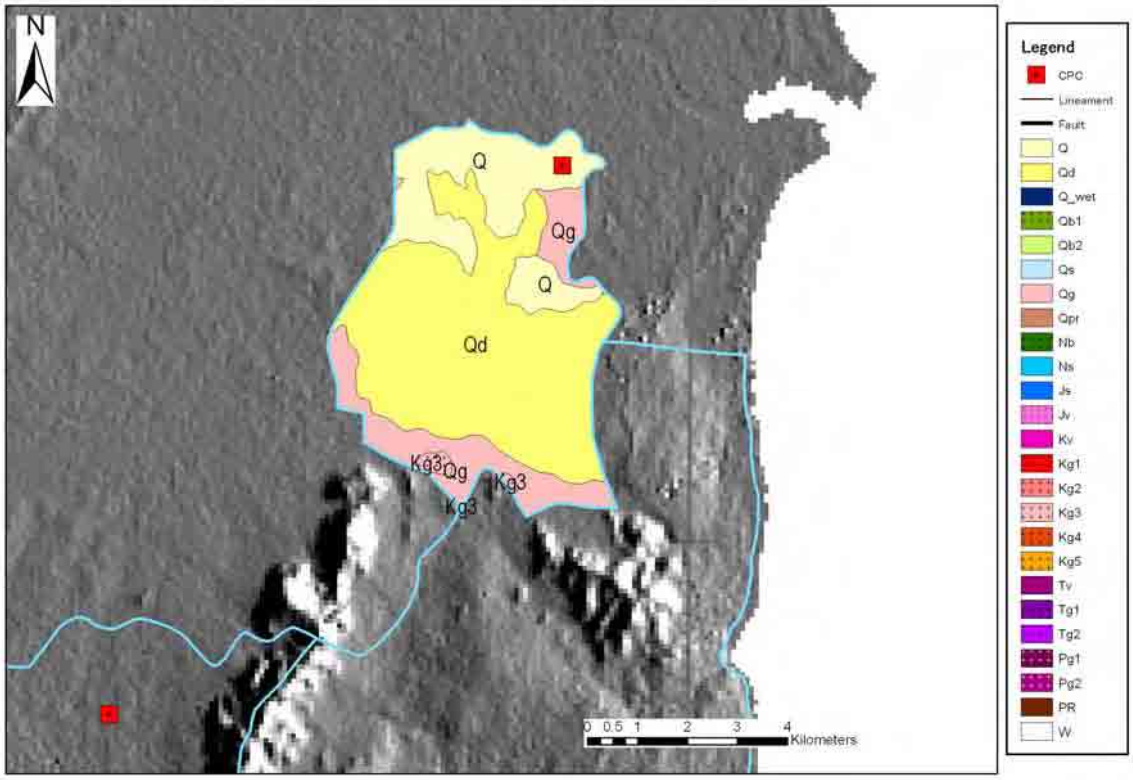
People usually use groundwater from dug wells for drinking. However they purchase drinking water from another commune during dry season because the yields of dug wells are short. Here is a dug well with good quality and large quantity. The well is five meters in depth, and has not dried up even in dry season. The owner sells the water as drinking water. The well is 3.2 km away from the CPC to the south.

Note:

The commune has a plan to reform their low land to salt field, and the plan is in progress. The groundwater aquifer will be fissure zone of plutonic rocks.

Table 7.1.16 Geomorphology and Hydro-geological Characteristics of Phuoc Dinh Commune (N-5)

Geological Map of the Commune



Hydro-geological characteristics of the commune

Geomorphology:
The commune is located on relatively higher lowland, and sand dune is widely distributed in the south part of the commune. People live on the foot of the sand dune or sand dune itself.

2. Geology:
Surface geology is sand dune deposit and alluvial deposit. The base rock is plutonic rock.

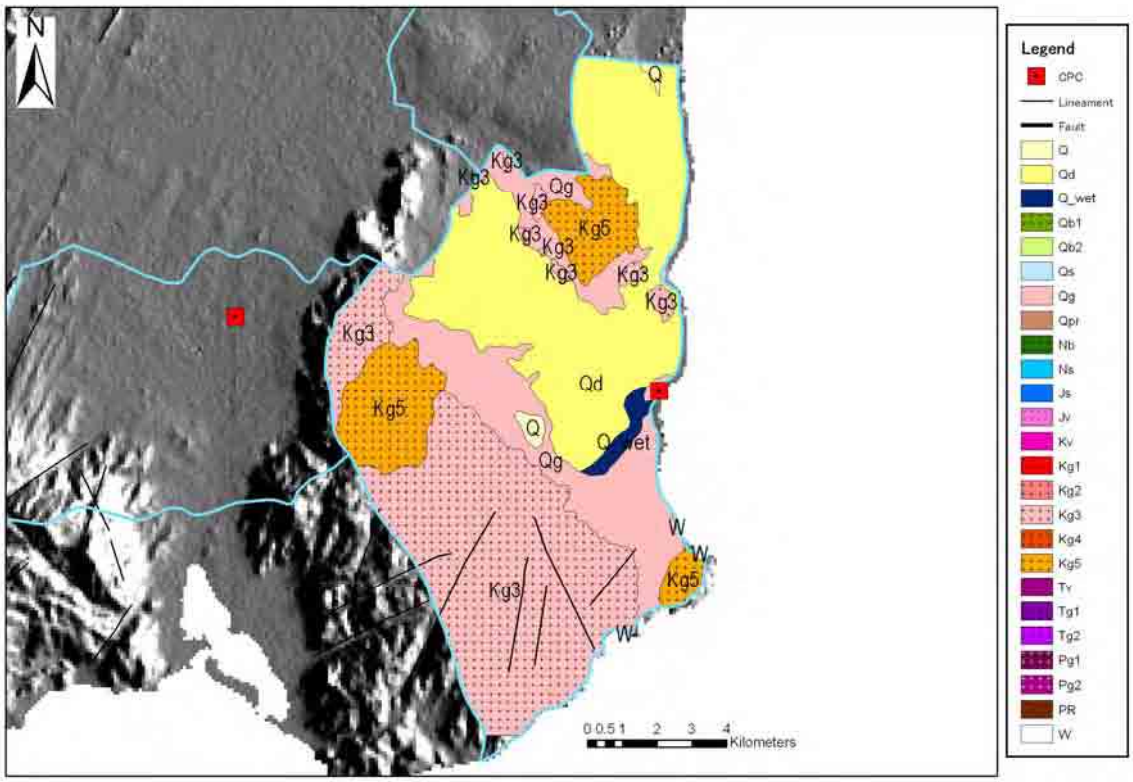
3. Condition of surface and groundwater
3.1 Current state of surface water
Here is a river named "Gia". The river flow into east. However, the river dries up during dry season.

3.2 Current state of groundwater
One spring water from sand dune is used for drinking water of one village through water supply system. Other spring waters converge to a stream and people of a village fetch their drinking water from the stream. Seventy percent of the dug wells in the commune have salty and metallic taste.

Note:
The groundwater aquifers will be sedimentary deposit and weathered zone of plutonic rocks.

Table 7.1.17 Geomorphology and Hydro-geological Characteristics of Phuoc Hai Commune (N-6)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

Mountains spread from south to west and north side near the center of the commune. The areas among these mountains are hills with gentle slope. Low land is distributed along a river at central part of the commune. The river flows through the commune from west to east between the mountainous areas. Main residential areas are distributed along the coast line. One village is on the low land at northwest of the commune.

2. Geology:

Mountains consist of plutonic rock (granite). Sand dune deposit overlies the plutonic rock at hill. Fault fracture zone with NW-SE direction may exists at south part of the mountains.

3. Condition of surface and groundwater

3.1 Current state of surface water

Here are three rivers. Those rivers dry up during dry season.

3.2 Current state of groundwater

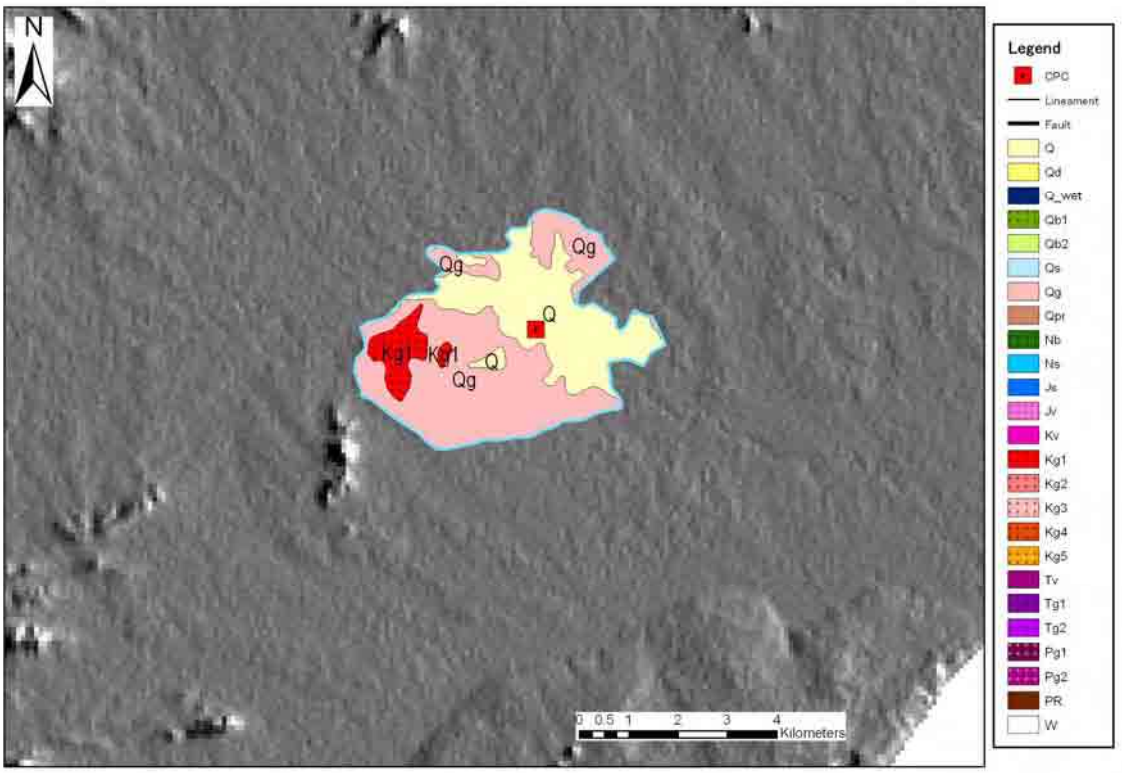
Here are one drinking water supply system which water source is a spring, and one distribution reservoir with five big dug wells. Almost all parts of groundwater of dug wells have salty taste.

Note:

It is said that DPC has a water supply plan and five deep wells were installed for the purpose. The groundwater aquifer will be fractured zone of plutonic rocks.

Table 7.1.18 Geomorphology and Hydro-geological Characteristics of Muong Man Commune (B-1)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The main geomorphology of the commune is low land. “Cai ” river flow through the center of the commune from south to east. A small mountain exists at the west end of the commune. The residential area is located along the river.

2. Geology:

Sedimentary deposit spreads over low land with the maximum thickness of 15 m. The base rocks are plutonic rock and/or sedimentary rock.

3. Condition of surface and groundwater

3.1 Current state of surface water

”Cai” river dries up during severe dry season.

3.2 Current state of groundwater

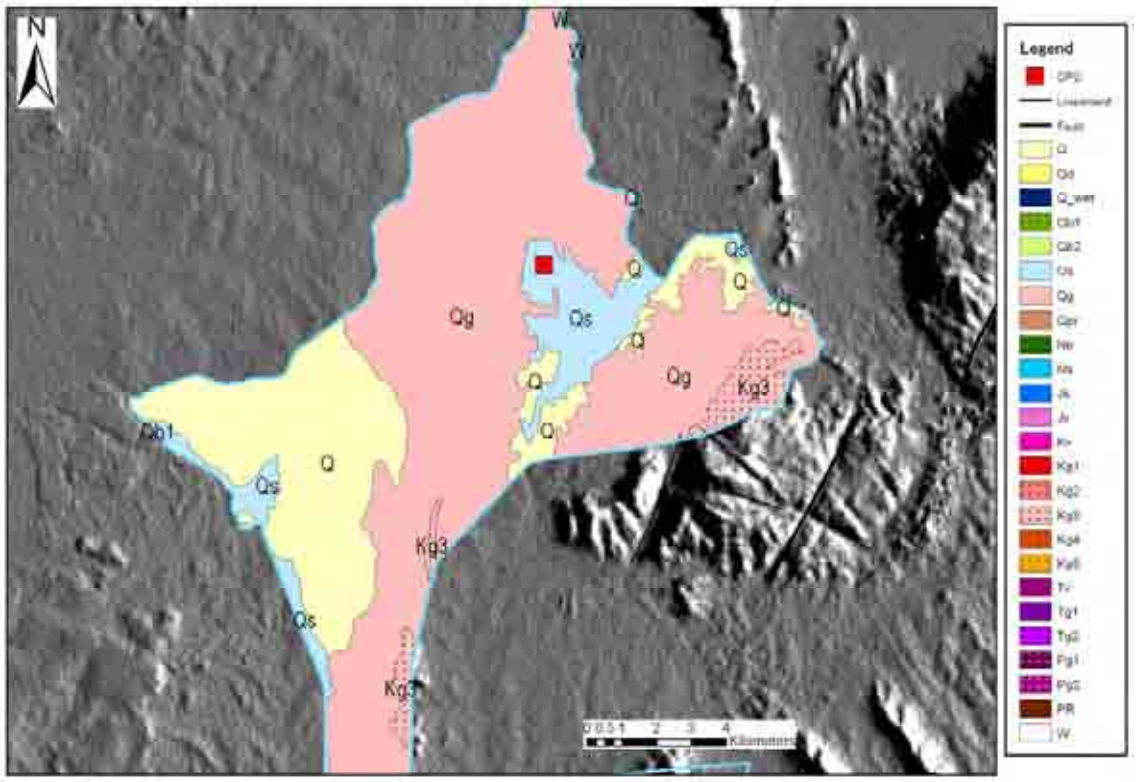
About 400 dug wells are distributed in 1,380 households of the commune. All dug wells produce groundwater with metallic taste and some with salty taste. Large parts of the wells dry up during dry season. In addition, about 300 drilled wells were installed for irrigation of dragon fruit; those don’t dry up even in dry season.

Note:

The groundwater aquifers will be sedimentary deposit, fissure zones of plutonic rocks and sedimentary rocks.

Table 7.1.19 Geomorphology and Hydro-geological Characteristics of Gia Huynh Commune (B-2)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

Main geomorphology is plateau with flat plain. Alluvial low land exists along a river that eroded the plateau. Small mountains exist at the south end of the commune and foot of mountains at east end.

2. Geology:

The base rock of the plateau and low land is plutonic rock. The mountains also consist of plutonic rock.

3. Condition of surface and groundwater

3.1 Current state of surface water

Rivers dry up during dry season. A lake is at the north outside of the commune, which also dries up in dry season.

3.2 Current state of groundwater

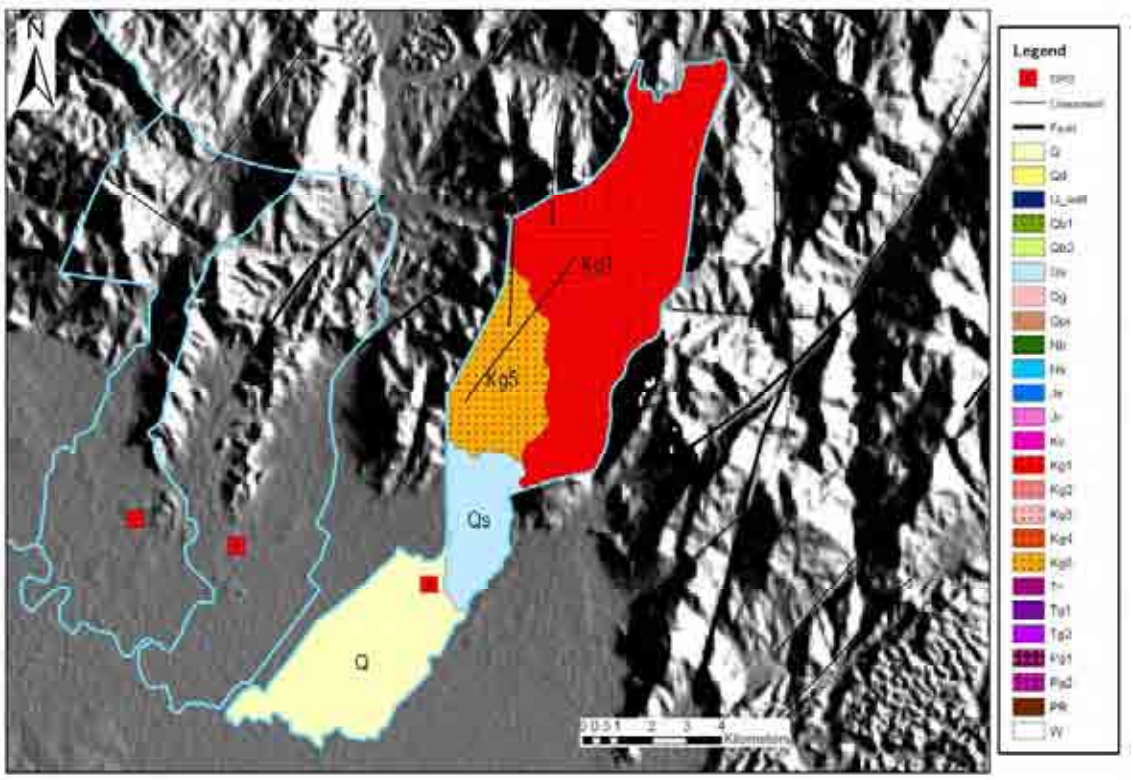
Eighty percent of dug wells dry up during dry season. The others decrease their productivities, and people share the scarce groundwater. Groundwater has thick metallic taste during dry season and thin during rainy season. Few drilled wells for individual use don't dry up during dry season.

Note:

One drilled well exists in the rail way station at southwestern end of the commune. The groundwater aquifers will be sedimentary deposit and fissured zone of plutonic rocks.

Table 7.1.20 Geomorphology and Hydro-geological Characteristics of Nghi Duc Commune (B-3)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The commune consists of mountains at northern half and plain land at southern half. The residential area is on the plain land.

2. Geology:

Mountains consist of plutonic rock. Lineaments with NE-SW direction are distributed in mountainous area. Sedimentary deposit covers base rocks at plain land, but the thickness may be thin.

3. Condition of surface and groundwater

3.1 Current state of surface water

Two rivers flow through the commune. One of them is water source for drinking water of the commune. One spring, which is two kilometers away from the CPC near a mountain stream, does not dry up even in dry season.

3.2 Current state of groundwater

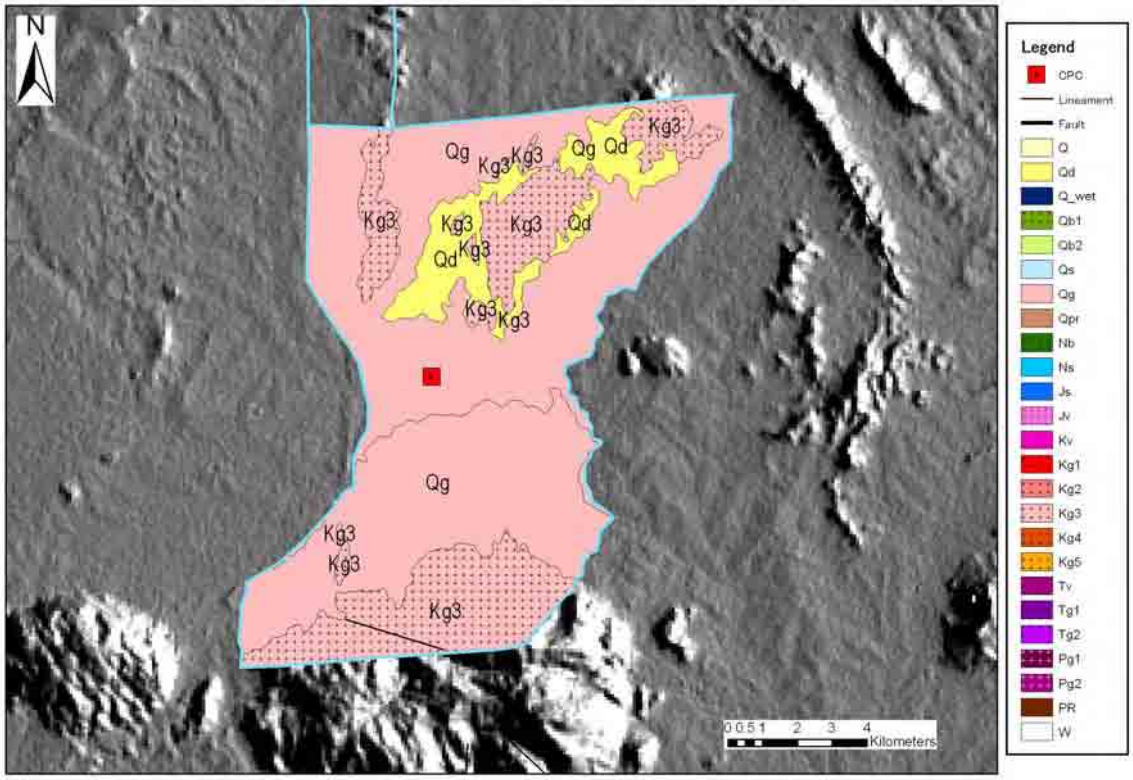
Almost all households have their own dug wells, and those wells don't dry up even in dry season but ten percent of the wells decrease their productivities. The groundwater becomes cloudy during rainy season. The average depth of the wells is about 10 meters (maximum 15 m). Here are two private drilled wells.

Note:

The groundwater aquifer will be fissure zone of plutonic rocks.

Table 7.1.21 Geomorphology and Hydro-geological Characteristics of Tan Duc Commune (B-4)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The commune mainly consists of plateau and mountainous area. The mountains are distributed at northern and southern parts. "Gieng" river flow through the commune from north to southwest. People live along the Highway No.1.

2. Geology:

The mountains consist of plutonic rock and the base rock of the plateau must be plutonic rock. The thickness of the surface later is estimated to be thin.

3. Condition of surface and groundwater

3.1 Current state of surface water

"Gieng" river does not dry up even in dry season.

3.2 Current state of groundwater

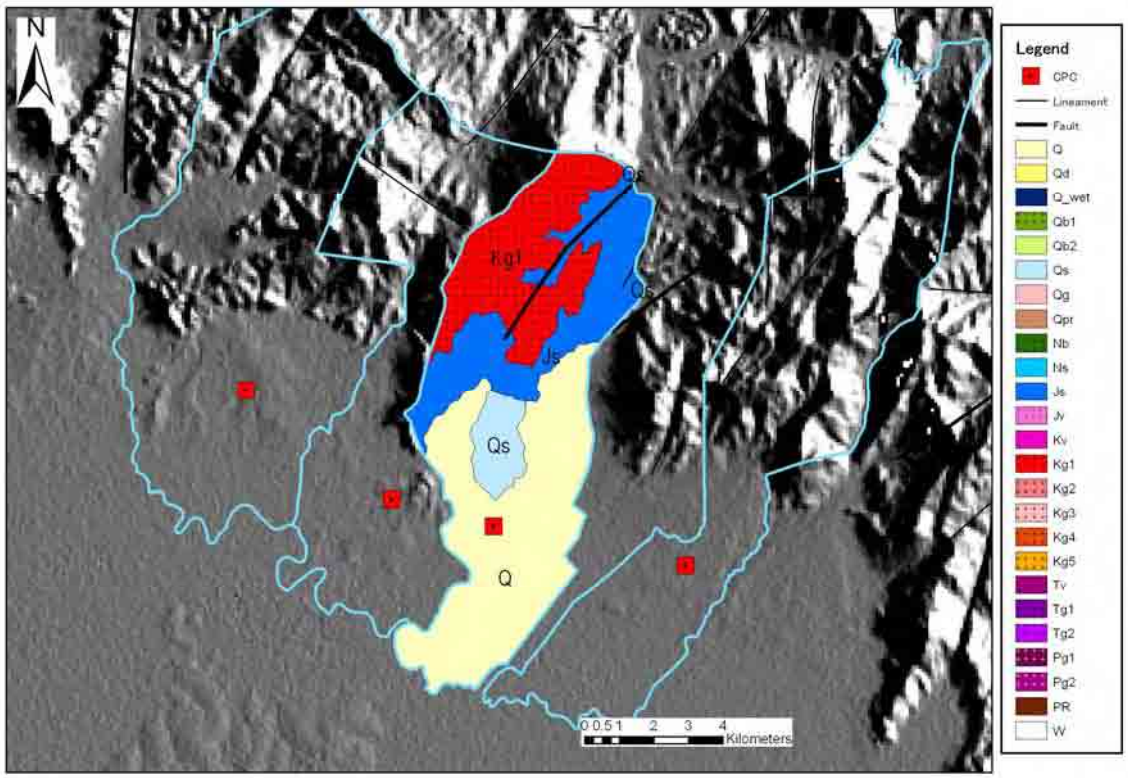
Almost all households have their own dug wells; however the water has metallic taste. Therefore, for drinking water, people use rainwater in rainy season, and purchase water from other commune or percolate the cloudy water in dug wells in rain season. Here are three to five drilled wells. A schoolmaster of elementary school said 27 percent of pupils, who use the water of a drilled well in the school, have yellow colored teeth.

Note:

The groundwater aquifer will be fissure zone of plutonic rocks.

