Chapter 5 Groundwater Potential in the target communes/towns

5.1 Water balance

In general, water balance study in a certain river basin for long years can be determined in the following formulas, if groundwater in-flow to the area and out-flow from the area are negligible and the storages water of surface and sub-surface are constant:

$P = S + G + E$

$S + G = R$

Where P: precipitation, S: surface runoff, G: groundwater runoff
E: evaporation, R: total runoff

According to the "Vietnam National Atlas (1996)", the average annual surface runoff in the central highlands is estimated to be from 400 to 1500mm/year. In the northern and southern parts of the central highlands, the average annual surface runoff is more than 1,200mm/year at the mountain area.

The minimum value of the average annual surface runoff is less than 400mm/year in the Cheo Reo-Phu Tuc lowland/depression. The average annual surface runoff in the Buon Ma Thuot and Plei Ku highlands ranges from 600 to 1,000mm/year.

The average annual groundwater runoff in the central highlands is estimated as 200-600mm/year. The minimum of the average annual groundwater runoff is found in the An Khe Lowland and Buon Ma Thuot highland. The average annual groundwater runoff is estimated to be mostly from 200 to 400mm/year.

The water balance equation in certain area is also expressed as the following equation. If the water balance is calculated for several ten years, δS (=F) can be neglected.

$P - E = I + U + \delta S$

where P: precipitation, E: evaporation,
I: river runoff in-flow to the area and out-flow from the area
U: underground in-flow to the area and out-flow from the area
δS: change in storage

According to DANIDA study, the annual rainfall, evaporation and river runoff in the Krong Buk river basin can be estimated as 1,400mm, 713mm and 685mm, in ascending river course. The Krong Buk river basin has a catchment area of 510 km^2. The groundwater flow at the river gauging station can also be calculated to be 730,000 m^3/year as the cross section is 2,000 km, which is equivalent to 2 mm/year.

There is no hydro-meteorological data on the surface runoff, precipitation and evaporation in the target communes/towns. Even if there are several hydro-meteorological stations in the central highlands, these hydro-meteorological data have not yet published by the authorities.

The groundwater recharge on the Buon Ma Thuot highland is assessed and estimated at 510 mm/year on a basis of the discharge data of the Ea Co Tam spring with a catchment of 7 km^2, which was monitored from 1978 to 1981 according to the Srepok water action plan report by DANIDA. The amount results in a base flow contribution to the streams of 165 mm (12.8 l/sec/km^2) in dry season and 345 mm (18.5 l/sec/km^2) in rainy season.

5.2 Water Balance Analysis

The southern part of the Kon Tum province is located in the northern part of the Plei Ku Highland. The northern, northeastern and western parts of the Kon Tum province are locted in the Se San river basin. Even if there are several hydro-meteorological stations in the Se San river basin, these hydro-meteorological data have not yet published by the authorities. Therefore, the water balance analysis in the Se San river basin is impossible.

According to "Vietnam National Altas", the groundwater runoff in the Kon Tum province ranges from 400 to 600 mm/year. It can be recognized that the result of the water balance analysis in the Srepok river basin can also be applied to that in the Kon Tum province.

Sugawara's tank model, which is one of the most effective runoff model, is applied in order to make clear a hydrological cycle in the Srepok river basin and to estimate recharge of precipitation to groundwater aquifer.

5.2.1 Tank Model and Procedure

The tank model is composed of four tanks vertically in series. Each tank corresponds to each runoff component. The top tank represents the ground surface and the outflow from the top tank corresponds to a surface runoff. The second tank represents the soil layer and the outflow from the second tank corresponds to an intermediate runoff. The third and fourth tanks represent groundwater layer and the outflow from these tanks corresponds to a base flow. The top tank is attached with soil structure in order to consider the effect of initial rainfall loss.

The characteristics of the tank model are described as follows:

- The tank model can analyze both flood and low flows.
- The tank model expresses non-linear relationship between rainfall and runoff.
- The time lag between rainfall and runoff is automatically calculated.
- The tank model is not necessary for complicated procedure of calculation.
- The tank model has to find coefficients of four tanks by trial and error.

5.2.2 Srepok River Basin

The Srepok river is one