Table 7.1.22 Geomorphology and Hydro-geological Characteristics of Me Pu Commune (B-5)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The commune consists of mountains at northern half and plain land at southern half. The residential area is on the plain land.

2. Geology:

Mountains consist of plutonic rock and sedimentary rocks. Lineaments with NE-SW direction are distributed in mountainous area. Sedimentary deposit covers base rocks at plain land.

3. Condition of surface and groundwater

3.1 Current state of surface water

Here are a few rivers which dry up in dry season.

3.2 Current state of groundwater

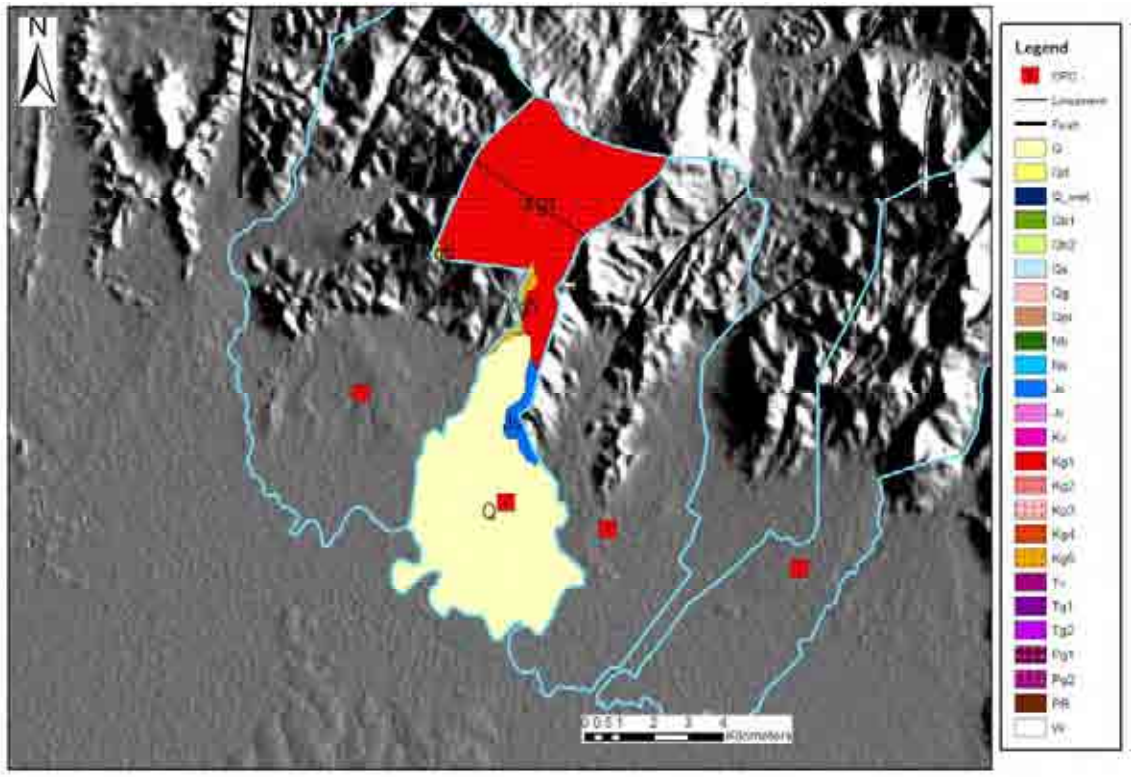
All households have their own dug wells. The wells distributed at north part of the CPC tend to dry up in dry season. The water of the wells without drying up have metallic taste.

Note:

The groundwater aquifer will be fissure zone of plutonic rocks.

Table 7.1.23 Geomorphology and Hydro-geological Characteristics of Sung Nhon Commune (B-6)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:
The commune consists of mountains at northern half and plain land at southern half. The residential area is on the plain land.

2. Geology:
Mountains consist of plutonic rock and sedimentary rocks. Lineaments with NE-SW direction are distributed in mountainous area. Sedimentary deposit covers base rocks at plain land.

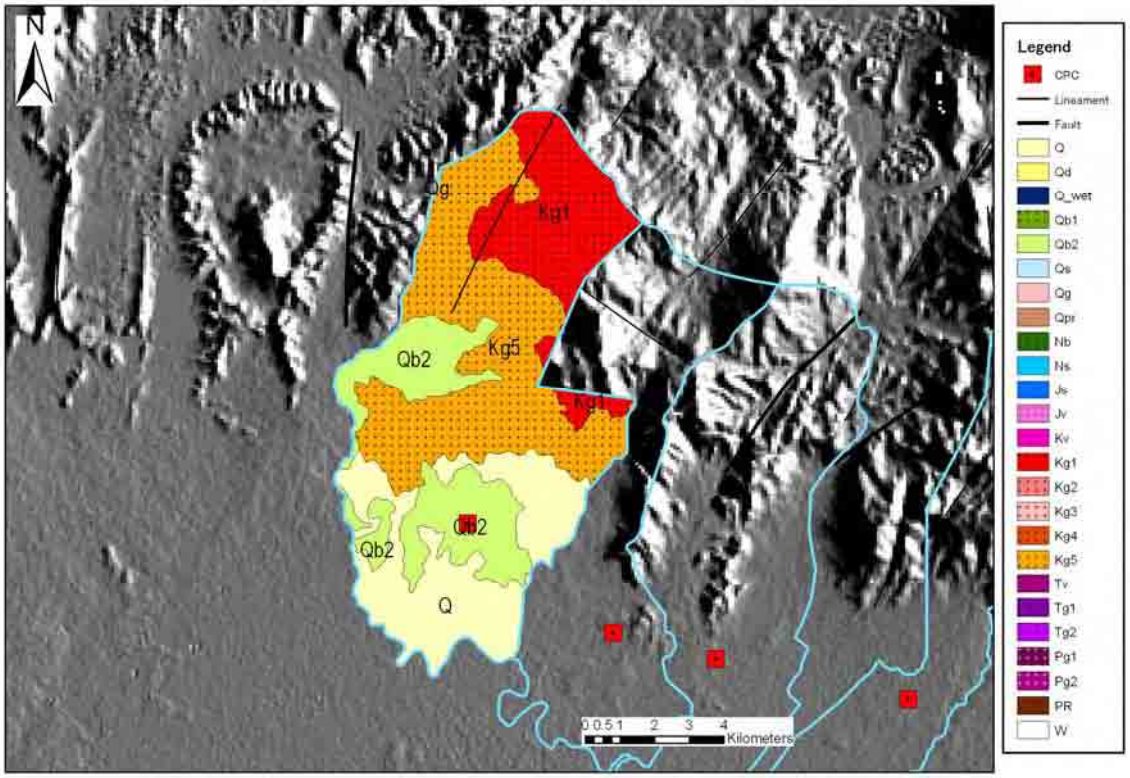
3. Condition of surface and groundwater
3.1 Current state of surface water
Here are a few rivers which dry up in dry season.

3.2 Current state of groundwater
All households have their own dug wells. In dry season, ten percent of them dry up, another ten percent are scarce in quantity, and the rest (80 %) have enough quantity. The waters of the wells without drying up have metallic taste.

Note:
One drilled well with 25 m in depth was constructed in the backyard of the CPC; however the well had no groundwater. The groundwater aquifer will be fissure zone of plutonic rocks.

Table 7.1.24 Geomorphology and Hydro-geological Characteristics of Da Kai Commune (B-7)

Geological Map of the Commune



Hydro-geological characteristics of the commune

1. Geomorphology:

The commune consists of mountains at northern half and plain land at southern half. The plain land has partly higher area. The residential area is on the plain land.

2. Geology:

The mountains consist of plutonic rock with lineaments that have NE-SW direction. Basalt is distributed in a plain land with relatively higher elevation. The thickness of the basalt is estimated to be thin. Sedimentary rock is recognized at river beds located at the west end of the commune.

3. Condition of surface and groundwater

3.1 Current state of surface water

Relatively big river flow down to the south at west end of the commune. The river sometimes dries up during severe dry season.

3.2 Current state of groundwater

Ninety percent of the households have their own dug wells. Some of them have metallic taste in dry season. Here are about ten drilled wells for individuals and three for mineral water factories.

Note:

The drilled wells of mineral water factories are located at the foot of the mountains; They are about two kilometers away from the CPC. The depths of the wells are from 35 m to 60 m, and the yields are about 33 l/min/well. The groundwater aquifer will be fissure zone of plutonic rocks.

7.2 Inventory Survey of Existing Wells

7.2.1 Preparation of Provisional Inventory on Existing Wells based on Existing Information

Based on the result of "Collection, Review and Analysis of Existing Related Data", a provisional inventory on existing wells about the targeted 24 communes was prepared. However the quality of existing well inventory which the Study Team could obtain was very poor: incorrect locations and few numbers in the Study Area, and the inventory was mainly limited to test boreholes information and did not include existing dug wells and drilling wells.

7.2.2 Determination of Data Format for the Complementary Field Inventory Survey

The data format for the field inventory survey on existing wells was created based on the provisional inventory on existing wells before mentioned. The data format was modified to suit for dug wells and drilling wells, because the main existing well structure were dug well but the information of drilling well were important for geophysical survey and the test drillings in the study. For inputting data and creation of the inventory, Microsoft Excel sheet was applied.

7.2.3 Complementary Field Inventory Survey of Existing Wells in the Target 24 Communes

As a result of review of existing information about wells in the target communes, it became apparent that there were no existing well inventories on dug wells. Therefore, The Study Team visited the target 24 communes, conducted interviews to representatives of the communes about existing wells, and identified the representative wells with highest water quality, water quantity richest and deepest depth in each target commune and so on. The coordinate of the existing wells were measured with GPS. The each survey result was shown in data sheets with tabular forms for identified dug wells and drilling wells. The result is summarized from Table 7.2.1 to Table 7.2.5.

7.2.4 Inventory Survey Result

The main findings of the survey are as follows:

a. Many of households in target communes have dug wells in their garden. Many dug wells dry up in dry season. They have custom to share groundwater of dug wells in water scarce season.
b. The main groundwater quality problem in the target communes are salinity and fluoride, especially all target communes in Ninh Thuan province have salinity problem.
c. The fluoride problem concentrates in Phu Yen and Khanh Hoa provinces.
d. An Tho and Ea Cha Rang communes have high pH problem. Groundwater with high pH may cause fluoride elution from rocks.

Table 7.2.1 Number of Surface Water Resources in the Target Communes

Province	No.	Commune	Number of Surface Water Resources				
			Rivers	Streams	Reservoirs/ (Ponds)	Springs	Swamps
Phu Yen	P-1	Xuan Phuoc	1		1	2	0
	P-2	An Dinh	1		0	1	0
	P-3	An Tho	0	many	0	1	0
	P-4	An My	0		0	some	1
	P-5	Son Phuoc	0		0	1	0
	P-6	Ea Cha Rang	0		0	2	0
	P-7	Suoi Bac	1		(1)	1	0
	P-8	Son Thanh Dong	2		2	1	0
Khanh Hoa	K-1	Cam An Bac	0		0	1	0
	K-2	Cam Hiep Nam	1		0	1	0
	K-3	Cam Hai Tay	0		0	0	0
Ninh Thuan	N-1	Nhon Hai	0	1	1	0	0
	N-2	Cong Hai	2		0	0	0
	N-3	Bac Son	1		0	0	0
	N-4	Phuoc Minh	1		(3)	0	0
	N-5	Phuoc Hai	0	1	0	2	0
	N-6	Phuoc Dinh	1	2	0	1	1
Binh Thuan	B-1	Muong Man	0	2	0	0	0
	B-2	Gia Huynh	0	3	0	0	1
	B-3	Nghi Duc	0	3	0	1	0
	B-4	Tan Duc	1	0	0	0	0
	B-5	Me Pu	0	1	0	4	0
	B-6	Sung Nhon	0	4	2	6	0
	B-7	Da Kai	0	2	0	0	0

Table 7.2.2 Perennial Surface Water Resources in the Target Communes

Province	No.	Commune	Perennial Water Resources		
			Resources		Note
Phu Yen	P-1	Xuan Phuoc	No		The water resources dry up in dry season.
	P-2	An Dinh	Yes	one river	
	P-3	An Tho	No		The water resources dry up from June to July.
	P-4	An My	No		The water resources dry up from June to August.
	P-5	Son Phuoc	No		The water resources dry up in dry season.
	P-6	Ea Cha Rang	No		The water resources dry up in dry season.
	P-7	Suoi Bac	No		The water resources dry up from May to August.
	P-8	Son Thanh Dong	No		The water resources dry up in dry season.
Khanh Hoa	K-1	Cam An Bac	No		The water resources dry up from April to September.
	K-2	Cam Hiep Nam	No		The water resources dry up in dry season.
	K-3	Cam Hai Tay	No		The water resources dry up in dry season.
Ninh Thuan	N-1	Nhon Hai	No		The water resources dry up in dry season.
	N-2	Cong Hai	Yes	2 rivers	
	N-3	Bac Son	Yes	one river	
	N-4	Phuoc Minh	No		The water resources dry up in dry season.
	N-5	Phuoc Hai		2 springs	
	N-6	Phuoc Dinh		one spring	
Binh Thuan	B-1	Muong Man	No		The water resources dry up in dry season.
	B-2	Gia Huynh	No		The water resources dry up in dry season.
	B-3	Nghi Duc	Yes	one spring	
	B-4	Tan Duc	Yes	one river	
	B-5	Me Pu	No		The water resources dry up in dry season.
	B-6	Sung Nhon	No		The water resources dry up in dry season.
	B-7	Da Kai	No		The water resources dry up in dry season.

Table 7.2.3 Resources for Drinking Water in the Target Communes

Province	No.	Commune	Resources for Drinking Water					
			Groundwater		Rain water use	River	Spring	Buying water
			Dug Well	Drilled Well				
Phu Yen	P-1	Xuan Phuoc	Main	few				
	P-2	An Dinh	Main		None			Yes
	P-3	An Tho	Main					
	P-4	An My	Main	few				
	P-5	Son Phuoc	Main	few	None			
	P-6	Ea Cha Rang	Main	few	Yes			
	P-7	Suoi Bac	Main		None			
	P-8	Son Thanh Dong	Main		None			Yes
Khanh Hoa	K-1	Cam An Bac	Main	few				Yes
	K-2	Cam Hiep Nam	Main	few	Yes			
	K-3	Cam Hai Tay	Main	few	Yes			
Ninh Thuan	N-1	Nhon Hai	few					Yes
	N-2	Cong Hai	Yes			Yes		
	N-3	Bac Son	few			Yes		Yes
	N-4	Phuoc Minh	Yes					Yes
	N-5	Phuoc Hai	Yes				Yes	
	N-6	Phuoc Dinh	Main				Yes	
Binh Thuan	B-1	Muong Man	Yes					Yes
	B-2	Gia Huynh	Main	few				
	B-3	Nghi Duc	Main	few				
	B-4	Tan Duc	Main	few	Yes			Yes
	B-5	Me Pu	Main					
	B-6	Sung Nhon	Main					
	B-7	Da Kai	Main	few				

Table 7.2.4 Current Situation of Existing Wells in the Target Communes

Province	No.	Commune	Information on Existing Wells			
			Number of Dug wells	Number of Drilling wells	Households	Own Ratio (%)
Phu Yen	P-1	Xuan Phuoc	1,500 - 1,600	few	2,051	75
	P-2	An Dinh	700		1,400	50
	P-3	An Tho	150		700	20
	P-4	An My	2,500	few	2,816	90
	P-5	Son Phuoc	250	few	769	30
	P-6	Ea Cha Rang	50	few	589	85
	P-7	Suoi Bac	296		1,393	20
	P-8	Son Thanh Dong	500 - 600		more than 1,000	55
Khanh Hoa	K-1	Cam An Bac	1,000	few	1,216	80
	K-2	Cam Hiep Nam	650	few	1,003	65
	K-3	Cam Hai Tay	1,400	few	2,051	70
Ninh Thuan	N-1	Nhon Hai	Almost all		2,573	----
	N-2	Cong Hai	unknown		1,473	----
	N-3	Bac Son	unknown	1	1,141	----
	N-4	Phuoc Minh	Almost all		900	----
	N-5	Phuoc Hai	1,500		2,302	65
	N-6	Phuoc Dinh	120	5	1,650	5
Binh Thuan	B-1	Muong Man	400	300		
	B-2	Gia Huynh	(irrigation)	1,380	30	
	B-3	Nghi Duc	Almost all	3	1,214	----
	B-4	Tan Duc	Almost all	2	2,050	----
	B-5	Me Pu	Almost all	3~5	1,600	----
	B-6	Sung Nhon	2,600		2,600	100
	B-7	Da Kai	1,692		1,692	100

Table 7.2.5 Water Quality Issues of Existing Wells in the Target Communes

Province	No.	Commune	Water Quality of Existing Wells						
			Sali-nity	F	Ca	High pH	Metallic taste	Tur-bidity	Odor
Phu Yen	P-1	Xuan Phuoc		●	●		●		
	P-2	An Dinh		●			●		
	P-3	An Tho	●	●		●	●		
	P-4	An My	●	●					
	P-5	Son Phuoc							●
	P-6	Ea Cha Rang		●	●	●			
	P-7	Suoi Bac			●				
	P-8	Son Thanh Dong							
Khanh Hoa	K-1	Cam An Bac	●	●					
	K-2	Cam Hiep Nam		●				●	
	K-3	Cam Hai Tay	●	●					
Ninh Thuan	N-1	Nhon Hai	●						
	N-2	Cong Hai	●				●		
	N-3	Bac Son	●						
	N-4	Phuoc Minh	●						
	N-5	Phuoc Hai	●				●		
	N-6	Phuoc Dinh	●						
Binh Thuan	B-1	Muong Man	●				●		
	B-2	Gia Huynh					●		
	B-3	Nghi Duc						●	
	B-4	Tan Duc		●			●		
	B-5	Me Pu					●		
	B-6	Sung Nhon					●		
	B-7	Da Kai					●		

Note: "●" expresses that the groundwater in existing wells of each commune has the problems captured above.

7.3 Groundwater Level Monitoring

Groundwater level of the test boreholes constructed in the study has been monitored in order to evaluate potentiality of groundwater development for the rural water supply in 24 communes.

(1) Location of Test Borehole

Test boreholes constructed during the phase 1 of the study are located as shown in Figure 7.3.1.

(2) Monitoring Period

The monitoring was carried out for more than half a year: March to September 2008.

(3) Frequency and Timing of Monitoring

Since groundwater monitoring is conducted daily in the rainy season and every 5 days in the dry season by MONRE (Ministry of Natural Resources & Environment), the monitoring in this study was compliance with it. Division of seasons is supposed as follows. Monitoring was done simultaneously at 7 am.

Table 7.3.1 Estimated Division of Season

Target Province	Rainy Season	Dry Season
Phu Yen	September to December (4 month)	January to August （8 month）
Khanh Hoa	September to December (4 month）	January to August （8 month）
Ninh Thuan	September to December (4 month）	January to August （8 month）
Binh Thuan	May to October (6 month)	November to April (6 month)

(4) Monitoring Equipment

Twenty-four “Portable Water Level Gauges” procured by JICA were used for the monitoring.

(5) Data Storage

Monitored data was input as an excel data file and used for drawing fluctuation curve of groundwater level as shown in Figure 7.3.2 to Figure 7.3.5 to evaluate potentiality of groundwater development and so on.

(6) Groundwater Fluctuation

Groundwater fluctuation of each test borehole is shown in Figure 7.3.2 to Figure 7.3.5 and its characteristic is described as follows by province.

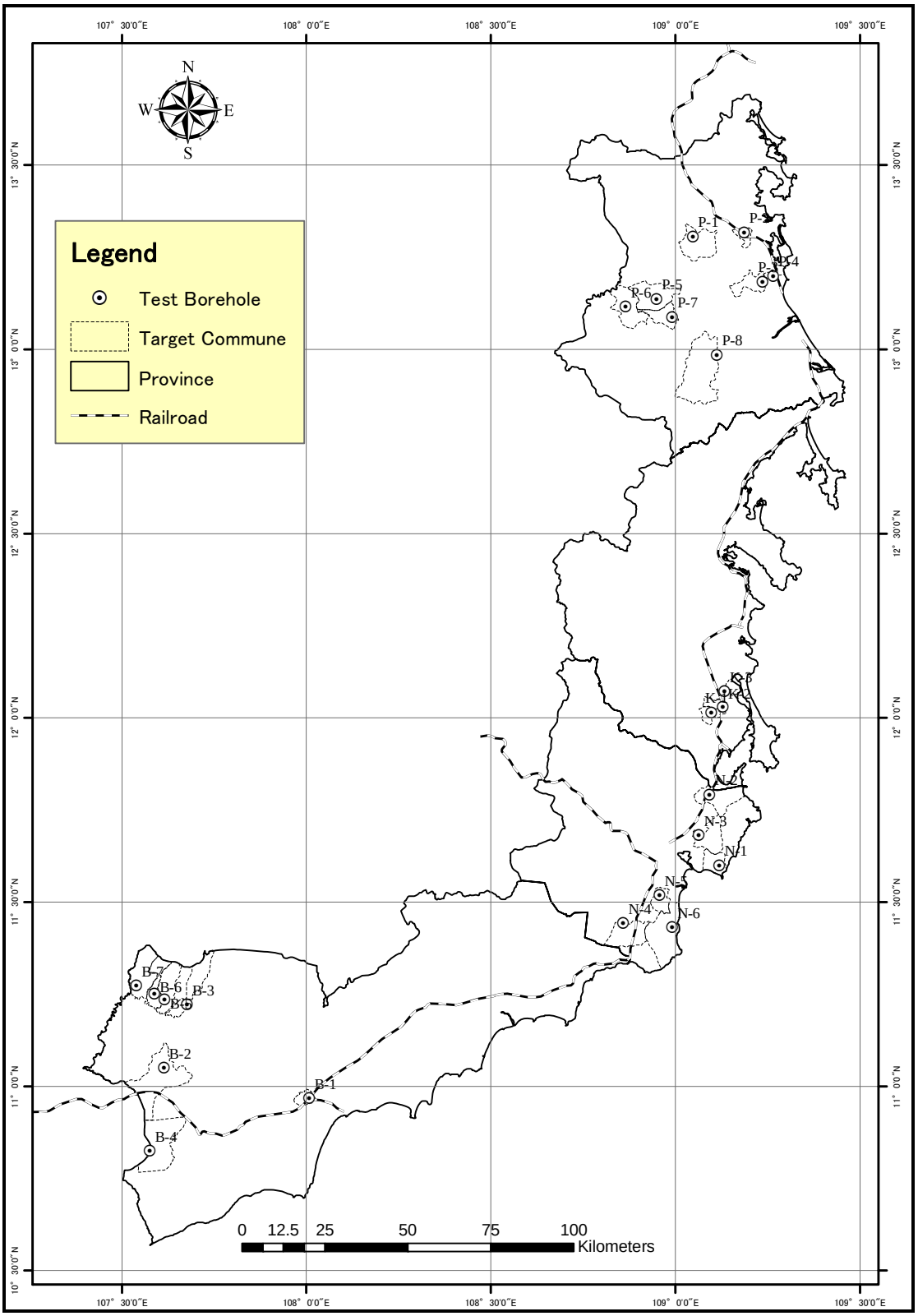


Figure 7.3.1 Location of Test Boreholes in the Study Area

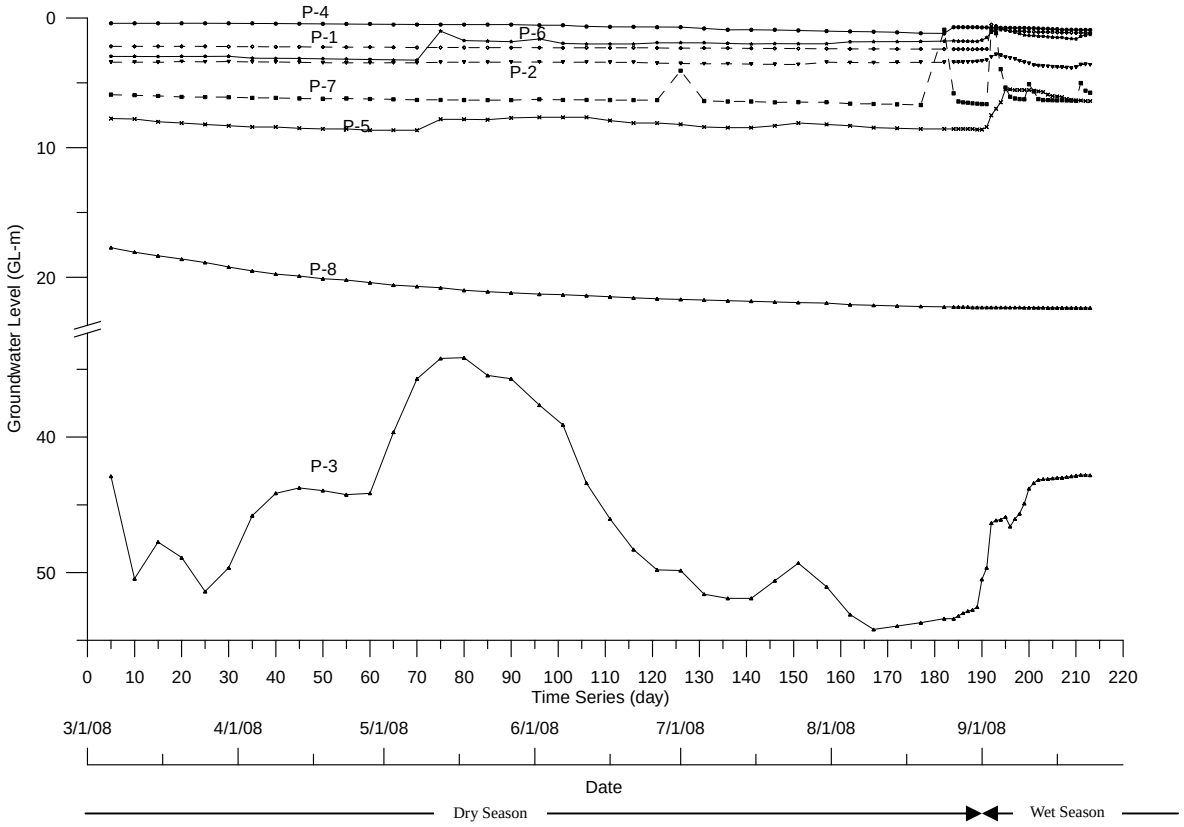


Figure 7.3.2 Fluctuation of Groundwater Level at Test Boreholes in Phu Yen Province

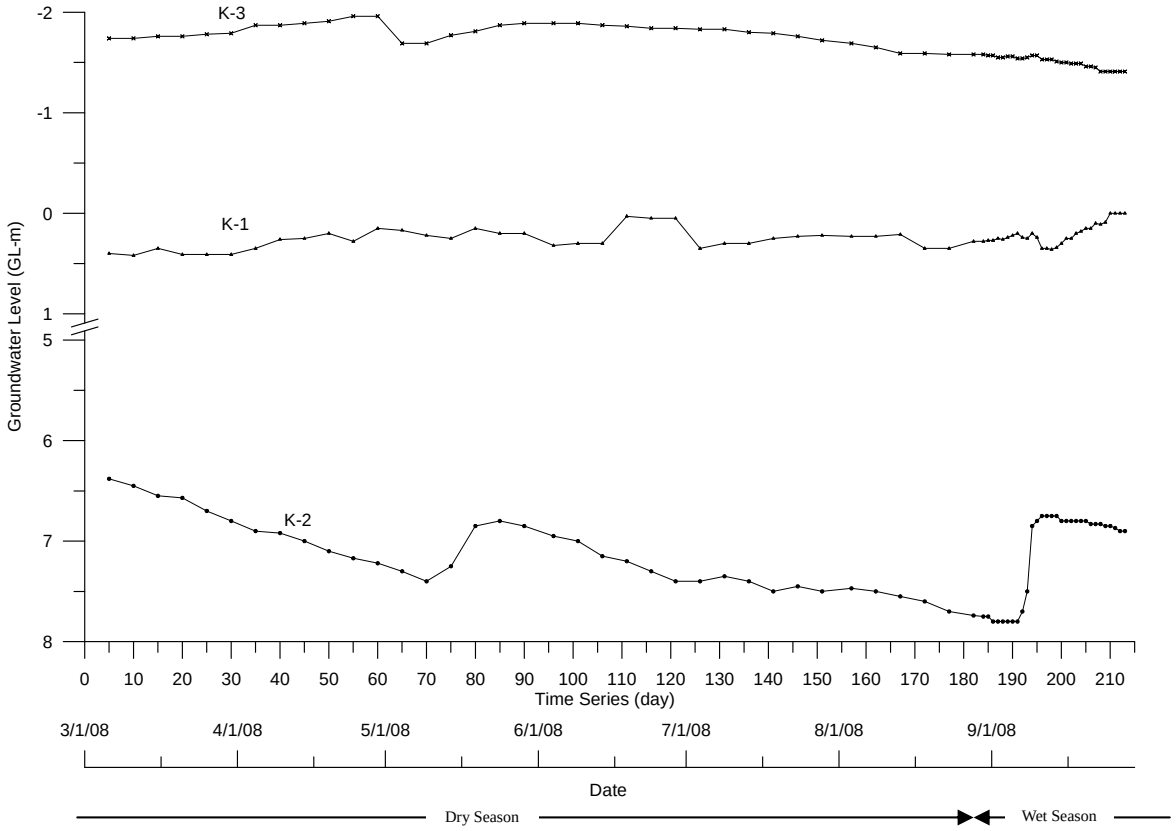


Figure 7.3.3 Fluctuation of Groundwater Level at Test Boreholes in Khanh Hoa Province

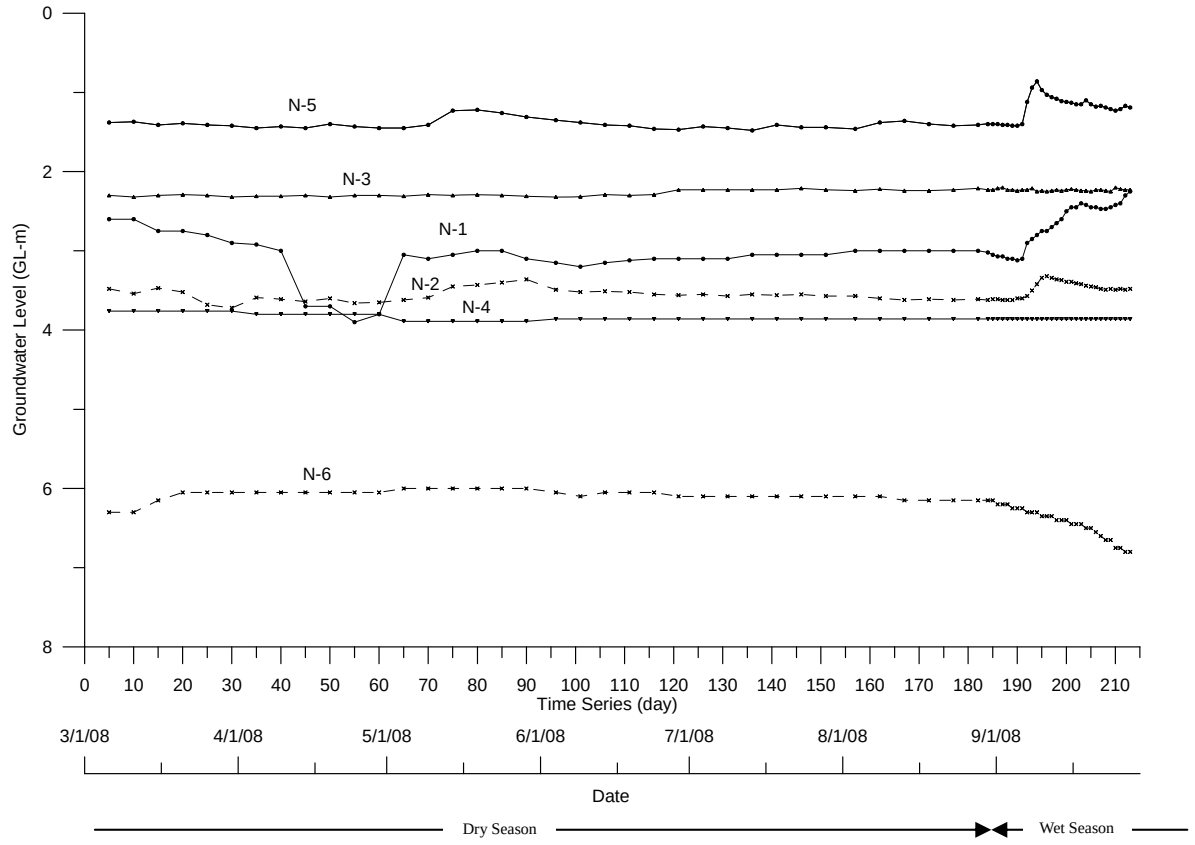


Figure 7.3.4 Fluctuation of Groundwater Level at Test Boreholes in Ninh Thuan Province

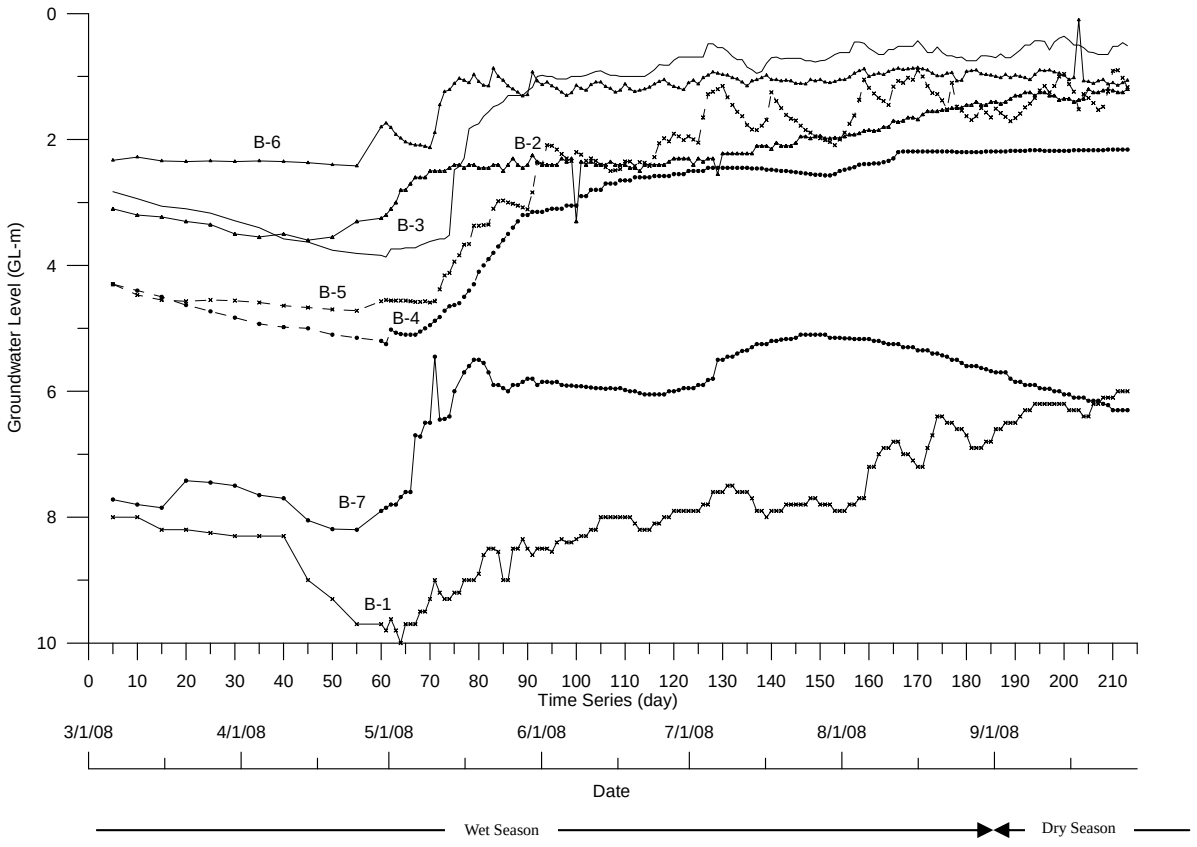


Figure 7.3.5 Fluctuation of Groundwater Level at Test Boreholes in Binh Thuan Province

1) Phu Yen province

Although fluctuation of groundwater level in the dry season is small except P-3, rising up of it from the beginning of the rain season in September is recognized. P-3 has deeper groundwater level and shows greater fluctuation than others do. The reason why P-3 shows the great water level rising of in the dry season is not clear. On the other hand, since P-8 has no seasonal fluctuation of water level, it may be under different hydrogeological conditions from others.

2) Khanh Hoa province

K-1 and K-3 have fracture type of aquifer and fluctuation of their water level is stable during the monitoring period. In contrast, K-2 has weathered granite aquifer and greater seasonal change than they do, and besides, have only one fifth of their withdrawal.

3) Ninh Thuan province

In general, water level fluctuation of all test wells in Ninh Thuan province is very small. Drawdown of N-1 in April seems to be withdrawn by water usage. N-1, N-2 and N-5 show water level rising at the starting of the rainy season. However, N-3 and N-4 has almost no reaction. For some reason, N-6 shows reverse of them after the rainy season.

4) Binh Thuan province

Since Binh Thuan province has much longer rainy season than other three provinces during the monitoring period, a dynamic movement of water level has been recorded. The annual fluctuation of groundwater level of the test wells in this province range from two meter to three meter.

CHAPTER 8

GROUNDWATER POTENTIAL EVALUATION

CHAPTER 8 GROUNDWATER POTENTIAL EVALUATION

8.1 Water Balance Analysis by Using Remote Sensing Techniques

8.1.1 Purpose of Analysis

A water balance is a numeric accounting of inputs, outputs, and storages of water and it can be used to manage water resources, to monitor and predict water shortage, to prevent flooding, and so on. The water balance of the study area is expressed simply by the following equation.

$$P = E + R \pm I \qquad (\mathbf{8.1})$$

Where; P is precipitation; E is evapotranspiration: R is runoff; and I is infiltration.

In this study, the water balance analysis was implemented for understanding the characteristic of water balance and evaluating the groundwater storage at each province and target commune. The primary goal of this analysis was to calculate the precipitation, evapotranspiration and runoff by using existing monitoring data and remote sensing data. Moreover, on the basis of these results, the infiltration which represents groundwater recharge and storage was estimated by the equation (**8.1**).
When applying the water balance analysis, a basic unit for analysis is “sub-catchment”, and the 4 contents of water balance equation are compiled at each sub-catchment. The study area was subdivided automatically into 92 sub-catchments and 4 coastal planes by the hydrologic analysis of SRTM-3 data. The location map of sub-catchments and coastal planes extracted from SRTM-3 data is shown in Figure 8.1.1.

In the water balance analysis, meteorological data and hydrological data are utilized as the existing monitoring data. The location map of meteorological and hydrological stations is shown in Figure 8.1.1 and the list of used monitoring data is shown in Table 8.1.1. The meteorological data of the study area was mainly provided by Hydrology and Geology Station Center. This data set consists of the monthly precipitation data, monthly average temperature data, monthly total sunshine duration data and monthly evaporation data, and it covers the period from 1996 to 2005 for the 9 meteorological stations. The monthly precipitation was observed at all stations, but the monthly total sunshine duration was measured only at 4 stations. Equally, the monthly average temperature and monthly evaporation were available at 7 stations. In addition, the meteorological data of major cities in Vietnam for the period from 2002 to 2005, being on public view at the website of General Statistics Office of Vietnam (GSO, http:// www.gso.gov.vn/), was available for the analysis. The monthly precipitation, monthly average temperature and monthly total sunshine, measured at 4 meteorological stations located in the periphery of the study area, were utilized. The hydrological data was provided by CEVIHEGEO and the monthly average water flow data measured at 4 hydrological stations was used mainly for the calculation of runoff.

Source: JICA Study Team

Figure 8.1.1 Location Map of Sub-Catchments, Planes, and Stations

Table 8.1.1 List of Used Monitoring Data

Station				Meteorology				Hydrology
Name	Province	Period	*Source	M. Precipitation	M. Ave. Temp.	M. Total Sunshine Duration	M. Evaporation	M. Ave. Water Flow
Tuy Hoa	Phu Yen	1996 - 2005	HGSC	O	O	O	O	
Son Hoa	Phu Yen	1996 - 2005	HGSC	O	O		O	
Nha Trang	Khanh Hoa	1996 - 2005	HGSC	O	O	O	O	
Cam Rang	Khanh Hoa	1996 - 2005	HGSC	O	O		O	
Tan My	Ninh Thuan	1996 - 2005	HGSC	O				
Phan Rang	Ninh Thuan	1996 - 2005	HGSC	O	O	O	O	
Phan Thiet	Binh Thuan	1996 - 2005	HGSC	O	O	O	O	
Ta Pao	Binh Thuan	1996 - 2005	HGSC	O				
La Gi	Binh Thuan	1996 - 2005	HGSC	O	O		O	
Da Nang	Da Nang	2002 - 2005	GSO	O	O	O		
Playku	Gia Lai	2002 - 2005	GSO	O	O	O		
Quy Nhon	Binh Dinh	2002 - 2005	GSO	O	O	O		
Da Lat	Lam Dong	2002 - 2005	GSO	O	O	O		
Vung Tau	Ba Ria	2002 - 2005	GSO	O	O	O		
Cung Son	Phu Yen	1996 - 2005	HGSC					O
Dong Trang	Khanh Hoa	1996 - 2005	HGSC					O
Song Luy	Binh Thuan	1996 - 2005	HGSC					O
Ta Pao	Binh Thuan	1996 - 2005	HGSC					O

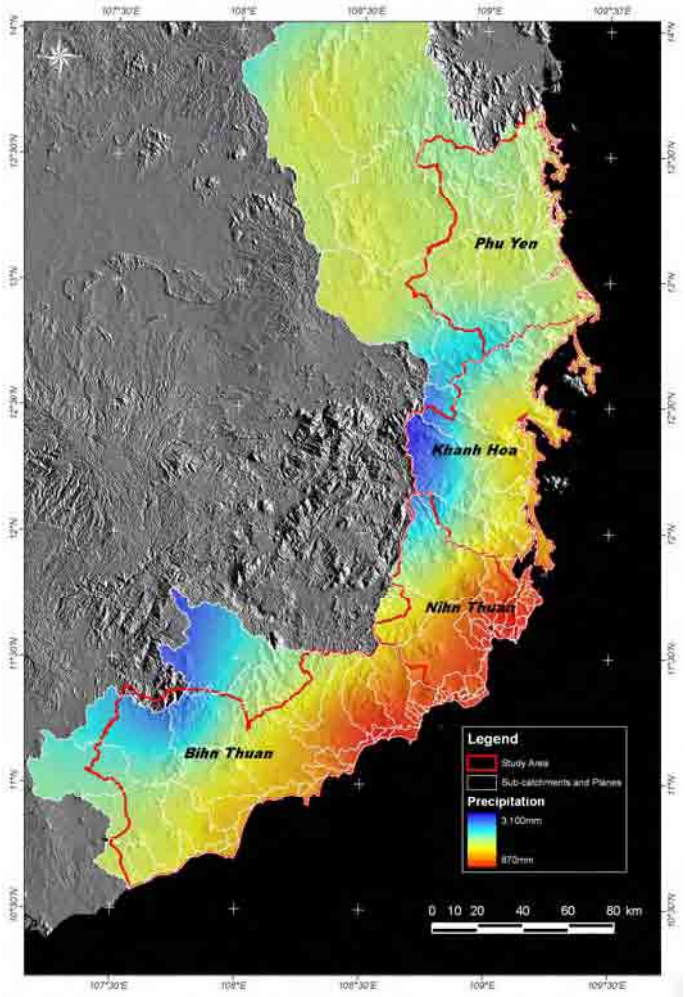
*HGSC: Hydrology and Geology Station Center, GSO: General Statistics Office

Source: JICA Study Team

8.1.2 Precipitation

The annual and monthly precipitation map of the study area was created from the precipitation data of the published atlas and meteorological stations. Figure 8.1.2 shows the annual precipitation map of the study area.

The study area belongs to tropical humid monsoon climate region and the annual precipitation varies from 780 to 3,100 mm. The annual precipitation in most of the study area is greater than 1,500 mm. Especially the mountainous area in Khanh Hoa and Binh Thuan province reaches to grater than 2,500 mm. On the other hand, the annual precipitation of coastal lowland areas in Ninh Thuan province and the northern part of Binh Thuan province is less than 1,000 mm and the precipitation in the dry season is significantly low.



Source: JICA Study Team

Figure 8.1.2 Annual Precipitation Map of the Study Area

8.1.3 Evapotranspiration

Makkink equation (Makkink, 1957) was adopted to estimate the annual and monthly potential evapotranspiration of the study area. The equation is defined as follows:

$$PET_{mak} = \frac{\Delta}{\Delta + \gamma}\frac{Rs}{\lambda} \quad (\mathbf{8.2})$$

Where; PET_{mak} (mm/day) is daily potential evapotranspiration at water surface; Δ (hPa/°C) is slope of saturation vapor pressure curve; γ (hPa/°C) is psychrometric constant; Rs (MJ/cm^2/day) is total solar radiation; λ (MJ/kg) is latent heat. In addition, the following equation (Nagai, 1993, ERSDAC, 2005) was proposed to estimate the potential evapotranspiration related to different land cover classes except for water surface (ex. forest, grassland, soil, etc.) for consideration of albedo.

$$PET_{mak} = (a + 0.08 - A)\frac{\Delta}{\Delta + \gamma}\frac{Rs}{\lambda} + b \quad (\mathbf{8.3})$$

Where; a and b are regional constant value; A is albedo value of each land cover class.

Rs was calculated by the following equation.

$$Rs = Ra(0.18 + 0.55\frac{n}{N}) \quad (\mathbf{8.4})$$

Where; Ra (MJ/m^2/day) is outer space solar radiation; n/N is percentage of sunshine; n (hour) is observed monthly total sunshine duration and N (hour) is monthly possible sunshine duration. $\Delta / (\Delta + \gamma)$, which is dimensionless parameter, and λ were determined by the following equations.

$$\frac{\Delta}{\Delta + \gamma} = \frac{1}{1.05 + 1.4 \times \exp(-0.0604T)} \quad (\mathbf{8.5})$$

$$\lambda = 2.5 - 0.0025 \times T \quad (\mathbf{8.6})$$

Where T (°C) is observed temperature.

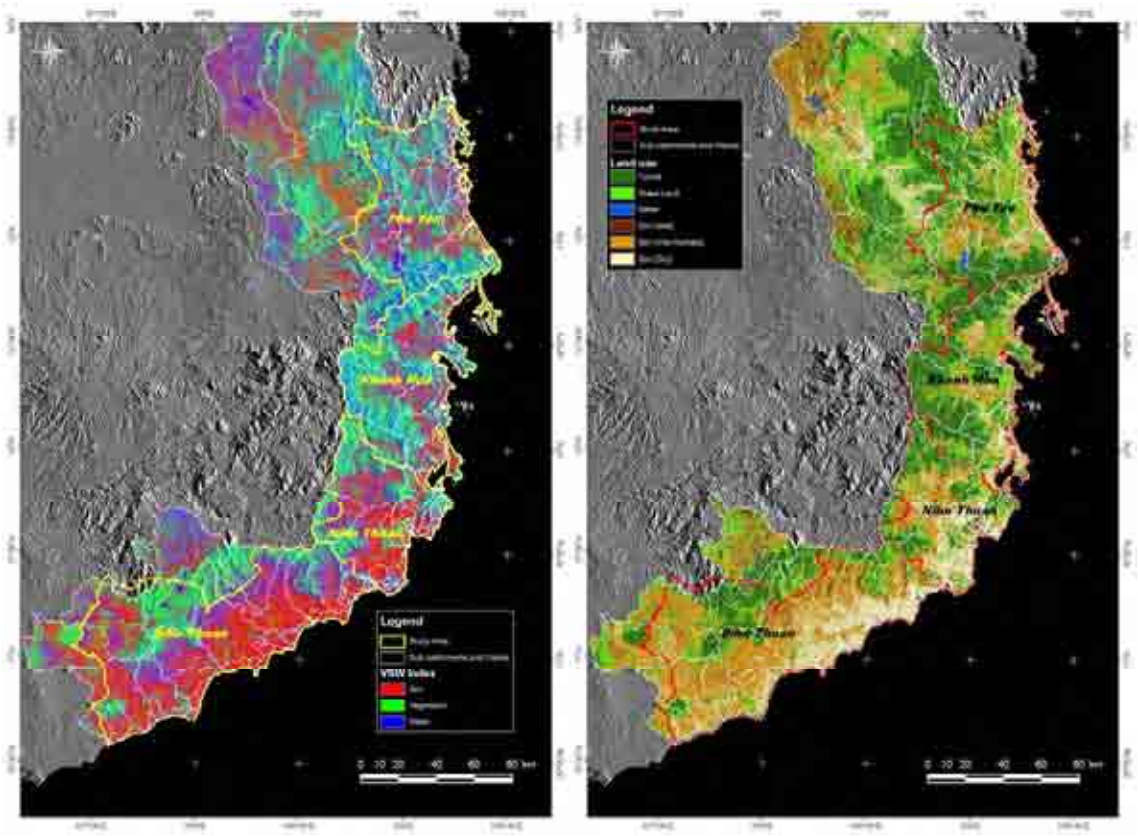
(1) Albedo (A)

The land cover map which is the basis for the consideration of albedo was processed from the VSW index map of LANDSAT image. The study area is classified into 6 land cover classes; forest, grassland, soil (wet), soil (mean), soil (dry), water, and the albedo values of each land cover class were defined as given in Table 8.1.2. The VSW index and land cover map are shown in Figure 8.1.3.

Table 8.1.2 Albedo Values of each Land Cover Class

Class	Forest	Grassland	Soil (wet)	Soil (mean)	Soil (dry)	Water
Albedo Value	0.14	0.23	0.10	0.23	0.35	0.08

Source: ERSDAC (2005)



Source: JICA Study Team

Figure 8.1.3 VSW index Map and Land Cover Map of the Study Area

(2) Outer space solar radiation (*Ra*)

The outer space solar radiation (*Ra*) of the study area and its surroundings is defined as Table 8.1.3. The outer space solar radiation maps were created by the interpolation of these values.

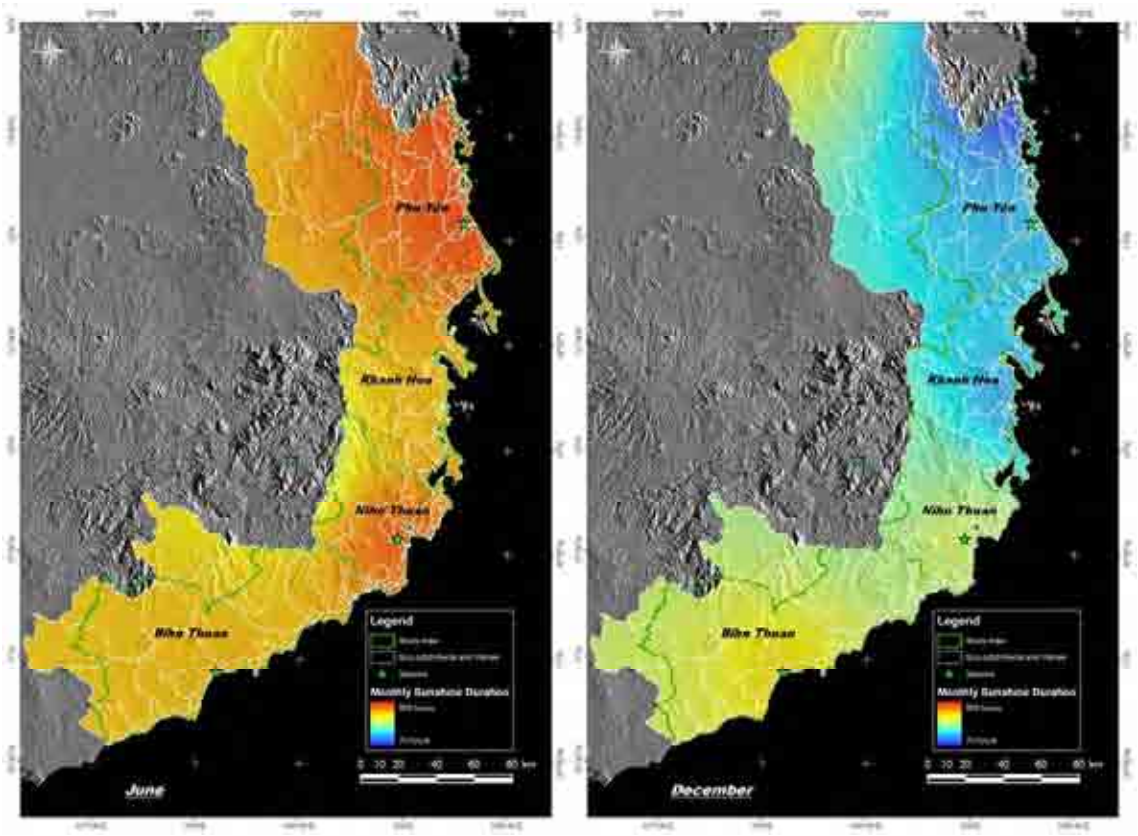
Table 8.1.3 Outer Space Solar Radiation of the Study Area, *Ra* (MJ/m^2/day)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
16°N	29.1	32.4	35.9	38.1	38.8	38.7	38.5	38.1	36.5	33.5	30.0	28.0
14°N	30.1	33.2	36.3	38.1	38.4	38.2	38.1	37.9	36.8	34.2	31.0	29.1
12°N	31.1	33.9	36.7	38.0	38.0	37.6	37.6	37.7	36.9	34.7	31.9	30.2
10°N	32.1	34.6	37.0	37.9	37.6	37.0	37.1	37.5	37.1	35.3	32.7	31.2

Source: Nagai et al. (2003)

(3) Percentage of sunshine (*n/N*)

The monthly total sunshine duration (n) was observed at 9 meteorological stations. On the basis of these observation data, the monthly total sunshine duration maps of each month were created by the interpolation. The maps of June and December are shown in Figure 8.1.4.



Source: JICA Study Team

Figure 8.1.4 Monthly Total Sunshine Duration Map (June and December) of the Study Area

The monthly possible sunshine duration (*N*) of the study area and its surroundings is defined as Table 8.1.4. The monthly possible sunshine hour maps were produced by the interpolation of these values.

Table 8.1.4 Monthly Possible Sunshine Hour of the Study Area, *N* (hour)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
16°N	346	321	370	371	395	388	398	389	364	362	338	343
14°N	350	324	370	370	392	384	395	387	363	363	341	347
12°N	353	325	370	368	389	380	391	384	362	364	344	351
10°N	356	327	371	367	386	377	388	382	362	366	347	354

Source: Nagai et al. (2003)

(4) Temperature (T)

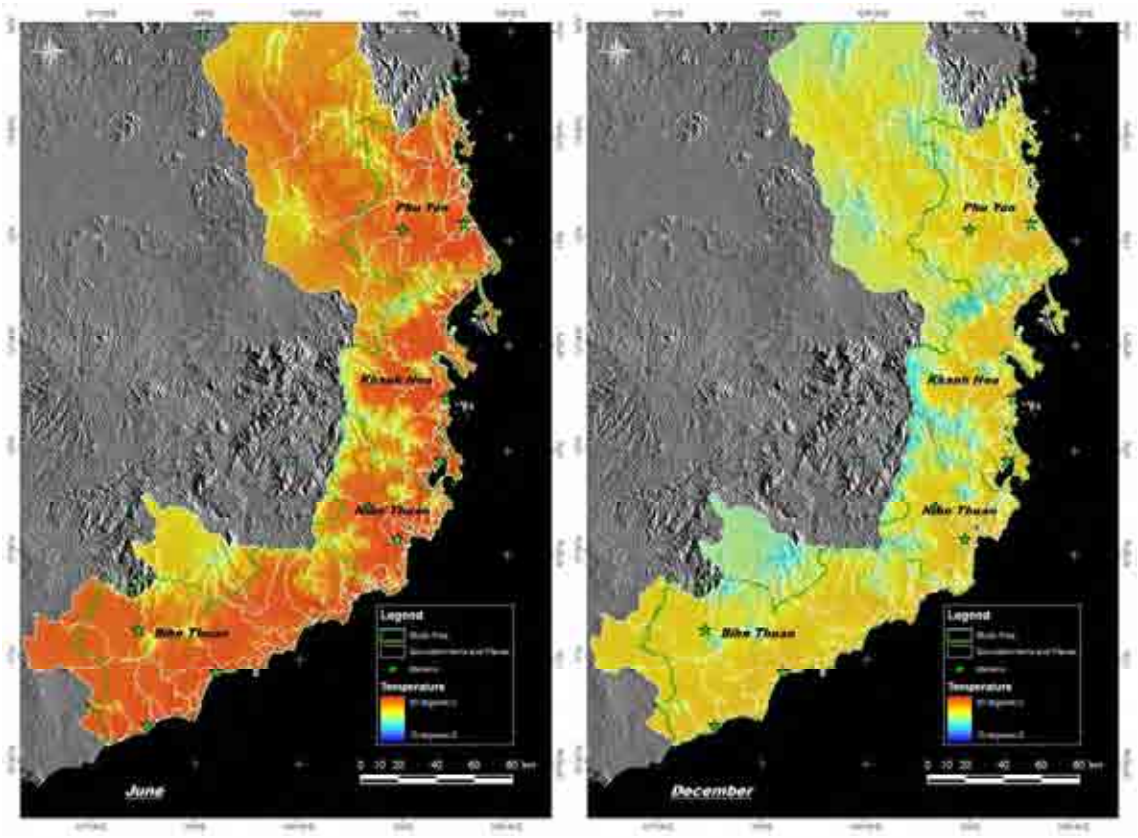
The monthly average temperature map of the study area can be processed by the interpolation of observed temperature data of the meteorological stations. However, the temperature distribution produced by this way can not reflect the altitude effect by which temperature changes in accordance with elevation. Such an altitude effect is known as “lapse rate” and the rate of change is typically

-0.6 °C per 100 m. Therefore, the temperature of the study area was estimated from the SRTM-3 data and observed temperature data by the following equation in consideration of the lapse rate.

$$T = T_{lowland} - 0.006 \times E \qquad (\mathbf{8.7})$$

Where; T (°C) is temperature; $T_{lowland}$ (°C) is average temperature in the coastal lowland area; E (m) is elevation from the SRTM-3 data. $T_{lowland}$ (°C) was calculated by averaging the temperature data of the meteorological stations located in the coastal lowland area.

The monthly average temperature maps of June and December are shown in Figure 8.1.5.



Source: JICA Study Team

Figure 8.1.5 Monthly Average Temperature Map (June and December) of the Study Area

(5) Regional constant value (a, b)

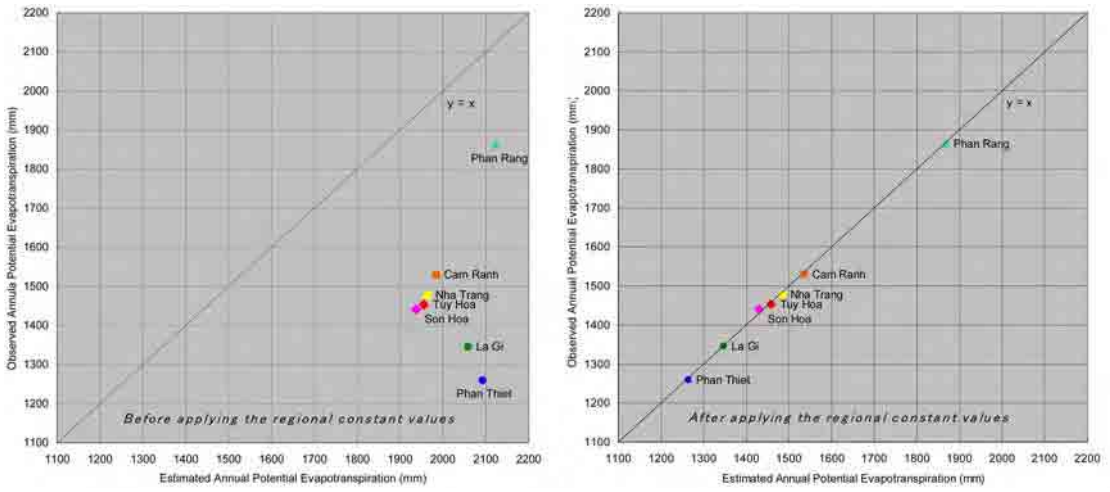
In order to examine the regional characteristic of evapotranspiration, the comparison between the potential evapotranspiration estimated by the Makkink equation (hereafter the estimated values) and the potential evapotranspiration measured at meteorological stations (hereafter the observed values) was carried out. The estimated values of the study area were processed by equation (8.2), and the obtained values are considered as potential evapotranspiration vales only when all the ground of the study area is covered by water surface. The observed values are measured by an evaporimeter, so that these values can be also considered as potential evapotranspiration values in the area of water surface.

As a result of comparing between the estimated and observed values at the same points (at the meteorological stations), it became evident that the estimated values were calculated to be grater than the observed values (Table 8.1.5 and the left image of Figure 8.1.6). The differences of both values vary from 13 % to 66 % against the measured values. Especially, the estimated values of Binh Thuan province were calculated to be in excess of more than 50 %. At present, the reason for this difference is unknown, but such a phenomenon was possibly caused by regional characteristics of climate, meteorology, and so on.

Table 8.1.5 Comparison between the Observed and Estimated Values

Station		Measured (mm)	Estimated (mm)	Ratio
Name	Province	A	B	(B-A)/A*100
Tuy Hoa	Phu Yen	1,453	1,955	34.6
Son Hoa	Phu Yen	1,441	1,938	34.5
Nha Trang	Khanh Hoa	1,478	1,964	32.9
Cam Ranh	Khanh Hoa	1,530	1,984	29.7
Phan Rang	Ninh Thuan	1,865	2,123	13.8
Phan Thiet	Binh Thuan	1,260	2,093	66.1
La Gi	Binh Thuan	1,345	2,059	53.0

Source: JICA Study Team

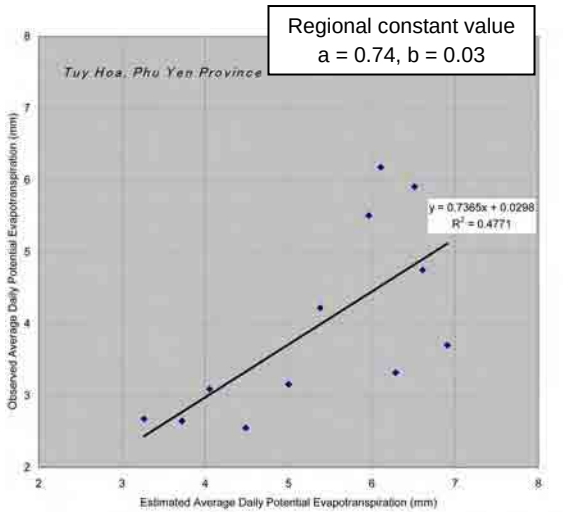


Source: JICA Study Team

Figure 8.1.6 Scatter Diagram of the Estimated and Observed Values

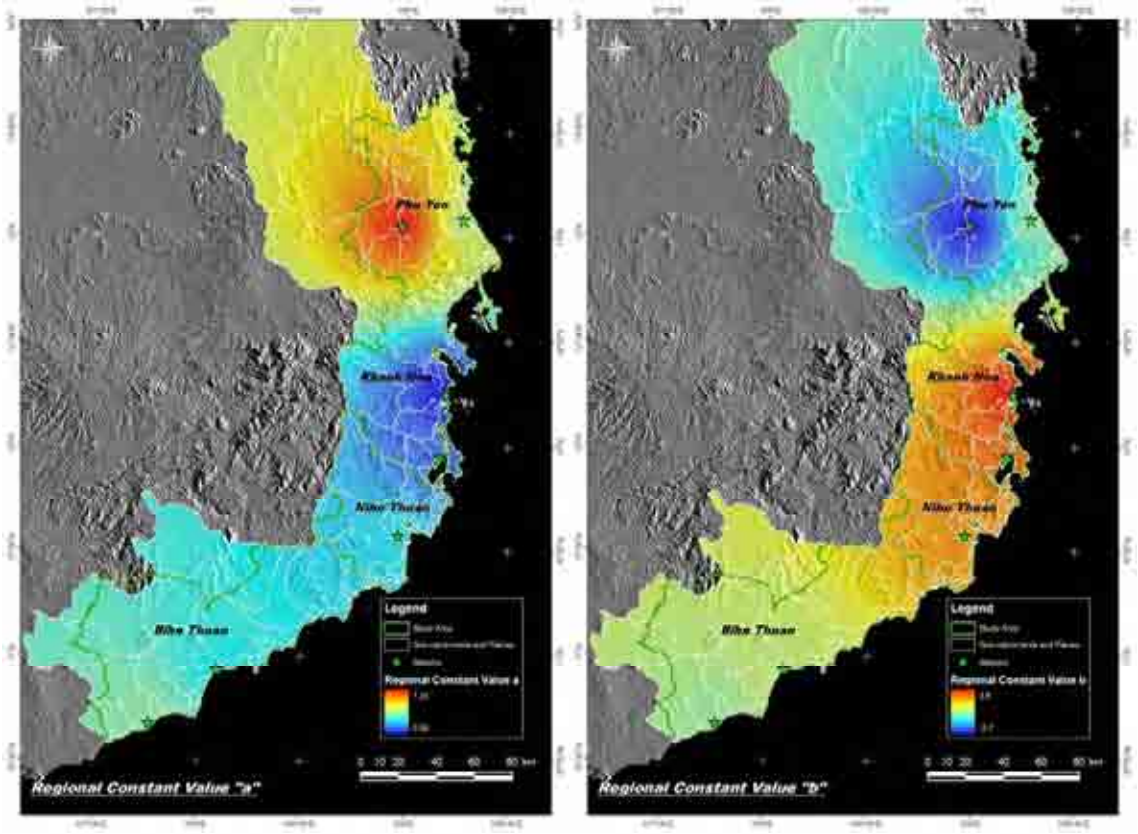
For correcting this distinction, the regional constant value a and b were defined. The regional constant value was obtained from the linear regression equation of the relationship between the estimated and observed values. The example of scatter diagram and linear regression equation calculated by the estimated and observed average daily potential evapotranspiration values of each month at the station of Tuy Hoa, Phu Yen province is shown in Figure 8.1.7. The x-coefficient 0.74 and y-intercept 0.03 of the linear regression equation correspond respectively to the regional constant

values a and b. Similarly, the regional constant values of other stations were determined, and then the regional constant value maps were drawn (Figure 8.1.8).



Source: JICA Study Team

Figure 8.1.7 Example of Scatter Diagram of the Station in Tuy Hoa, Phu Yen Province



Source: JICA Study Team

Figure 8.1.8 Regional Constant value "a" and "b" Map of the Study Area

The scatter diagram between the estimated values corrected by the regional constant values and the measured value is shown in the right side image of Figure 8.1.6. As the x-coefficient of linear regression equation shows almost one, it is obvious that the correction is highly effective against the removal of regional characteristics.

(6) Convert potential evapotranspiration to actual evapotranspiration

The potential evapotranspiration is the amount of evapotranspiration that would occur if a sufficient water source on the Earth's surface were available. When water storage in soil is shortage, an evapotranspiration would not occur. Therefore, an actual evapotranspiration value in the dry season will be less than a potential evapotranspiration value.

In this study, the potential evapotranspiration values were converted to the actual evapotranspiration by the following equation.

$$AET_{mak} = \alpha PET_{mak} \qquad (8.8)$$

Where; AET_{mak} (mm) is actual evapotranspiration; α is conversion value from potential evaporation value to actual evapotranspiration value; PET_{mak} (mm) is potential evapotranspiration by the Makkink equation in consideration of albedo.

The conversion value α is determined from the monthly average precipitation and monthly evaporation of meteorological stations. The example of determination of α at the station of Phan Rang, Ninh Thuan province is shown in Table 8.1.6.

Table 8.1.6 Example of the Determination of α in the Station of Phan Rang, Ninh Thuan Province

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	SUM
Precipitation (mm)	9	26	77	59	43	44	136	178	179	117	2	1	
P. Evapotranspiration (mm)	179	154	147	156	169	166	124	107	124	158	193	185	1862 (a)
Water Storage in soil (mm)	0	0	0	0	0	0	12	98	100	59	0	0	
Water Shortage (mm)	170	128	70	97	126	122	0	0	0	41	191	184	
Water Excess (mm)	0	0	0	0	0	0	12	71	55	0	0	0	
A. Evapotranspiration (mm)	9	26	77	59	43	44	124	107	124	158	61	1	833 (b)

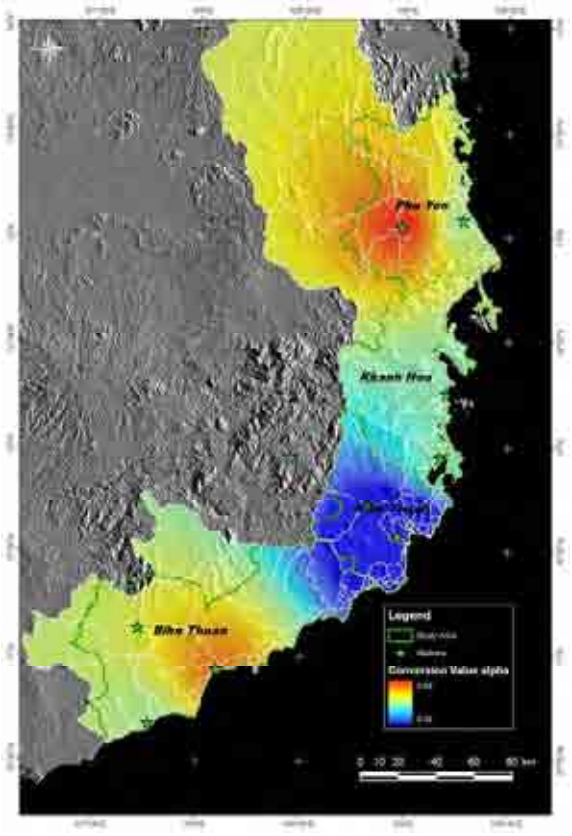
*Maximum Water Storage is assumed to 100mm

α = 0.45 (b/a)

The conversion values of each station are shown in Table 8.1.7. The conversion values vary from 0.45 to 0.69, and the lowest value is 0.45 in Phan Rang, Ninh Thuan province where the evapotranspiration value exceeds the precipitation value for nine months (the "Water Shortage" of Table 8.1.6).

Table 8.1.7 Conversion Values of each Stations

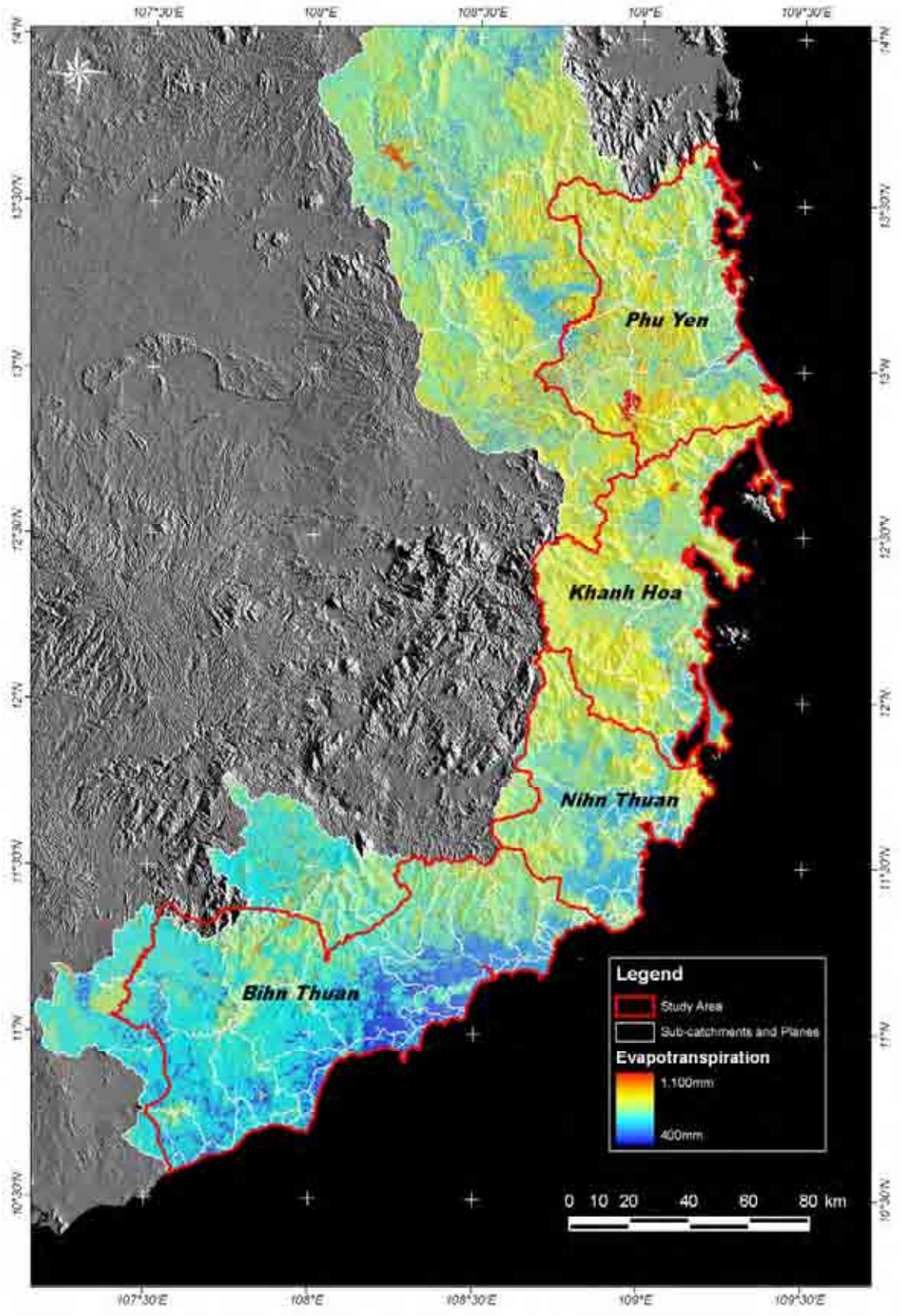
Station		Conversion Value
Name	Province	α
Tuy Hoa	Phu Yen	0.61
Son Hoa	Khanh Hoa	0.69
Nha Trang	Khanh Hoa	0.60
Cam Ranh	Ninh Thuan	0.60
Phan Rang	Ninh Thuan	0.45
Phan Thiet	Binh Thuan	0.67
La Gi	Binh Thuan	0.61



Source: JICA Study Team

Figure 8.1.9 Conversion Value "α" Map of the Study Area

Figure 8.1.9 shows the annual evapotranspiration map of the study area which shows the actual evaporation value. The annual evapotranspiration value varies from 400 to 1,100 mm. The water surfaces (dams, water reservoirs) and forests of mountainous area show high evapotranspiration value, on the other hand, the lowlands, being distributed in the coastal area and intermountain area, show low values.



Source: JICA Study Team

Figure 8.1.10 Annual Evapotranspiration Map of the Study Area

8.1.4 Runoff

The ratio of runoff or river discharge was estimated by the techniques of geomorphometry. In order to examine the water flow on the Earth's surface, the SRTM-3 data-based geomorphometry was carried out at each sub-catchment.

(1) Geomorphometry

The items of geomorphometry calculated at each sub-catchment are as follows:

Average erosion height

Average erosion height calculated by the following equations can be used as a factor of surface relief.

$$He = \sum_{i}^{n} Es_i - E_i \qquad (\mathbf{8.9})$$

Where; He is average erosion height of certain sub-catchment; n is number of pixels; Es_i is elevation of summit plane of certain pixel; E_i is elevation of certain pixel.

Standard deviation of laplacian

Laplacian of elevation is defined as a derivation value of gradient and its differences show a grade of surface relief. Laplacian is calculated by the following equation.

$$L_{(m,n)} = E_{(m-1,n)} + E_{(m+1,n)} + E_{(m,n-1)} + E_{(m,n+1)} - 4 \times E_{(m,n)} \qquad (\mathbf{8.10})$$

Where $L_{(i,\ j)}$ is laplacian of elevation of pixel(i, j). In addition, standard deviation of laplacian calculated by the following equations is used to evaluate surface texture.

$$Sx_{laplacian} = \sqrt{\frac{\sum_{i=1}^{n}(L_i - \overline{L})}{n}} \qquad (\mathbf{8.11})$$

Where; $Sx_{laplacian}$ is standard deviation of laplacian of certain sub-catchment; L_i is laplacian of elevation of certain pixel; $\overline{L}$ is mean of laplacian of certain sub-catchment.

Standard deviation of elevation

Standard deviation of elevation calculated by the following equation is used to measure a grade of surface relief.

$$Sx_{elevation} = \sqrt{\frac{\sum_{i=1}^{n}(E_i - \overline{E})}{n}} \qquad (\mathbf{8.12})$$

Where, $Sx_{elevation}$ is standard deviation of elevation of certain sub-catchment; E_i is elevation of certain pixel; $\overline{E}$ is mean of elevation of certain sub-catchment.

Drainage relief number

Drainage relief number is defined as an average slope of sub-catchment and is calculated by the following equations.

$$Dr = \frac{V}{A^{1.5}} \qquad \textbf{(8.13)}$$

Where; *Dr* is average erosion height of certain sub-catchment; *V* is volume of sub-catchment; *A* is area of sub-catchment.

Drainage frequency

Drainage frequency calculated by the following equation is used to evaluate a drainage network of sub-catchment quantitatively.

$$Fd = \sum_{\omega}^{\Omega} \frac{N_{\omega}}{A_{\Omega}} \qquad \textbf{(8.14)}$$

Where; *Fd* is drainage frequency of certain sub-catchment; $N\omega$ is number of ω^{th} order stream; Ω is maximum number of drainage order; *A* is area of sub-catchment.

Bifurcation ratio of 2nd and 3rd order stream

Bifurcation ratio of 2nd and 3rd order stream is calculated by the following equation.

$$R_{2/3} = \frac{N_2}{N_3} \qquad \textbf{(8.15)}$$

Where; $R_{2/3}$ is bifurcation ratio of certain sub-catchment; N_i is number of pixels of i^{th} order stream of sub-catchment.

Bifurcation ratio of 1st and 2nd order stream

Bifurcation ratio of 1st and 2nd order stream is calculated by the following equation.

$$R_{1/2} = \frac{N_1}{N_2} \qquad \textbf{(@.16)}$$

Where; $R_{1/2}$ is bifurcation ratio of certain sub-catchment; N_i is number of pixels of i^{th} order stream of sub-catchment.

Drainage form ratio

Drainage form ratio, calculated by the following equation, represents topological feature of sub-catchment.

$$Rl = \frac{(P_{\max})^2}{A} \qquad \textbf{(8.17)}$$

Where; *Rl* is drainage form ratio of certain sub-catchment; *Pmax* is maximum distance of drainage of sub-catchment; *A* is area of sub-catchment.

Basin form ratio

Basin form ratio calculated by the following equation is used to evaluate a shape of sub-catchment.

$$Rf = \frac{(L_{\max})^2}{A} \qquad (\mathbf{8.18})$$

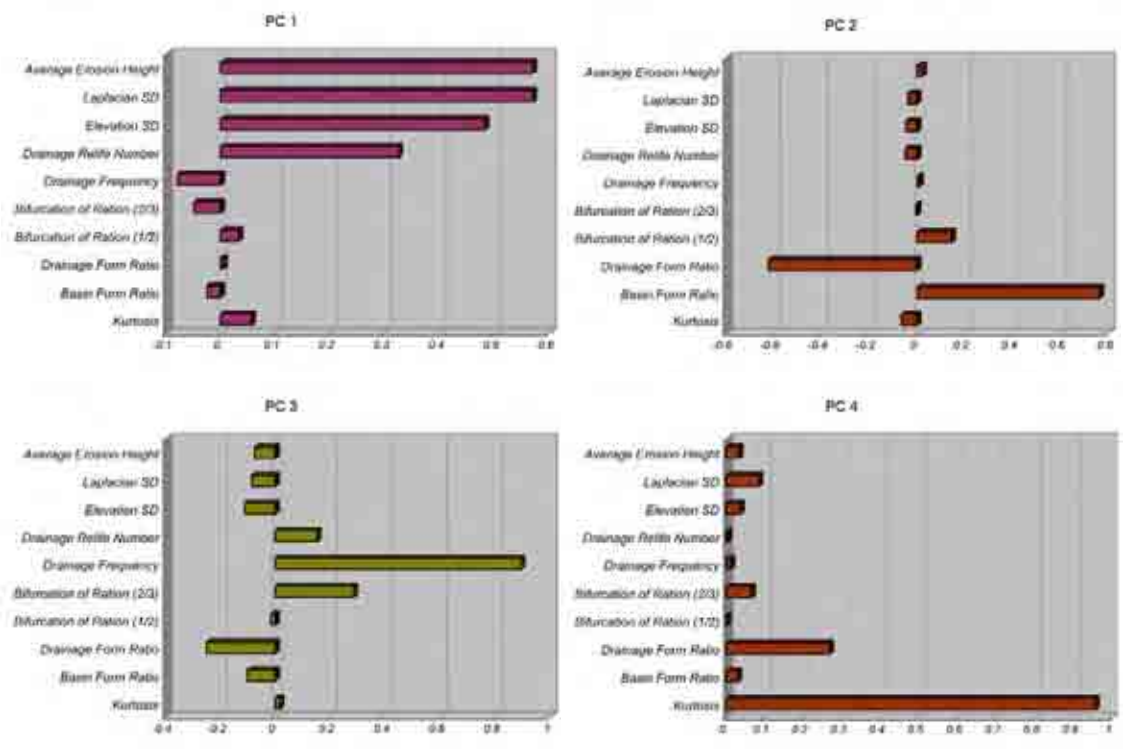
Where; *Rf* is basin form ratio of certain sub-catchment; *Lmax* is maximum width of sub-catchment; *A* is area of sub-catchment.

Kurtosis

Kurtosis represents topographic properties related to drainage network.

(2) Principle component analysis

In order to compile the measurement result of each item and evaluate the runoff of the study area, the principle component analysis (PCA) was conducted to the result of geomorphometry. The PC loading of each item of first principle component (PC 1) to fourth principle component (PC 4) calculated by PCA are shown in Figure 8.1.11.

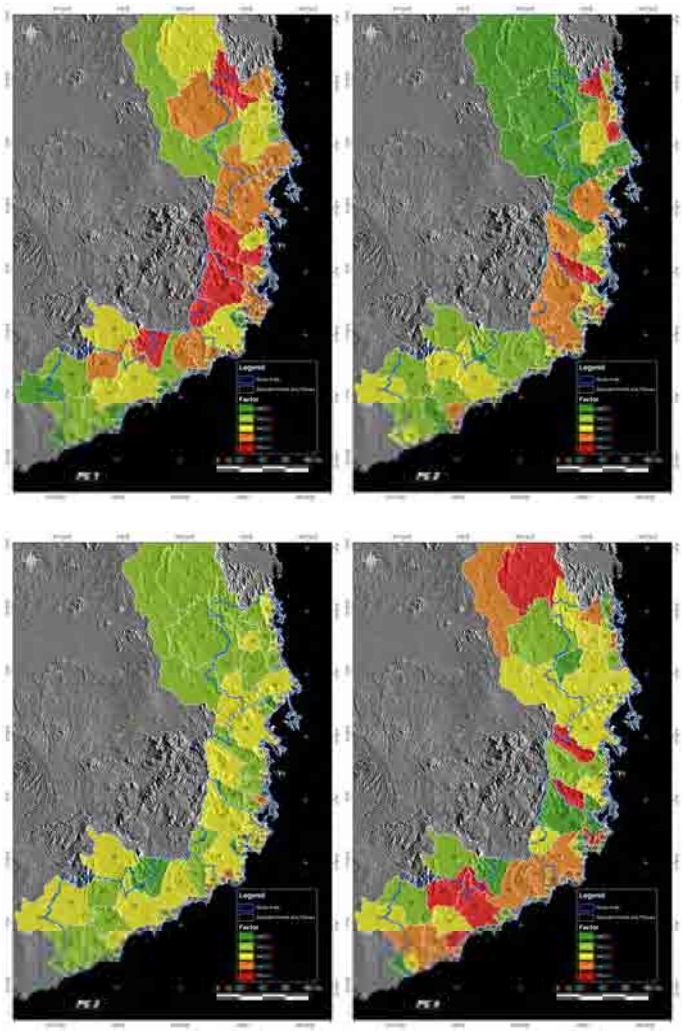


Source: JICA Study Team

Figure 8.1.11 Loading of Principle Component Analysis

Concerning PC 1, the loadings of average erosion height, standard deviation of laplacian, standard deviation of elevation and drainage relief number are clearly higher than other items. These items are related to a relief of terrain, and therefore PC 1 is considered as the factor representing “the relief of terrain”. Equally, PC 2 is “the shape of sub-catchment”, PC 3 is “the growth of drainage”, and PC 4 is “the drainage network”. As three components of PC 1, PC 2, and PC 3 of four principle components can be directly related to the runoff, these three PCs were utilized to evaluate the runoff of the study area.

The PC score of three PCs at each sub-catchment were subdivided into 5 grades by the Jenks’ natural break classification. The subdivisions of PC score are shown in the map of Figure 8.1.12.



Source: JICA Study Team

Figure 8.1.12 Grade Maps of the PC score

Since PC 1, PC 2, and PC 3 are related to the runoff of the study area, it is considered that the higher the grade of three PCs gives higher runoff ratio. For this reason, the quantitative evaluation of runoff was implemented by the following equation.

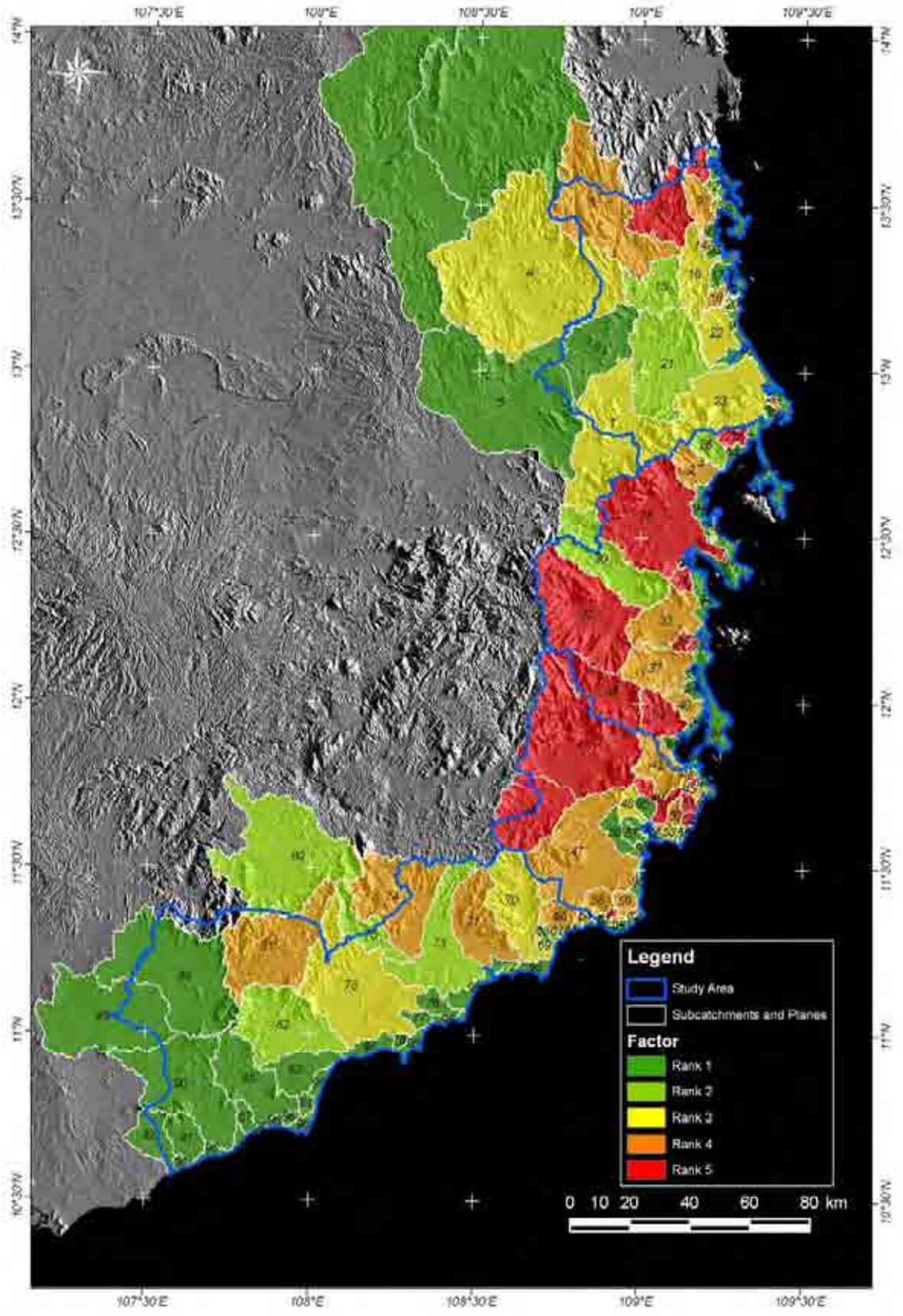
$$G_{runoff} = G_{PC1} \times w_{PC1} + G_{PC2} \times w_{PC2} + G_{PC3} \times w_{PC3} \quad (\mathbf{8.19})$$

Where; G_{runoff} is grade of the runoff evaluation; G_{PCx} is grade of PC score in PC x: w_{PCx} is weight of PC x. In this study, the contribution ratio of each PCs obtained by PCA was used as the weight of each PCs (Table 8.1.8).

Table 8.1.8 Weight Value for the Calculation of G_{runoff}

W_{PC1}	W_{PC2}	W_{PC3}
0.51	0.28	0.21

Figure 8.1.14 shows the grade of runoff evaluation determined by the equation (**8.19**). In the grade map, the sub-catchments located in the steep-sided mountainous area, with horizontally oblong form show relatively high grade (red and orange colored in the Figure 8.1.14), while the sub-catchments located in the coastal and intermountain lowland, with vertically oblong form show low grade (dark green colored in the Figure 8.1.14).



Source: JICA Study Team

Figure 8.1.13 Grade Maps of the Result of Quantitative Runoff Evaluation

(3) Runoff ratio

There are four hydrological stations in the study area and the runoff ratio can be estimated by the monthly average water flow actually observed at these stations. In this study, the runoff ratio of the study area was estimated through the relationship between the actual runoff ratio of the stations and the result of geomorphometry in the station's sub-catchment was discussed. The location map of the hydrological stations and its sub-catchments is shown in Figure 8.1.14 and the actual runoff ratio and the result of geomorphometry are shown in Table 8.1.9.

Source: JICA Study Team

Figure 8.1.14 Location Map of the Hydrological Stations and its Catchment

Table 8.1.9 Result of Geomorphometry in the Station's Sub-Catchment and its Runoff

Station		Geomorphometry and PCA				Observed Runoff Ratio
Name	Province	G_{PC1}	G_{PC2}	G_{PC3}	G_{runoff}	of Stations
Cung Son	Phu Yen	3	1	2	2.23	0.330
Dong Trang	Khanh Hoa	5	4	3	4.30	0.628
Phan Thiet	Binh Thuan	4	2	1	2.81	0.326
La Gi	Binh Thuan	4	1	2	2.74	0.511

The scatter diagram of the G_{runoff} and the observed runoff ratio of Table 8.1.9 is shown in the Figure 8.1.15.

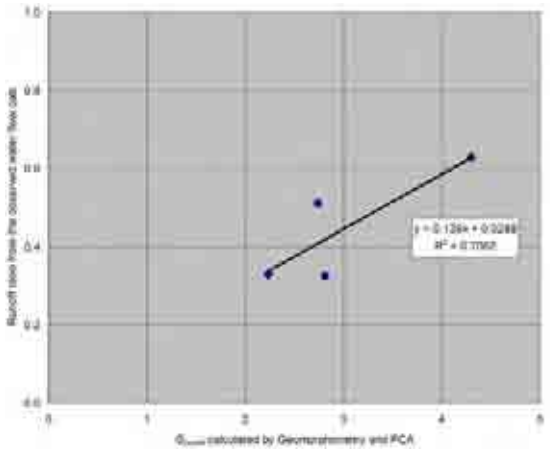


Figure 8.1.15 Scatter Diagram of the G_{runoff} and Runoff Ratio at the Hydrological Stations

The correlation of the both is strong (R2 = 0.71), and then the Grunoff of all sub-catchment can be converted to the runoff ratio by the following equation from the linear regression equation of the scatter diagram.

$$R_{ratio} = 0.14 \times G_{runoff} + 0.03 \qquad (\mathbf{8.20})$$

Where; Rratio is runoff ratio of sub-catchment; G_{runoff} is grade of the runoff evaluation.

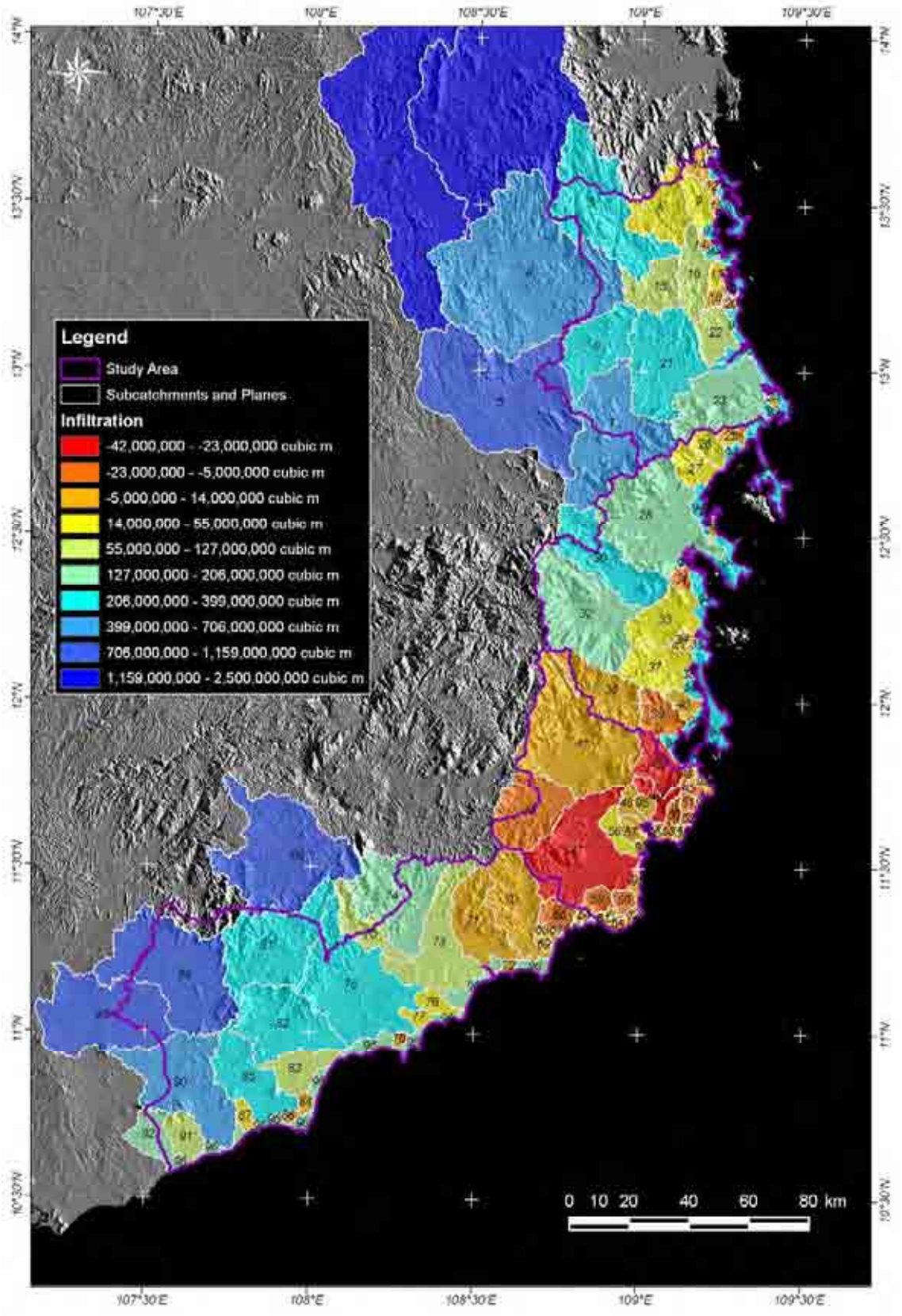
8.1.5 Infiltration

On the basis of the precipitation, evapotranspiration, and runoff ratio estimation, the infiltration, reflecting the ground water recharge and storage, can be expressed by the following equation.

$$I = P - AET_{mak} - P \times R_{ratio} \qquad (\mathbf{8.21})$$

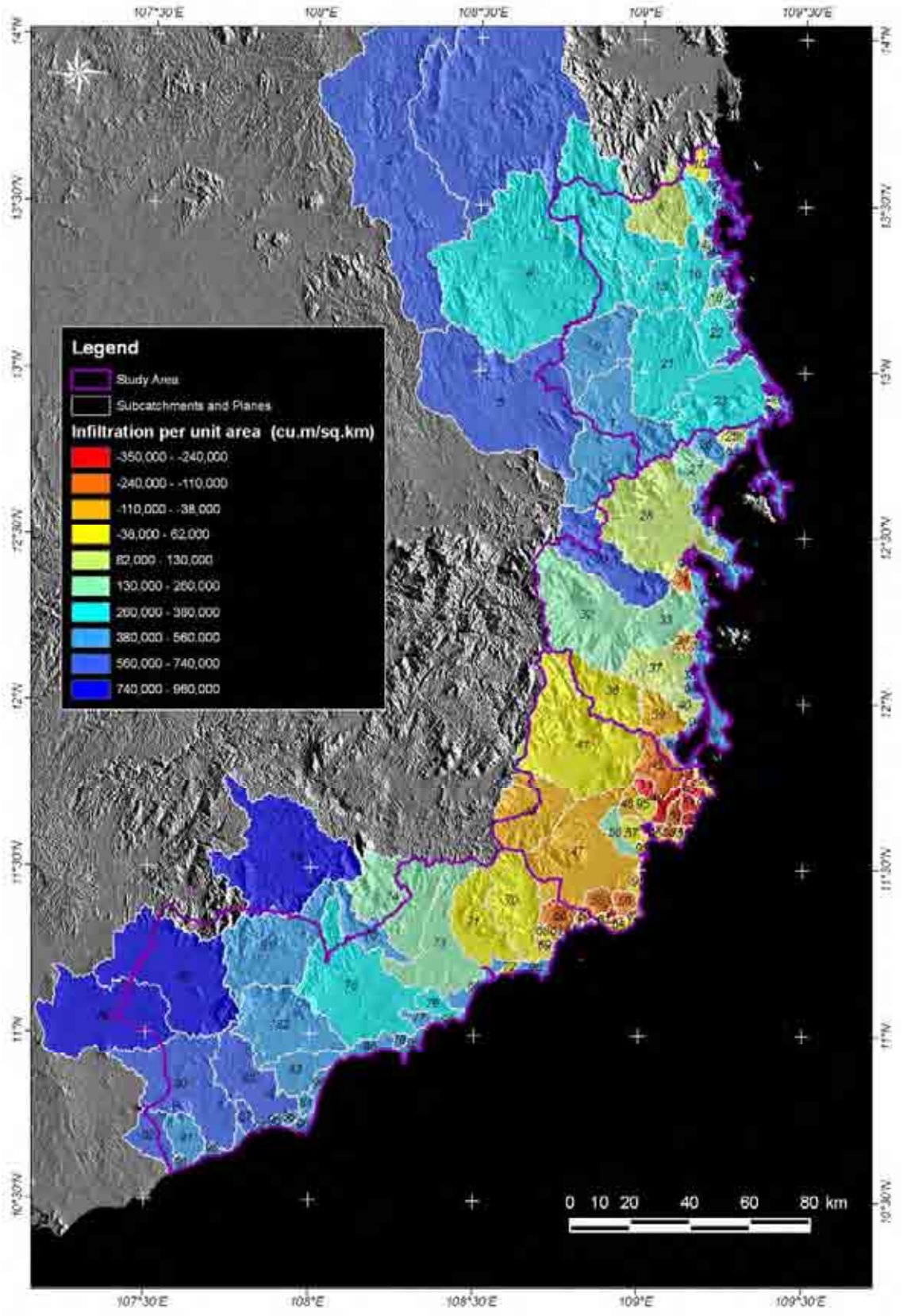
Where; I (mm) is amount of infiltration; P (mm) is amount of precipitation; AET_{mak} (mm) is actual evapotranspiration value; R_{ratio} is runoff ratio.

The infiltration map of the study area is shown in the Figure 8.1.16 to Figure 8.1.18.



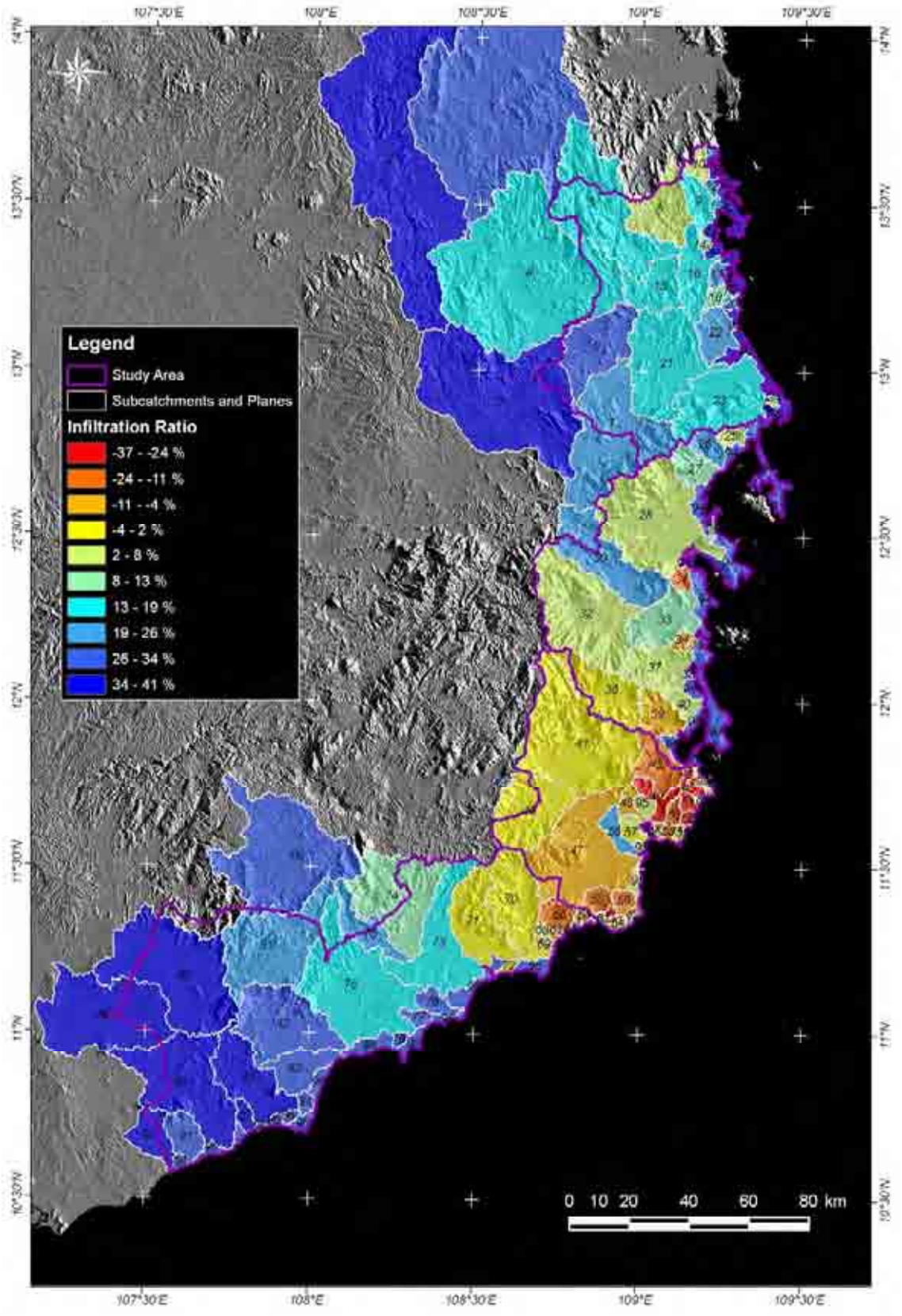
Source: JICA Study Team

Figure 8.1.16 Annual Infiltration Map of the Study Area



Source: JICA Study Team

Figure 8.1.17 Annual Infiltration Map (per unit area) of the Study Area



Source: JICA Study Team

Figure 8.1.18 Annual Infiltration Ratio Map of the Study Area

8.1.6 Water Balance Analysis

The results of water balance analysis for each province and target commune are shown in the Table 8.1.10 and Table 8.1.11.

Table 8.1.10 Water Balance of each Province

Province		Precipitation	Evapotranspiration	Runoff	Infiltration	Infiltration
Name	Area (km^2)	(m^3)	(m^3)	(m^3)	(m^3)	on (%)
Phu Yen	5,000	10,953,540,431	4,084,661,607	4,717,357,774	2,151,521,050	19.6
Khanh Hoa	4,610	9,538,991,944	3,492,193,853	4,919,180,766	1,127,617,324	11.8
Ninh Thuan	3,350	5,004,441,470	2,410,110,593	2,745,525,211	-151,194,334	-3.0
Binh Thuan	7,810	15,151,919,461	5,347,714,746	5,837,280,230	3,966,924,485	26.2

Table 8.1.11 Water Balance of each Target Commune

Commune				Precipitation	Evapotranspiration	Runoff	Infiltration	Infiltration
No.	Name	Province	Area (km^2)	(m^3)	(m^3)	(m^3)	(m^3)	on (%)
P-1	Xuan Phuoc	Phu Yen	81	152,284,306	58,411,041	61,958,697	31,914,567	21.0
P-2	An Dinh	Phu Yen	18	33,158,801	12,356,861	15,109,438	5,692,502	17.2
P-3	An Tho	Phu Yen	44	78,619,040	30,124,474	33,304,048	15,190,518	19.3
P-4	An My	Phu Yen	14	24,725,234	9,636,067	9,985,904	5,103,263	20.6
P-5	Ea Cha Rang	Phu Yen	83	149,995,347	63,183,077	46,018,572	40,793,697	27.2
P-6	Son Phuoc	Phu Yen	79	143,964,216	59,847,559	44,168,222	39,948,436	27.7
P-7	Suoi Bac	Phu Yen	41	71,897,452	31,333,420	22,058,138	18,505,894	25.7
P-8	Son Thanh	Phu Yen	181	361,147,340	140,557,941	150,501,292	70,088,107	19.4
K-1	Cam An Bac	Khanh Hoa	21	32,259,896	14,202,876	15,319,224	2,737,795	8.5
K-2	Cam Hiep Nam	Khanh Hoa	19	29,818,444	12,786,974	14,159,855	2,871,616	9.6
K-3	Cam Hai Tay	Khanh Hoa	17	26,904,833	10,919,369	10,269,252	5,716,213	21.2
N-1	Nhon Hai	Ninh Thuan	40	35,207,161	24,473,589	15,695,352	-4,961,780	-14.1
N-2	Cong Hai	Ninh Thuan	74	76,309,074	54,537,348	39,436,072	-17,664,345	-23.1
N-3	Bac Son	Ninh Thuan	61	54,805,451	39,695,826	26,729,988	-11,620,364	-21.2
N-4	Phuoc Minh	Ninh Thuan	75	75,702,092	44,930,597	38,896,189	-8,124,694	-10.7
N-5	Phuoc Dinh	Ninh Thuan	33	31,352,483	18,952,822	15,197,740	-2,798,079	-8.9
N-6	Phuoc Hai	Ninh Thuan	130	126,658,937	80,316,066	61,396,400	-15,053,529	-11.9
B-1	Muong Man	Binh Thuan	18	28,608,358	10,498,083	10,808,066	7,302,208	25.5
B-2	Gia Huynh	Binh Thuan	158	333,962,936	93,666,136	112,167,797	128,129,003	38.4
B-3	Nghi Duc	Binh Thuan	38	101,584,292	23,775,279	34,119,015	43,689,999	43.0
B-4	Tan Duc	Binh Thuan	137	254,522,682	78,560,902	78,087,559	97,874,222	38.5
B-5	Me Pu	Binh Thuan	47	124,246,356	29,337,564	41,730,499	53,178,293	42.8
B-6	Sung Nhon	Binh Thuan	35	89,027,184	21,695,243	29,901,471	37,430,470	42.0
B-7	Da Kai	Binh Thuan	67	171,252,513	41,300,073	57,518,410	72,434,030	42.3

8.2 Alternative Water Sources

8.2.1 Required Water Quantity for Abstraction from Alternative Water Sources

Due to the results of the hydrogeological investigation of the Study, it was made cleared that only two communes (P-4 and P-8) in Phu Yen Province and one commune (K-1) in Khanh Hoa Province have enough groundwater potential with good water quality. As a result, it becomes necessary to study possibility for alternative water sources (especially from surface water) for the rest of the twenty-one communes.

Based on the estimated water demand and design water capacity in 2020, the required water quantity for abstraction for the 21 communes from alternative water sources is shown in Table 8.2.1.

Table 8.2.1 Required Water Quantity for Abstraction from Alternative Water Sources

Province	Code	Commune	Water Demand and Design Water Supply Capacity		Required Quantity for Abstraction	
			Daily Average Water Demand (m^3/day)	Design Water Supply Capacity (m^3/day)	Monthly Average Quantity (m^3/day)	Daily Maximum Quantity (l/sec)
Phu Yen	P-1	Xuan Phuoc	814.9	977.9	24,400	11.3
	P-2	An Dinh	497.8	597.4	14,900	6.9
	P-3	An Tho	317.5	381.0	9,500	4.4
	P-4	An My	Water Supply from Groundwater			
	P-5	Son Phuoc	231.3	277.6	6,900	3.2
	P-6	Ea Cha Rang	190.4	228.5	5,700	2.6
	P-7	Suoi Bac	478.2	573.8	14,300	6.6
	P-8	Son Thanh Don	Water Supply from Groundwater			
Khanh Hoa	K-1	Cam An Bac	Water Supply from Groundwater			
	K-2	Cam Hiep Nam	593.8	712.6	17,800	8.2
	K-3	Cam Hay Tay	957.7	1149.2	28,700	13.3
Ninh Thuan	N-1	Nhon Hai	1522.4	1826.9	45,700	21.1
	N-2	Cong Hai	729.2	875.0	21,900	10.1
	N-3	Bac Son	347.7	417.2	10,400	4.8
	N-4	Phuoc Minh	368.0	441.6	11,000	5.1
	N-5	Phuoc Hai	1164.5	1397.4	34,900	16.2
	N-6	Phuoc Dinh	962.9	1155.5	28,900	13.4
Binh Thuan	B-1	Muong Man	550.3	660.4	16,500	7.6
	B-2	Gia Huynh	457.8	549.4	13,700	6.4
	B-3	Nghi Duc	861.6	1033.9	25,800	12.0
	B-4	Tan Duc	440.6	528.7	13,200	6.1
	B-5	Me Pu	1130.6	1356.7	33,900	15.7
	B-6	Sung Nhon	711.0	853.2	21,300	9.9
	B-7	Da Kai	988.5	1186.2	29,700	13.7

8.2.2 Site Reconnaissance and Data Analyses of Possible Sites for Alternative Water Sources

(1) Candidate Sites

Possible alternative sources are classified into three. They are 1) rivers, 2) reservoirs or ponds, and 3) existing urban water supply systems. The study on alternative water sources was conducted mainly focusing on surface water sources composed of rivers and reservoirs or ponds. Figure 8.2.1 and Figure 8.2.2 shows the investigated candidate sites for alternative water sources. Composition of the candidate sites is shown in the table below.

Table 8.2.2 Number of the Candidate Sites

Province	River	Reservoir / Pond
Phu Yen	6	2
Khanh Hoa	1	2
Ninh Thuan	2	1
Binh Thuan	4	3

(2) Possible Alternative Water Sources in Phu Yen Province

In Phu Yen Province, there are two major rivers relating to the target communes of the Study. They are the Ky Lo River and the Ba River. The Ky Lo River is the right tributary of the Cai River, and flows near P-1. Ba River flows near P-5, P-6 and P-7.

In addition to the above, there are two reservoirs, which locate near P-1 and P-2. They are “Phu Xuan Reservoir” located in P-1 and “Dong Trong Reservoir” located near P-2.

1) Possible Alternative Water Sources for P-1

Based on the analysis on the Landsat images (2000 to 2003), aerial photographs, topographic map with scale 1/250,000 as well as the information from P-CERWASS and DARD, it could be understood that there are three candidate sites of surface water sources for P-1 as listed below.

- PS-1 site: Phu Xuan Reservoir
- PS-2 site: Upstream reach of the Ky Lo River
- PS-3 Site: Midstream reach of the Ky Lo River

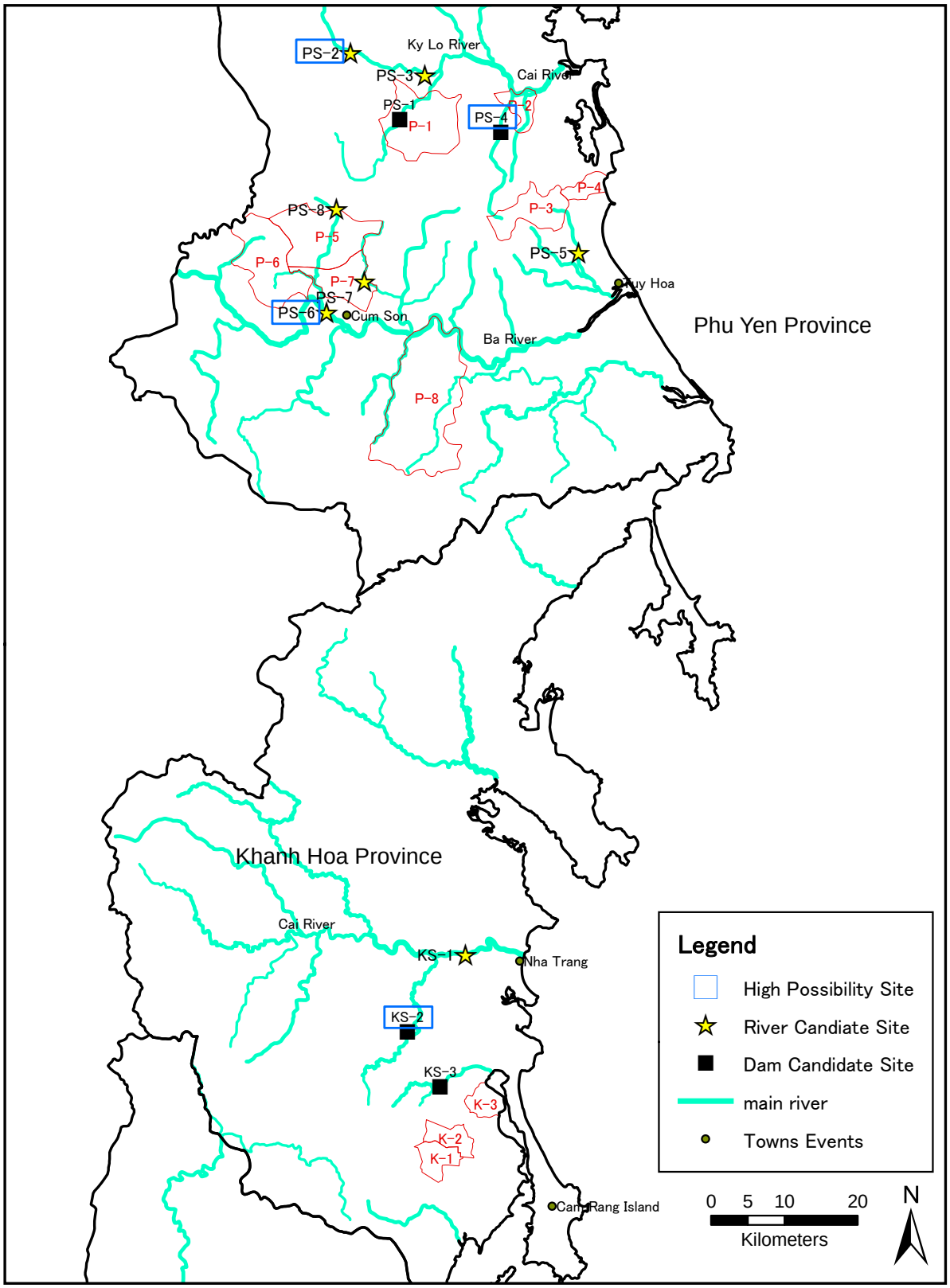


Figure 8.2.1 Locations of Candidate Sites and High Possibility Sites for Surface Water Sources (1/2)

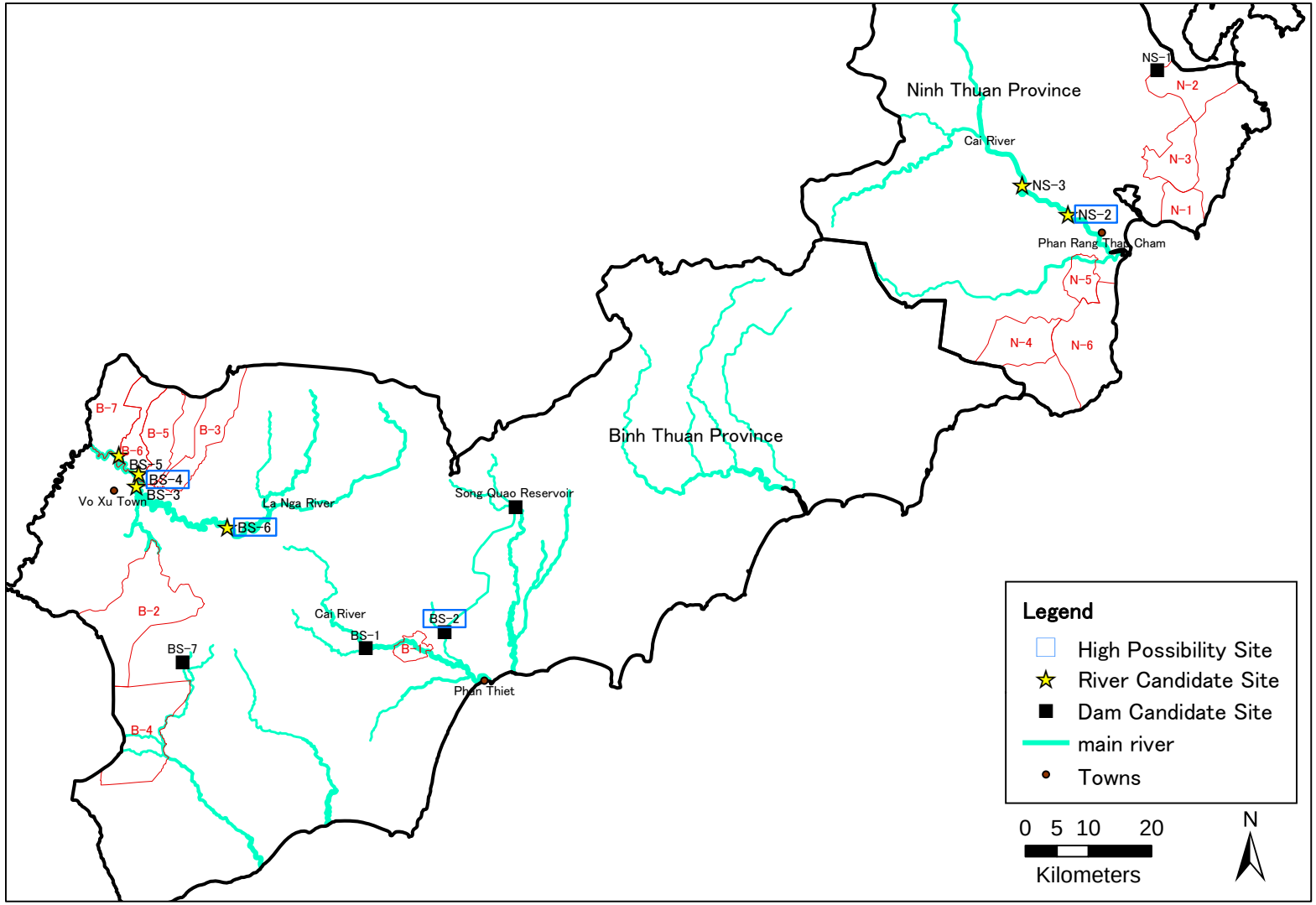


Figure 8.2.2 Locations of Candidate Sites and High Possibility Sites for Surface Water Sources (2/2)

PS-1 Site: Phu Xuan Reservoir

Phu Xuan Reservoir (PS-1 site) locates about 3 km southwest from the center of P-1. This is an irrigation reservoir constructed in 1996 and managed by Irrigation Company. Its own catchment area is about 100 km^2. Service area for irrigation during the dry season is about 300 ha.

Table 8.2.3 Design Parameters of Phu Xuan Reservoir

1. High water level (HWL)	36.0 m	2. Gross storage volume	10.45 mcm
3. Maximum water level	37.0 m	4. Maximum storage volume	12.00 mcm
5. Sediment level	25.9 m (estimated by 6.)	6. Sediment storage volume	0.63 mcm (estimated: 2. x 6 %)
7. Effective Water Depth	10.1 m Max. 11.1m	8. Effective storage volume	9.82 mcm Max.11.37mcm
1) Data Source: Irrigation Company, Phu Yen Province 2) Note: Sediment storage volume is assumed at 6 % of the gross storage volume, which is referred to the design of Dong Tron Reservoir located near P-2.			

Table 8.2.4 Annual Minimum Water Level and Storage Volume of Phu Xuan Reservoir

Year	Lowest WL (m)	Minimum Storage (mcm)	Minimum Effective Water Depth(m)	Min. Effective Storage (mcm)	Min Effect. Storage/Design Effect. Storage (%)
1998	28.77	2.193	3.07	1.563	15.9
1999	28.75	2.180	2.85	1.550	15.8
2000	30.50	3.660	4.60	3.030	30.9
2001	28.17	1.785	2.27	1.155	11.8
2002	24.60	0.210	-1.30	-0.420	-4.3
2003	29.71	2.930	3.81	2.300	23.4
2004	30.04	3.210	4.14	2.580	26.3
2005	27.43	1.345	1.53	0.715	7.3
2006	30.03	3.199	4.13	2.569	26.1
2007	28.95	2.316	3.05	1.686	17.2
Average	28.70	2.300	2.82	1.670	17.0
Data Source: Irrigation Company, Phu Yen Province					

mcm: million m^3

Based on the above operation data of Phu Xuan Reservoir, water level becomes minimum in the end of the dry season, which was only about 2.8 m above the estimated sediment level in an average from 1998 to 2007. The average minimum effective storage volume is about 1.7 million m3 (mcm), which is only 17 % of the estimated design effective storage. Especially, the minimum storage volume in 2002 became lower than the sediment storage volume. The minimum storage volume in 2005 was also very small. Although the required water quantity for P-1 is only 24,400 m^3 for one month to 73,200 m^3 for three months, as the allowance of the effective storage volume is very small, which is less than 30 % and even less than 20 % during the dry season, it has a possibility of unstable water supply in

drought year due to lowering the reservoir water level and storage to keep supplying irrigation water. Therefore, Phu Xuan Reservoir has low possibility for surface water sources for P-1.

PS-2 Site: Upstream Reach of the Ky Lo River

PS-2 site locates at the outlet of the mountainous area of the Ky Lo River, and about 13 km northwest from P-1. The width of the river is about 30 to 40 m. There is no discharge data available around this site. However, according to information of the manual ferry operator at the site, flow condition during the dry season becomes about 20 m of water width and about 1 to 1.2 m of water depth. It can be estimated that discharge of the river at PS-2 site becomes about 3 to 5 m^3/s during the dry season. Water quality in this reach is generally very good. However, turbidity will be high during floods.

There are two irrigation pumping stations locate near the site. Even under operation of these irrigation pumping stations, this site has enough water quantity. Therefore PS-2 site has a high possibility of surface water source for P-1, which requires only 11.3 l/sec.

PS-3 Site: Midstream Reach of the Ky Lo River

PS-3 site locates in the midstream reach of the Ky Lo River, which is about 5 km from P-1 and 5 km upstream from the junction with the Cai River. Width of the river at the site is about 40 to 50 m. Velocity of the flow is very slow like impounding. Water quantity is assumed to be bigger than the PS-2 site. In terms of water quantity, this site has marginal possibility for surface water sources for P-1, however it is not recommendable due to the problem of water quality.

2) Possible Alternative Water Source for P-2

There is only one candidate site of surface water source for P-2.

- PS-4 site: Dong Tron Reservoir

Dong Tron Reservoir (PS-4 site) locates at about 5 km south-southwest from P-2. This is an irrigation reservoir constructed in 2005 and managed by Irrigation Company. Its own catchment area is about 58 km^2. Service area for irrigation during the dry season is about 120 ha. In addition to the pipe for irrigation water supply, another pipe with 300 mm diameter for drinking water supply is already installed in the dam. However, water transmission pipeline for drinking water supply from the dam to the downstream area has not been constructed yet.

Table 8.2.5 Design Parameters of Don Tron Reservoir

1. High water level (HWL)	35.5 m	2. Gross storage volume	19.5 mcm
3. Maximum water level		4. Maximum storage volume	
5. Low water level (Sediment level)	18.0 m	6. Sediment storage volume	1.24 mcm (6.3 % of 2.)
7. Effective Water Depth	17.5 m	8. Effective storage volume	18.26 mcm
Data source: Irrigation Company, Phu Yen Province			

Table 8.2.6 Annual Minimum Water Level and Storage Volume of Don Tron Reservoir

Year	Lowest WL (m)	Minimum Storage (mcm)	Minimum Effective Water Depth (m)	Min. Effective Storage (mcm)	Min Effect. Storage/Design Effect. Storage (%)
2005	26.00	7.00	8.00	5.76	31.5
2006	29.00	10.40	11.00	9.16	50.2
2007	30.00	11.60	12.00	10.36	56.7
Average	28.33	9.67	10.33	8.43	46.1
Data Source: Irrigation Company, Phu Yen Province					

mcm: million m^3

Based on the above operation data of Don Tron Reservoir, even though it is only three years data, the storage volume with water level become minimum at the end of dry season, which is 9.7 m above the low water level with effective storage volume of 8.4 million m3 (46 % of the design effective storage volume) in an average. Therefore, Dong Trong Reservoir has still enough allowance in the minimum storage volume during the dry season, and has a capacity of supplying water to P-2, which requires only 14,900 m3 of water for one month and 44,700 m3 for three months. Therefore, Don Tron Reservoir has high possibility to be a surface water source for P-2.

3) Possible Alternative Water Source for P-3

There is only one candidate site of surface water source for P-3.

- PS-5 site: Small river originated from P-3 area.

However, as the water quantity of the small river from P-3 area is insufficient, there is no possibility to take water from this river to P-3. It is better to consider supplying water to P-3 from the Urban Water Supply System of Tuy Hoa City.

4) Possible Alternative Water Sources for P-5, P-6 and P-7

There are three candidate sites of surface water source for P-5, P-6 and P-7 as follows;

- PS-6 site: Ba River near P-5, P-6 and P-7.
- PS-7 site: Suoi Bac River (left tributary of the Ba River) near P-7.
- PS-8 site: Another left tributary of the Ba River near P-5.

PS-6 Site: Ba River near P-5, P-6 and P-7

Distance from the Ba River (PS-6 site) to P-5, P-6 and P-7 is about 4 to 10 km. The minimum monthly average discharge of the Ba River during dry season between 1995 and 2006 is 22 to 107 m^3/s at the discharge gauging station in Cum Son Town, which locates at about 3 km south from P-7 (see Table below). Cum Son Town takes surface water from the Ba River, treats the water and supply to the town. According to the Urban Water Supply Agency, water quality of the Ba River is generally good except high turbidity during the rainy season especially during floods.

Table 8.2.7 Minimum Average Monthly Discharge of the Ba River at Cum Son Gauging Station (Catchment Area at the G.S.: 12,400 km^2)

Year	Month	Discharge (m3/s)	Year	Month	Discharge (m3/s)
1995	4	28.8	2001	4	48.8
1996	4	52.0	2002	4	24.4
1997	3	74.4	2003	4	31.3
1998	4	22.6	2004	4	39.7
1999	3	107.0	2005	3	22.2
2000	3	105.0	2006	4	48.3
Average (1995 – 2006) = 50.4 m^3/s					
Data source: Meteorological Center in Nha Trang					

There is an under-constructed hydropower dam called "Downstream Ba River Hydro-electricity" on the Ba River main stream at about 9 km upstream from PS-6 Site. This hydropower dam is managed by Vietnam Electricity Corporation. Gross storage volume of the dam is 349 million m^3 and effective storage volume is 165 million m^3. Environmental flow discharged to the downstream of the river is maximum 393 m^3/s and minimum 56.7 m^3/s. As the environmental flow is more than 56.7 m^3/s, it will not make decreasing the minimum discharge of the Ba River at PS-6 site.

Therefore, PS-6 site has high possibility to be a surface water source for P-5, P-6 and P-7, which require only total 12.6 litter/sec of water.

PS-7 and PS-8 Sites: Left Tributaries of the Ba River

PS-7 site in the Suoi Bac River locates at about 2.5 km northeast from the center of P-7. However, water quantity becomes very small or almost no water during the dry season. Therefore, PS-7 site has no possibility to be a surface water source for P-7 (even for P-5 and P-6).

PS-8 site is another left tributary of the Ba River, which locates about 4 km north from the center of P-5. Water quantity in this reach also becomes very small or almost no water during the dry season. Therefore, PS-8 site has no possibility to be a surface water source for P-5 and P-6 (even for P-7).

(3) Possible Alternative Water Source in Khanh Hoa Province

In Khanh Hoa Province, there is the Cai River, which flows through Nha Trang City. The Cai River is the water source of Nha Trang City. However, distance from the Cai River to the target communes for alternative water sources (K-2 and K-3) is long about 21 to 26 km. Therefore the Cai River is considered a reference site (KS-1). There are two reservoirs locate near K-2 and K-3, which locate in the smaller river basins. They are Suoi Dau Reservoir and Cam Ranh Reservoir.

1) Possible Alternative Water Sources for K-2 and K-3

Candidate sites are as follows;

KS-2 site: Suoi Dau Reservoir, KS-3 site: Cam Ranh Reservoir.

KS-2 Site ; Suoi Dau Reservoir

Suoi Dau Reservoir locates at about 13 km northwest from K-2. This is an irrigation reservoir constructed in 2005, and managed by Irrigation Company. Purpose of the reservoir is irrigation and drinking water supply. Its own catchment area is about 120 km2. Service area for irrigation is 4,505 ha. Suoi Dau Reservoir is currently supplying water to Suoi Dau Industrial Zone and Cam Ranh Island with water volume of 10 million m3/year.

Table 8.2.8 Design Parameters of Suoi Dau Reservoir

1. High water level (HWL)	38.5 m (estimated)	2. Gross storage volume	28.88 mcm
3. Maximum water level	42.4 m	4. Max. storage volume	41.54 mcm (est.)
5. Sediment level	29.5 m	6. Sediment storage volume	1.44 mcm (esti.: 5 % x 2.)
7. Effective Water Depth	9.0 m Max. 12.9 m	8. Effective storage volume	27.44 mcm Max. 40.10 mcm
Data source: Irrigation Company, Khanh Hoa Province			

mcm: million m^3

Table 8.2.9 Annual Minimum Water Level and Storage Volume of Suoi Dau Reservoir

Year	Lowest WL (m)	Minimum Storage (mcm)	Minimum Effective Water Depth (m)	Min. Effective Storage (mcm)	Min Effect. Storage/Design Effect. Storage (%)
2006	32.92	10.01	3.42	8.57	31.2
2007	35.10	18.03	5.60	16.59	60.5
Average	34.01	14.02	4.51	12.58	45.9
Data source: Irrigation Company, Khanh Hoa Province					

mcm: million m^3

KS-3 Site; Cam Ranh Reservoir

Cam Ranh Reservoir locates about 4 km north from K-2. This reservoir was constructed in 1992 and is managed by Irrigation Company. Its own catchment area is about 62 km^2. Purpose of Cam Ranh Reservoir is irrigation and drinking water supply. Service area of irrigation is 3,000 ha. A private company is taking water from the irrigation canal near K-2, and supplies raw water to Cam Ranh Island.

Table 8.2.10 Design Parameters of Cam Ranh Reservoir

1. High water level (HWL)	29.6 m (estimated)	2. Gross storage volume	19.39 mcm
3. Maximum water level	32 m	4. Max. storage volume	25.60 mcm (est)
5. Sediment level	22 m	6. Sediment storage volume	0.89 mcm (est.)
7. Effective Water Depth	7.60 m Max. 10.00 m	8. Effective storage volume	18.50 mcm Max. 24.71 mcm
Data source: Irrigation Company, Khanh Hoa Province			

mcm: million m^3

Table 8.2.11 Annual Minimum Water Level and Storage Volume of Cam Ranh Reservoir

Year	Lowest WL (m)	Minimum Storage (mcm)	Minimum Effective Water Depth (m)	Min. Effective Storage (mcm)	Min Effect. Storage/Design Effect. Storage (%)
2005	19.70	0	-2.30	-0.89 (est.)	-4.8
2006	26.02	10.29	4.02	9.40	50.8
2007	23.25	3.20	1.25	2.31	12.5
Average	22.99	4.50	0.99	3.60	19.5
Data source: Irrigation Company, Khanh Hoa Province					

mcm: million m^3

Possible Surface Water Sources:

Based on the available reservoir operation data, Suoi Dau Reservoir has enough water even during the dry season with the minimum effective storage of 30 to 60 %. On the other hand, Cam Ranh Reservoir became empty in 2005, and also the minimum effective storage became only 12.5 % in 2007. Therefore, there is a possibility of occurrence of insufficient storage volume of Cam Ranh Reservoir during the dry season especially during drought. Suoi Dau Reservoir has high reliability for stable water supply, and high possibility of surface water source to K-2 and K-3. Due to the possibility of unreliable water supply during the dry season, Cam Ranh Reservoir has marginal possibility for surface water source to K-2 and K-3. Therefore, in case of using Cam Ranh Reservoir for surface water source, it is better to consider back-up supply from Suoi Dau Reservoir and/or groundwater wells to increase the reliability for water supply in drought year. In addition, for the water supply to K-3 commune, the water supply capacity 1,230 m^3/day from Cam Ranh Reservoir is appraised as feasible by the Irrigation Company that is responsible for the operation and maintenance of Cam Rang Reservoir.

(4) Possible Alternative Water Source in Ninh Thuan Province

In Ninh Thuan Province, the Cai River (another name: Dinh River), which relates to the possibility of surface water sources for the target communes of the Study. In addition to the Cai River, there is Song Trau Reservoir located near N-2. There are three candidate sites for surface water sources as follows;

- NS-1 site: Song Trau Reservoir.
- NS-2 site: Cai River at Lam Cam Weir
- NS-3 site: Cai River at Nha Trinh Weir

NS-1 Sites: Song Trau Reservoir for N-1, N-2 and N-3

Song Trau Reservoir (NS-1 site) locates about 3 km northwest from the center of N-2. This is an irrigation reservoir constructed in 2005 and managed by Irrigation Company. Its own catchment area is about 55 km^2. Service area of irrigation is 3,000 ha. The reservoir has also design water supply

volume of 1.4 million m^3/year (3,836 m^3/day) for the nearby communes, which is bigger than the required water volume by N-1, N-2 and N-3 of 2,600 m^3/day. However, there is no water supply pipe. According P-CERWASS, a tunnel was tried to be constructed from 15 km downstream, but it has not been completed yet. Furthermore, there is a future plan of supplying industrial water to Du Lang Industrial Zone (400 ha) and 4 to 5 communes with 20,000 m^3/day (=7.3 million m^3/year) from this reservoir. The plan has been already submitted to PPC.

Table 8.2.12 Design Parameters of Song Trau Reservoir

1. High water level (HWL)	42.30 m	2. Gross storage volume	31.53 mcm
3. Sediment level	28.70 m	4. Sediment storage volume	1.13 mcm (3.6 % of 2.)
5. Effective Water Depth	13.60 m	6. Effective storage volume	30.40 mcm
Data source: Irrigation Company, Ninh Thuan Province			

mcm: million m^3

Table 8.2.13 Annual Minimum Water Level and Storage Volume of Song Trau Reservoir

Year	Lowest WL (m)	Minimum Storage (mcm)	Minimum Effective Water Depth (m)	Min. Effective Storage (mcm)	Min Effect. Storage/Design Effect. Storage (%)
2006	35.00	9.03	6.30	7.90	26.0
2007	30.54	2.39	1.84	1.26	4.1
Average	32.77	5.71	5.71	4.58	15.1
Data source: Irrigation Company, Ninh Thuan Province					

mcm: million m^3

In 2007, the minimum effective storage became 1.26 million m^3, which was only 4 % of the design effective storage of the reservoir. Therefore, there is a possibility that storage volume of the reservoir may become very small in the dry season to keep supplying irrigation water.

Water quality of the reservoir is polluted with some bad smell including eutrophication problem. It may be caused by wastewater from the settlements and pasturage of cows and water buffalos in the own catchment area of the reservoir.

Due to the reason of pollution of water in the reservoir, Song Trau Reservoir has low possibility of surface water source for N-1, N-2 and N-3.

NS-2 Sites: Cai River at Lam Cam Weir for N-1 to N-3 and N-4 to N-6

NS-2 site locates in Phan Rang Thap Cham City about 10 km upstream from the river mouth of the Cai River. The width of the river is about 50 to 60 m. Lam Cam Weir is non-gated weir with height of several meters. Phan Rang Thap Cham City takes water from just upstream of the weir on the left bank, treats the water and supply drinking water to the city.

From Da Nihm Reservoir, which is a hydropower reservoir and locates in the upstream basin of the Don Nai River, about 20 m^3/s of water is transferred to the upper reach of the right tributary of the Cai River in Ninh Thuan Province.

There are two irrigation canals start from Nha Trinh Weir (NS-3 site), and one irrigation canal starts from Lam Cam Weir. Estimated total abstraction quantity by these three irrigation canals is about 10 m^3/s.

Quantity of abstraction of water for Phan Rang City at Lam Cam Weir is currently 20,000 m^3/day (about 230 l/sec). Future plan of abstraction is 50,000 m^3/day (about 580 l/sec.).

Based on the observed discharge data at upstream gauging station at Quan Ninh (catchment area: 656 km^2), discharge of the river at NS-2 site by rainfall runoff during the dry season is estimated at about three times of that at Quan Ninh, and become around 3 to 20 m^3/s with average of 11 m^3/s (see table below).

Table 8.2.14 Estimated Annual Minimum Discharge at Lam Cam Weir (NS-2 Site)

Year	Month	Quan Ninh G.S. Discharge (m^3/s)	At NS-2 Site Estimated Discharge (m^3/s)	Year	Month	Quan Ninh G.S. Discharge (m^3/s)	At NS-2 Site Estimated Discharge (m^3/s)
1997	6	6.68	20.04	2003	4	3.24	9.72
1998	6	1.78	5.34	2004	3	3.15	9.45
1999	4	5.96	17.88	2005	4	1.00	3.00
2000	3	5.28	15.84	2006	5	4.51	13.53
2001	5	4.37	13.11	2007	4	2.36	7.08
2002	5	2.76	8.28	Average		3.74	11.21
Data source: Meteorological Center in Nha Trang							
Note: Estimated discharge at NS-2 Site = 3 x Discharge at Quan Ninh G.S.							

Estimated water quantity at Lam Cam Weir:

Current condition: 3 to 18 (average 11) m^3/sec + 20 m^3/s (from Da Nihm Reservoir) – 10 m^3/s (for irrigation) – 0.23 m^3/sec (water supply to Phan Rang City) =13 to 28 (average 21) m^3/s.

Future condition: 3 to 18 (average 11) m^3/sec + 20 m^3/s (from Da Nihm Reservoir) – 10 m^3/s (for irrigation) – 0.58 m^3/sec (water supply to Phan Rang City) =12 to 27 (average 20) m^3/s.

Required water demand for N-1, N-2 and N-3 is 36.0 l/s, that of N-4, N-5 and N-6 is 34.7 l/s, and total of N-1 to N-6 is 70.7 l/s. The discharge of the river during the dry season at this site is sufficient for supplying this required quantity. Water quality of the river is generally good except slightly high

NH3 content (based on the water quality data of MONRE at NS-2 site).

Therefore, NS-2 site has a high possibility of surface water source for N-1 to N-3. This site also has a high possibility of surface water source for N-4 to N-6.

NS-3 Sites: Cai River at Nha Trinh Weir

NS-3 site locates about 25 km upstream from the river mouth of the Cai River. Condition of the river is similar to NS-2 site. However as the distance to the target communes (N-1 to N-6) are long, this site is considered as a reference site.

(5) Possible Alternative Water Sources in Binh Thuan Province

In Binh Thuan Province, there are two major rivers relating to the target communes of the Study. They are the Cai River and the La Nga River. The Cai River flows near B-1. The La Nga River is one of the tributaries of the Dong Nai River, which is one of the major rivers in Vietnam. The Dong Nai River is the water source of Ho Chi Minh City. The La Nga River flows near to B-3, B-5, B-6 and B-7.

In addition to these rivers, there are two reservoirs locate near B-1. They are Bao Bau Reservoir located in the midstream reach of the Cai River. Another one is Cam Hang Reservoir.

1) Possible Alternative Water Sources for B-1

There are two candidate sites of surface water source for B-1 as follows;

- BS-1 site: Bao Bau Reservoir
- BS-2 site: Cam Hang Reservoir

BS-1 Site: Bao Bau Reservoir

Bao Bau Reservoir (BS-1 site) is an irrigation reservoir, which locates at about 9 km west from B-1 along the Cai River. The reservoir is managed by Irrigation Company. Topography around the dam site and reservoir area is rather flat.

Table 8.2.15 Design Parameters of Bao Bau Reservoir

1. High water level (HWL)	39.00 m	2. Gross storage volume	1.262 mcm
3. Maximum water level	42.00 m	4. Maximum storage volume	6.938 mcm
Data source: Irrigation Company, Binh Thuan Province			

mcm: million m^3

Water in the reservoir is very much polluted including eutrophication problem. Therefore, Bao Bau Reservoir has low possibility to be a surface water source for B-1.

BS-2 Site: Cam Hang Reservoir

Cam Hang Reservoir (BS-2 site) locates about 5 km northeast from B-1. Cam Hang Reservoir is the lower reservoir of Song Quao Reservoir. Song Quao Reservoir locates about 25 km north from Phan Thiet City. These two reservoirs are managed by Irrigation Company. Song Quao Reservoir (own

catchment area of about 296 km^2) is irrigation reservoir and also the water source for the urban water supply system of Phan Thiet City as well as for industrial water supply. Water is transferred through canal to Cam Hang Reservoir from Song Quao Reservoir, and then goes to the urban water supply system of Phan Thiet City.

Table 8.2.16 Design Parameters of Cam Hang Reservoir

1. High water level (HWL)	25.00 m	2. Gross storage volume	1.20 mcm
3. Maximum water level	25.50 m	4. Maximum storage volume	1.93 mcm
5. Sediment level	21.00 m	6. Sediment storage volume	0.013 mcm (1.7 % of item 2.)
7. Effective Water Depth	13.60 m	8. Effective storage volume	1.17 mcm
Data source: Irrigation Company, Binh Thuan Province			

mcm: million m^3

Table 8.2.17 Design Parameters of Song Quao Reservoir

1. High water level (HWL)	89.00 m	2. Gross storage volume	73.0 mcm
3. Maximum water level	91.00 m	4. Maximum storage volume	
5. Sediment level	72.00 m	6. Sediment storage volume	5.7 mcm (7.8 % of item 2.)
7. Effective Water Depth	13.60 m	8. Effective storage volume	67.3 mcm
9. Service Area for Irrigation: 8120 ha			
10. Supply for Drinking Water: 0.231 m^3/s			
11. Supply for Industrial Water: 0.194 m^3/s			
Data source: Irrigation Company, Binh Thuan Province			

mcm: million m^3

Table 8.2.18 Annual Minimum Water Level and Storage Volume of Song Quao Reservoir

Year	Lowest WL (m)	Minimum Storage (mcm)	Effective Water Depth (m)	Min. Effective Storage (mcm)	Min Effect. Storage/Design Effect. Storage(%)
1997	80.00	28.85	8.00	23.15	31.7
1998	70.00	3.65	-2.00	-2.05	-2.8
1999	85.82	54.52	13.82	48.82	66.9
2000	78.00	22.00	6.00	16.30	22.3
2001	72.30	6.39	0.30	0.69	0.9
2002	72.30	6.39	0.30	0.69	0.9
2003	74.87	12.76	2.87	7.06	9.7
2004	74.42	11.02	2.42	5.32	7.3
2005	73.17	8.08	1.17	2.38	3.3
2006	74.20	10.67	2.20	4.97	6.8
2007	77.49	19.60	5.49	13.90	19.0
Average	75.69	16.72	3.69	11.02	15.09
Data source: Irrigation Company, Binh Thuan Province					

mcm: million m^3

Average minimum effective storage volume of Song Quao Reservoir from 1997 to 2007 is 11.02 million m^3 with 15 % of design effective storage volume. The minimum effective storage volume became very small in 1998, 2001 and 2002, but its tendency has been slightly improved from 2003 to 2007. Although the percentage of the minimum effective storage volume is only 15 % of the design

effective volume, the average minimum effective storage volume of Song Quao Reservoir is sufficient. Furthermore, for the water supply to B-1 commune, the water supply capacity 1,000 m^3/day from Cam Hang Reservoir is ensured by an Irrigation Company that is responsible for the operation and maintenance of Cam Hang and Song Quao Reservoirs, and water quality in Cam Hang Reservoir looks like good. Therefore, Cam Hang Reservoir has a high possibility of surface water source for B-1, which requires water of only 16,500 m^3 for one month and 49,500 m^3 for three months.

2) Possible Alternative Water Sources for B-3, B-5, B-6 and B-7

There are two candidate sites of surface water source for B-3, B-5, B-6 and B-7 as follows;

- BS-4 site: Right bank of the La Nga River near B-6
- BS-5 site: Right Bank of the La Nga River near B-7

In addition to the above two sites, there is a reference site (BS-3 site) on the left bank of the La Nga River near Vo Xu Town, which locates on the opposite side of the river of these four target communes. There is Vo Xu Water Factory (water purification plant) at BS-3 site, which is managed by P-CERWASS, Binh Thuan Province. The water purification plant takes water from the La Nga River through the existing irrigation pumping station and supply drinking water to Vo Xu Town.

BS-4 and BS-5 Sites: Right Bank of the La Nga River near B-6 and B-7

BS-4 site locates at about 4 km south from the center of B-6, which is on the right bank of the La Nga River. The width of the La Nga River at this site is about 20 to 30 m. The minimum discharge during the dry season at Ta Pao Discharge Gauging Station, which locates at about 25 km upstream from this site with catchment area of 2012 km^2, is 5 m3/s to 42 m^3/s with average of 20 m^3/s from 1995 to 2006. Assuming that the catchment area of BS-4 site is about 3 times of that of Ta Pao Discharge Gauging Station., the minimum discharge at BS-4 site is estimated to be more than 16 m^3/s with an average of 60 m^3/s. Even if irrigation takes several m^3/s of water from the upper reaches, the minimum discharge of the river around BS-4 site is estimated to be more than 10 m^3/s. Therefore, discharge of the river is sufficient even during the dry season.

Table 8.2.19 Estimated Annual Minimum Discharge at The La Nga River (BS-4 Site)

Year	Month	Ta Pao G.S. Discharge (m3/s)	At BS-4 Site Estimated Discharge (m3/s)	Year	Month	Ta Pao G.S. Discharge (m3/s)	At BS-4 Site Estimated Discharge (m3/s)
1995	4	7.39	22.17	2001	3	15.30	45.90
1996	3	7.47	22.41	2002	2	32.00	96.00
1997	3	12.70	38.10	2003	2	30.30	90.90
1998	3	5.30	15.90	2004	3	31.00	93.00
1999	3	17.80	53.40	2005	2	42.00	126.00
2000	5	6.40	19.20	2006	1	35.90	107.70
					Average	20.30	60.90
Data source: Meteorological Center in Nha Trang							
Note: Estimated discharge at BS-4 Site = 3 x Discharge at Ta Pao G.S.							

According to the information of P-CERWASS, water quality of the river tested at BS-3 site is generally good except turbidity, which should be similar to BS-4 site. There is an existing irrigation pumping station at BS-4 site, which also has intake structure from the river. BS-5 site locates about 1 km south from the center of B-7. Condition of the La Nga River at BS-5 site is almost same as that of BS-4 site. However, there is no intake structure at BS-5 site.

Considering the availability of the existing intake structure relating to the irrigation pumping station, BS-4 site has high possibility and BS-5 site has marginal possibility of surface water source for B-3, B-5, B-6 and B-7. For constructing a pumping station and water purification plant at or around BS-4 site, it is necessary to set the structures with equipment as well as the access road to be sufficient height over flood water level around the site. In addition to that, it is also necessary for the access road to have drainage channels to avoid destruction with overflowing during floods.

3) Possible Alternative Water Sources for B-2 and B-4

There are two candidate sites of surface water source for B-2 and B-4 as follows;

- BS-6 site: Upstream Reach of the La Nga River around Dong Kho Town
- BS-7 site: Irrigation Pond near B-2.

BS-6 Sites: Upstream Reach of the La Nga River around Dong Kho Town

BS-6 site locates around the end of mountainous area of the La Nga River. Ta Pao Discharge Gauging Station locates near this site. Water quality looks like good with lower turbidity than the downstream reach at BS-3 to BS-6 sites. As there are two hydropower dams with hydropower stations exist in the most upstream basins of the La Nga River, it can be estimated that fluctuation of discharge of the river occurs in a day. Although distance between BS-6 site and B-2 and B-4 is long about 16 km to 36 km, as these two communes have no good surface water sources around their areas, BS-6 site has a high possibility to be a surface water source for B-2 and B-4.

BS-7 Sites: Irrigation Pond near B-2

BS-7 site locates between B-2 and B-4, at about 13 km from B-2 and about 200 m east from the road from B-2 to B-4. Water quantity of this pond during the dry season is small. Water quality in the pond is not so good including eutrophication problem. Therefore, BS-7 site has no possibility to be a surface water source to B-2 (even with B-4).

(6) Summary of the Site Reconnaissance and Data Analyses

Based on the results of the site reconnaissance and relating analysis, summary of the possibility for alternative water sources focusing surface water is shown in the table below as well as detail in Table 8.2.20.

Table 8.2.20 Summary of the Possibility for Alternative Water Sources from Surface Water

Province	Site No.	Name of River / Reservoir	Kind of Water Source	Target Commune	Possibility
1. Phu Yen	PS-1	Phu Xuan Res.	Reservoir	P-1	Low
	PS-2	Ky Lo River (upstream reach)	River	P-1	**High**
	PS-3	Ky Lo River (Midstream reach)	River	P-1	Marginal
	PS-4	Dong Tron Res.	Reservoir	P-2	**High**
	PS-5	Small river	River	P-3	No
	PS-6	Ba River	River	P-5, P-6 and P-7	**High**
	PS-7	Suoi Bac River	River	P-7	No
	PS-8	Tributary Ba River	River	P-5 and P-6	No
2. Khanh Hoa	KS-1 (Reference site)	Cai River	River	-	-
	KS-2	Suoi Dau Res.	Reservoir	K-2 and K-3	**High**
	KS-3	Cam Ranh Res.	Reservoir	K-2 and K-3	Marginal (better combining with other water sources)
3. Ninh Thuan	NS-1	Song Trau Res.	Reservoir	N-1, N-2 and N-3	Low
	NS-2	Cai River at Lam Cam Weir	River	N-1, N-2, N-3, N-4, N-5 and N-6	**High**
	NS-3 (Reference site)	Cai River at Nha Trinh Weir	River	-	-
4. Binh Thuan	BS-1	Bao Bau Res.	Reservoir	B-1	Low
	BS-2	Cam Hang Res.	Reservoir	B-1	**High**
	BS-3 (Reference site)	La Nga River (left bank near Vo Xu Town)	River	-	-
	BS-4	La Nga River (right bank near B-6)	River	B-3, B-5, B-6 and B-7	**High**
	BS-5	La Nga River (right bank near B-7)	River	B-3, B-5, B-6 and B-7	Marginal
	BS-6	La Nga River (upstream around Dong Kho Town)	River	B-2 and B-4	**High**
	BS-7	Pond near B-2	Pond	B-2 and B-4	No

Table 8.2.21 Summary of the Site Reconnaissance and Data Analysis of Possible Surface Water Sources (1/2)

Site No.	River / Reservoir	Coordinates (at observed site)	Target Commune	Distance (Item 2 to 4)	Difference of Elevation (Item 2 – 4)	Water Quantity during dry season	Water Quality (Ocular observation)	Others	Possibility of Water Supply Source
1	2	3	4	5	6	7	8	9	10
1. Phu Yen Province									
PS-1	Phu Xuan Reservoir	13.29053 ºN 109.03555 ºE	P-1	About 3 km	10 m	Not enough	Not so bad	Irrigation reservoir	Low possibility
PS-2	Ky Lo River (Upstream reach)	13.37263 ºN 108.97303 ºE	P-1	About 13 km	10 m	Enough	Very good	Exist 2 irrig. pump stations.	High possibility
PS-3	Ky Lo River (Midstream reach)	13.34549 ºN 109.06671 ºE	P-1	About 5 km	-5 m	Enough	Not so good	-	Marginal possibility
PS-4	Dong Tron Reservoir	13.27567 ºN 109.16115 ºE	P-2	About 5 km	15 m	Enough	Probably good	Irrigation res. also with water supply pipe	High possibility
PS-5	Small river	13.12818 ºN 109.26200 ºE	P-3	-		Not enough	-	-	No possibility
PS-6	Ba River	13.05220 ºN 108.94560 ºE	P-5, P-6 and P-7	About 4 to 10 km	-120 to -40 m	Enough	Good	-	High possibility
PS-7	Suoi Bac River (tributary Ba R.)	13.09116 ºN 108.99264 ºE	P-7	About 2.5 km	36 m	Not enough	Good	-	No possibility
PS-8	River in P-5 (tributary Ba R.)	13.17042 ºN 108.95661 ºE	P-5 and P-6	About 4 to 12 km	-10 to 15 m	Not enough	Not so good	-	No possibility
2. Khanh HoaProvince									
KS-1	Cai River (in Nha Trang)	12.26101 ºN 109.12584 ºE	-	About 21 to 26 km		Enough	Good	Water source of Nha Trang City	- (reference site)
KS-2	Suoi Dau Reservoir	12.16636 ºN 109.05357 ºE	K-2 and K-3	About 16 to 18 km	0 to 20 m	Enough	Good	Irrigation and water supply reservoir	High possibility
KS-3	Cam Ranh Reservoir	12.09826 ºN 109.09554 ºE	K-2 and K-3	About 8 to 9 km	-10 to 10 m	Not enough	Good	Irrigation and water supply reservoir	Marginal possibility (better combining with KS-2 for back-up WS)

Table 8.2.22 Summary of the Site Reconnaissance and Data Analysis of Possible Surface Water Sources (2/2)

Site No.	River / Reservoir	Coordinates (at observed site)	Target Commune	Distance (Item 2 to 4)	Difference of Elevation (Item 2 – 4)	Water Quantity during dry season	Water Quality (Ocular observation)	Others	Possibility of Water Supply Source
1	2	3	4	5	6	7	8	9	10
3. Ninh Thuan Province									
NS-1	Song Trau Reservoir	11.80315 ºN 109.06749 ºE	N-1, N-2 and N-3	About 3 to 25 km	45 m	Not enough	Bad	Irrigation res. incl. design for water supply	Low possibility
NS-2	Cai River at Lam Cam Weir	11.59657 ºN 108.93936 ºE	N-1to 3, N-4 to 6	About 8 to 26 km	0 m	Enough	Good	Water source of Phan Rang City	High possibility
NS-3	Cai River at Nha Trinh Weir	11.63788 ºN 108.87256 ºE	-	About 16 to 29 km		Enough	Good	Irrigation weir	- (reference site)
4. Binh Thuan Province									
BS-1	Bao Bau Reservoir	10.96631 ºN 107.92632 ºE	B-1	About 9 km	25 m	Enough	Bad	Irrigation reservoir	Low possibility
BS-2	Cam Hang Reservoir	10.99128 ºN 108.04044 ºE	B-1	About 5 km	10 m	Enough	Good	Water source of Phan Thiet City from Song Quao Res.	High possibility
BS-3	La Nga River (Left Bank near Vo Xu Town)	11.19543 ºN 107.59187 ºE	B-3, B-5, B-6 and B-7	About 6 to 10 km	0 to 5 m	Enough	Good	Irrigation PS and water treatment plant	- (reference site)
BS-4	La Nga River (Right Bank near B-6)	11.21343 ºN 107.59513 ºE	B-3, B-5, B-6 and B-7	About 4 to 9 km	-20 m	Enough	Good	Irrigation PS with intake structure	High possibility
BS-5	La Nga River (Right Bank near B-7)	11.23943 ºN 107.56582 ºE	B-3, B-5, B-6 and B-7	About 3 to 12 km	-10 m	Enough	Good	No intake structure	Marginal possibility
BS-6	La Nga River (around Dong Kho Town)	11.13765 ºN 107.72428 ºE	B-2 and B-4	About 16 to 36 km	20 to 70 m	Enough	Good		High possibility
BS-7	Irrigation Pond near B-2	10.94367 ºN 107.66137 ºE	B-2 and B-4	About 10 km	0 to 50 m	Not enough	Not so good	Irrigation pond	No possibility

Note: Elevation is mainly measured by simple GPS.

8.2.3 Water Quality Test of the Selected Alternative Water Sources

The purpose of the water quality test is to know whether the water sources are applicable for drinking water supply or not.

As a result of the site reconnaissance and data analyses on alternative water sources, eight (8) sources with high possibility and one (1) source with marginal possibility were selected as candidate water sources to conduct water sampling and water quality test for feasibility study. The selected alternative water sources to be tested are shown in the Table below.

Table 8.2.23 Selected Alternative Water Sources for Water Quality Test

Province	Selected Alternative Water Sources for Water Quality Test	
	Code Name	Name of Water Source
Phu Yen	PS-2	Ky Lo River
	PS-4	Dong Tron Reservoir
	PS-6	Ba River
Khanh Hoa	KS-2	Suoi Dau Reservoir
	KS-3	Cam Ranh Reservoir
Ninh Thuan	NS-2	Lam Cam Weir
Binh Thuan	BS-2	Cam Hang Reservoir
	BS-4	La Nga River near Sung Nhon Pumping Station
	BS-6	La Nga River near Dong Kho Town

KS-3 (Cam Ranh Reservoir) is a water source with marginal possibility due to unreliable water storage volume during the dry season. However, there are possibilities of combination use of Cam Ranh Reservoir and other water sources in order to make up the shortage of water. Those are groundwater wells and Soui Dau Reservoir. To explore the possibility of those combination uses, the water quality test for the water in Cam Ranh Reservoir was implemented in spite of its marginal possibility.

Table 8.2.24 shows the results of the water quality tests. Values described by white characters within gray colored cells in the Table show that those do not have conformity with “the Drinking Water Hygienic Standard: 1329/2002/BYT/QD” or “Domestic supply water – Quality requirements: TCVN 5502: 2003”.

According to the test results, almost all water sources need treatment on Turbidity, Fe, Total coli-form. and E-coli-form. PS-4 site has odour with sulphide. There is a possibility of production of hydrogen sulphide under anaerobic condition near the bottom of the reservoir. It may be better to

adopt "selective withdrawal method" to take water from selected depth under aerobic condition in the reservoir.

Table 8.2.24 Results of the Water Quality Test at Nine (9) Selected Candidate Sites

(Standard: Drinking Water Hygienic Standard No.1329/2002/BYT/QD)

Item	Standard		Selected Candidates Sites								
	Value	Unit	PS-2	PS-4	PS-6	KS-2	KS-3	NS-2	BS-2	BS-4	BS-6
Color	15	mg/l Pt	15			7	0			11	8
Odor, taste	Non	---	Non	Smelly	Non	Non	Non	Non	Non	Non	Non
Turbidity	2	NTU	32	2	215	5	2	32	105	20	7
pH	6.0 ~ 8.5	---	6.59	6.85	7.24	7.18	7.52	7.20	7.00	6.58	6.58
Hardness	300	mg/l	13	40	30	10	13	23	25	13	15
TDS	1000	mg/l	64	76	84	66	60	72	88	32	36
Alminium	0.2	mg/l	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.05	0.00
$NH4^+$-N	1.5	mg/l	0.02	0.03	0.04	0.01	0.01	0.02	0.01	0.01	0.02
Antimony	0.005	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	0.05	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloride	250	mg/l	10.6	12.4	10.6	8.9	10.6	10.6	8.9	8.9	8.9
Chromium	0.05	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	2.0	mg/l	<0.001	<0.001	0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001
Cyanide	0.07	mg/l	0.004	0.003	0.008	0.004	0.005	0.004	0.006	0.003	0.005
Fluoride	0.7 - 1.5	mg/l	0.18	0.46	0.49	0.17	0.12	0.39	0.54	0.2	0.15
H_2S	0.05	mg/l	0.01	0.06	0.02	<0.01	<0.01	<0.01	0.01	0.01	0.01
Fe	0.5	mg/l	0.79	1.77	1.37	0.08	0.07	0.65	1.23	0.95	0.55
Lead	0.01	mg/l	<0.001	0.001	<0.001	0.001	0.001	0.001	<0.001	0.001	0.001
Manganese	0.5	mg/l	0.071	0.164	0.074	0.016	0.014	0.052	0.079	0.048	0.022
Hg	0.001	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
NO_3^-	50.0	mg/l	0.25	0.03	0.22	0.03	0.02	0.17	0.37	0.45	0.39
NO_2^-	3.0	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.03	<0.01	<0.01
Zinc	3.0	mg/l	0.004	0.004	0.015	0.01	0.246	0.015	0.015	0.009	0.010
$KMnO_4$	2.0	mg/l	1.44	0.08	1.68	0.24	0.56	0.08	1.84	0.08	0.16
Total coli	0	MPN/100ml	$3.8x10^3$	$8x10^3$	$>130x10^3$	$1x10^3$	$26x10^3$	$67x10^3$	$41x10^3$	$13x10^3$	$11.5x10^3$
E.coli	0	MPN/100ml	$3.5x10^3$	$0.5x10^3$	$24x10^3$	$0.1x10^3$	$10.2x10^3$	$13x10^3$	$15x10^3$	$4x10^3$	$3.4x10^3$

Other Reference Items Standard: Domestic supply water – Quality requirements, TCVN 5502: 2003

Item	Standard		Selected Candidates Sites								
	Value	Unit	PS-2	PS-4	PS-6	KS-2	KS-3	NS-2	BS-2	BS-4	BS-6
DO	> 6	mg/l	7.6	7.0	9.0	9.8	9.7	9.8	9.4	8.2	7.6
Pesticide 1	0.01	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pesticide 2	0.1	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenols	0.01	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Pesticide 1: Organic fertilizer pesticide, Pesticide 2: Organic chloride pesticide.

8.2.4 Intake Conditions of the Selected Alternative Water Sources

The selected alternative water sources before mentioned have such kind of intake conditions as shown in the Table below.

Table 8.2.25 Intake Conditions of Selected Alternative Water Resources

Site No.	River / Reservoir	Stability of Intake point	Upstream Condition	Salinity Intrusion
PS-2	Ky Lo River (Upstream reach)	Water route is stable. Intake point locates at undercut slope.	Natural area.	None
PS-4	Dong Tron Reservoir	A pipe for drinking water supply is already installed in the bank. Adoption of selective withdrawal method may be recommendable against water quality change under anaerobic condition.	Natural area.	None
PS-6	Ba River	Water route is stable. Intake point locates at a cliff.	Rural area and a Hydropower dam is under construction. The control of illegal mining is necessary to keep safety of water source.	None
KS-2	Suoi Dau Reservoir	Intake structure will be installed at existing irrigation channel close by the reservoir.	Natural area.	None
KS-3	Cam Ranh Reservoir	Intake structure will be installed at existing irrigation channel close by the reservoir.	Natural area.	None
NS-2	Cai River at Lam Cam Weir	Water route is stable owing to the Lam Can Weir and water transfer from Da Nihm Reservoir	Rural area.	None
BS-2	Cam Hang Reservoir	Intake structure will be installed at existing irrigation channel close by the reservoir.	Rural area.	None
BS-4	La Nga River (Right Bank near B-6)	Water route is stable. Intake structures including water treatment plant need counter measures against flooding.	Rural area.	None
BS-6	La Nga River (around Dong Kho Town)	Water route is stable but there is large flow rate change in a day due to the water use by hydropower stations in the upper stream.	Natural area and tow hydropower dams are operating.	None

CHAPTER 9

EXISTING WATER SUPPLY CONDITION

CHAPTER 9 EXISTING WATER SUPPLY CONDITION

9.1 Present Condition of Water Supply

Table 9.1.1 Present Condition of Piped Water Supply System in Four (4) Provinces

	Province	Phu Yen	Khanh Hoa	Ninh Thuan	Binh Thuan
1	Population in 2006	938,072	1,128,652	565,000	1,165,599
2	Population served in 2006	182,962	825,406	391,000	407,959
3	Rate of population served (%)	19.5	73.1	69.2	35.0
4	Population in 2007	N/A	1,169,208	573,500	1,177,193
5	Population served in 2007	N/A	915,095	401,450	466,750
6	Rate of population served (%)	N/A	78.3	70.0	39.6
Urban Water Supply Company					
7	Total No. of Systems	9	6	3	6
8	Total No. of Household	34,470	85,730	70,000	86,173
9	Total No. of Household Served	18,278	62,883	30,000	36,500
10	Total Population	173,132	428,652	180,000	430,865
11	Total Population Served	91,310	314,417	130,000	200,750
12	Rate of population served (%)	52.7	73.4	72.2	46.6
13	Average Daily Water Supply (m^3/day)	14,000	25,153	12,000	50,000
P-CERWASS					
14	Total No. of Systems	46	55	24	24
15	Total No. of Household	13,443	137,600	33,000	34,379
16	Total No. of Household Served	13,443	100,498	22,000	8,000
17	Total Population	67,213	688,000	200,000	295,032
18	Total Population Served	67,213	502,489	136,000	136,000
19	Rate of population served (%)	100.0	73.0	66.7	46.1
20	Average Daily Water Supply (m^3/day)	2,880	30,149	10,000	10,300
District People's Committee					
21	Total No. of Systems	19	7	20	15
22	Total No. of Household	160,378	2,400	30,000	47,218
23	Total No. of Household Served	4,487	1,700	20,000	11,800
24	Total Population	697,727	12,000	185,000	451,296
25	Total Population Served	24,439	8,500	125,000	130,000
26	Rate of population served (%)	2.8	70.8	66.7	28.8
27	Average Daily Water Supply (m^3/day)	1140	425	7,000	5,200
Remark		7-27; data in 2006	7-27; data in 2006 The water supply systems of DPC cover to urban and rural area as service area.	7-27; data in 2006	7-27; data in 2007

Source: P-CERWASS in four (4) provinces

Table 9.1.2 Present Condition of Access to Safe Water in Phu Yen Province

			2003	2004	2005	2006
1) Population and Household in rural area						
	Population in rural area		669,046	672,494	687,978	690,400
	Household in rural area		148,676	149,443	152,884	
2) Water Supply						
	Implemented Water Supply System		25	30	36	40
		Piped system	5	4	6	4
		Simple piped water supply system	0	0	0	0
		Drilled well	2	3	4	3
		Rain water tank	320	0	0	0
		Simple water filter	0	0	0	0
	Increased population (person)		9,276	6,867	8,597	4,055
	Growth rate of population (%)		1.39	1.02	1.24	0.60
	Population served (person)		259,542	270,599	303,316	342,438
	Rate of population served (%)		41.0%	43.0%	48.0%	49.6%

Source: Preparatory survey by JICA

Table 9.1.3 Present Condition of Access to Safe Water in Khanh Hoa Province

			2003	2004	2005	2006
1) Population and Household in rural area						
	Population in rural area		669,515	670,809	683,639	700,000
	Household in rural area					
2) Water Supply						
	Implemented Water Supply System					
		Piped system	32	45	51	56
		Simple piped water supply system	76	112	147	187
		Drilled well	370	370	370	370
		Rain water tank	3,013	3,013	3,013	3,013
		Simple water filter	940	940	940	940
	Increased population (person)		26,100	82,405	33,600	42,320
	Growth rate of population (%)		3.90%	12.30%	4.90%	6.00%
	Population served (person)		352,664	435,069	468,669	510,989
	Rate of population served (%)		52.7%	64.9%	68.6%	73.0%

Source: Preparatory survey by JICA

Table 9.1.4 Present Condition of Access to Safe Water in Ninh Thuan Province

			2003	2004	2005	2006
1) Population and Household in rural area						
	Population in rural area		371,296	376,808	382,344	388,079
	Household in rural area		74,259	75,362	76,469	77,616
2) Water Supply						
	Implemented Water Supply System		28	40	51	60
		Piped system	5	7	9	7
		Simple piped water supply system	2	5	2	2
		Drilled well				
		Rain water tank	700	600	900	500
		Simple water filter				
	Increased population (person)		15,409	19,669	24,049	17,075
	Growth rate of population (%)		4.15%	5.22%	6.29%	4.40%
	Population served (person)		55,694	75,362	99,409	116,424
	Rate of population served (%)		29.09%	34.31%	40.60%	45.00%

Source: Preparatory survey by JICA

Table 9.1.5 Present Condition of Access to Safe Water in Binh Thuan Province

			2003	2004	2005	2006
1) Population and Household in rural area						
	Population in rural area		939,860	959,082	977,842	992,809
	Household in rural area		187,950	191,800	195,550	198,500
2) Water Supply						
	Implemented Water Supply System		40	44	49	56
		Piped system	40	44	49	56
		Simple piped water supply system				
		Drilled well	25	25	25	25
		Rain water tank	3,407	2,597	1,800	200
		Simple water filter	12	13	15	15
	Increased population (person)		35,979	43,563	54,415	44,600
	Growth rate of population (%)		3.82%	4.54%	5.56%	4.50%
	Population served (person)		479,328	532,290	591,594	645,130
	Rate of population served (%)		51.00%	55.50%	60.50%	65.00%

Source: Preparatory survey by JICA

9.2 Existing Piped Water Supply Systems in the Target Communes

There are eleven (11) existing piped water supply systems in eleven (11) communes out of twenty four (24) communes. The ratio of population served in these communes to their total population is 29%. Based on the pattern of management, the existing water supply system is categorized as:

(1) Private water supply : 2 systems
(2) Community water supply : 6 systems
(3) Urban water supply : 3 systems

Table 9.2.1 shows the detail of existing water supply system and pictures are shown in below.

- ***Pictures of the existing water supply systems (1/2)***

<P-3 An Tho> Reservoir

<P-3 An Tho> Distribution pipe

<P-5 Son Phuoc> Water treatment plant

<P-6 Ea Cha Rang> Deep well and Pump house

<P-6 Ea Cha Rang> Elevated tank

<K-1 Cam An Bac> Dug well

<K-1 Cam An Bac> Elevated tank

- ***Pictures of the existing water supply systems (2/2)***

 <N-3 Bac Son> Public tap	 <N-3 Bac Son> House connection
 <N-5 Phuoc Hai> Deep well	 <N-5 Phuoc Hai> Reservoir
 <N-6 Phuoc Dinh> Water treatment plant (1)	 <N-6 Phuoc Dinh> Water treatment plant (2)
 <B-2 Gia Huynh> Dug well	 <B-2 Gia Huynh> Elevated tank

Table 9.2.1 The Detail of Existing Water Supply Systems in the Target Communes

Province	District	Commune	Code	Existing or Plan	Service Area (village name)	Project Cost (VND)	Year of completion	Population served (Persons)	Design water supply hour (hr)	Facilities					Management		
										Water sources	Water Treatment	Distribution Tank	Distribution Pipeline	Service Level	Organization	No. of Operator	Water charge
Phu Yen	Tuy An	An Tho	P-3	Existing	Phu Can, Phu My, Kim Son and Quang Duc	12 million	1999	184	24	4 Dug Wells	Non	Reservoir	Material; PVC Diameter; 20mm	HC*3	Private	0	Free of charge
	Son Hoa	Son Phuoc	P-5	Existing	N. Hon Ong	1.1 billion	2007	777	24	5 Deep Wells H=30~40m	Screen	Reservoir Q=20m3	Material; PVC, SP Diameter; 80mm	HC	CPC	2	700VND/m3
		Ea Cha Rang	P-6	Existing	Village A and C	800million	2005	772	8	2 Deep Wells H=50m	Non	Elevated Tank Q=20m3	Material; PVC Diameter; 50mm and 20mm	HC	CPC	1	1800~2000VND/m3
		Suoi Bac	P-7	Existing	Phu Huu, Tan Phu	1 billion	2006	600	24	Urban Water Supply Company	N/A	Non	Material; HDPE*1, PVC Diameter; 65mm	HC	Urban Water Supply	N/A	2200VND/m3
Khan Hoa	Cam Rann	Cam An Bac	K-1	Existing	Tan An	493 million	2006	1,305	12	1 Dug Well	Chlorination	Elevated Tank Q=4m3 H=7m	Material; PVC Diameter; 60mm, 50mm and 42mm	HC (Pending approval)	CPC	N/A	N/A
Ninh Thuan	Ninh Hai	Bac Son	N-3	Existing	Binh Nghia, Ran Ma and Xon Ban	300 million	2001	4,226	12 (Ran Ma and Binh Nghia), 24 (Xon Ban)	Spring (Hun Hai)	Non	Non	Material; PVC Diameter; 80mm and 20mm	HC(Ran Me and Binh Nghia), PT(Xon Bac)	CPC/DPC	6	2000VND/m3 (Ram Me and Binh Nha) Free of charge(Xson Ban)
	Ninh Phuoc	Phuoc Hai	N-5	Existing	Than Tin	N/A	1975	4,581	24	3 Deep Wells	Non	Non	Material; SP*2, PVC Diameter; 20mm	HC	CPC	3	Free of charge
		Phuoc Dinh	N-6	Existing	Vinh Truong, Tu Thien	290 million	2007	1,717	24	5 Deep Wells H=25~45m	Filtration	Reservoir Q=16m3	Material; SP and PVC Diameter; 90mm(SP) and 20mm (PVC)	HC	CPC	2	Financial comfortable (2,500VND/m3)
Binh Thuan	Tanh Linh	Gia Huynh	B-2	Existing	Village No.3	1,800 million	2006	117	24	Dug Well H=10m	Non	Elevated Tank Q=10m3	Material; PVC Diameter; 90mm and 20mm	PT*4 (Design)	Private	0	Free of charge
	Ham Tan	Tan Duc	B-4	Plan	Village 3 and 4 (Only minority area)	N/A	2007	314	N/A	Urban Water Supply	N/A	N/A	N/A	N/A	Urban Water Supply	N/A	N/A

Source: Field survey for water supply system by JICA Study Team

*1: High-density polyethylene, *2: Steel pipe, *3: House connection, *4: Public tap

In general, the private water supply system is small scale and the ratio of population served in these cases is low with less than 6%. Many facilities such as intake and distribution reservoir are demolished or partially destroyed because of aging or defective maintenance.

The drinking water quality of some community water supply systems is unsatisfactory due to defects in treatment system. Turbidity is high compared to drinking water standards. In some of the water sources of dug well, there is lack of water in dry season for duration of 4 to 5 months. The distribution pipeline is roughly in favorable conditions. Rehabilitation or reconstruction of some intake facilities for water source is required. In Cam An bac commune, construction of water supply facilities has been completed and this system is under procedure of approval for implementation of waterworks.

Two (2) communes are supplied water from urban water supply system. In this case, the water volume and quality is controlled under urban water supply company. However, it is expected that the diameter of distribution pipeline will not meet water flow requirements in future. In Phuoc Minh commune (N-4), there is water supply plan funded by ADB, will complete construction at the year 2011. Evaluation of the existing water supply system is presented in Table 9.2.2.

Table 9.2.2 Evaluation of Existing System

Province	Commune	Code	Available water sources	Supply capacity (l/c/d)	Treatment Process	Facility				Evaluation
						Intake	Treatment plant	Distribution Reservoir	Distribution pipe	
Phu Yen	An Tho	P-3	Good	33-50	Insufficiency	Deterioration	Aging	Deterioration	Aging	x
	Son Phuoc	P-5	Good	33-50	Sufficiency	Good	N/A	Good	Good	O
	Ea Cha Rang	P-6	Good	30-45	Sufficiency	Good	N/A	N/A	Good	O
	Suoi Bac	P-7	From urban water supply	20-30	Sufficiency	N/A	N/A	N/A	Good	O
Khanh Hoa	Com An Bac	K-1	Good	30-50 (Under procedure of approval)	Sufficiency	Good	Good	Good	Good	O
Ninh Thuan	Bac Son	N-3	Good	50-60	Sufficiency	Good	N/A	N/A	Good	O
	Phuoc Minh	N-4	From urban water supply	(Plan)	Sufficiency	N/A	N/A	N/A	Good	O
	Phuoc Hai	N-5	Good	40-50	Insufficiency	Aging	N/A	Deterioration	Defect	x
	Phuoc Dinh	N-6	Dry up in dry season	40-50	insufficiency	Defect	Good	Good	Good	x
Binh Thuan	Gia Huynh	B-2	Dry up in dry season	40-50	Insufficiency	Deterioration	N/A	Deterioration	Defect	x
	Tan Duc	B-4	From urban water supply	50-60	Sufficiency	N/A	N/A	N/A	Good	O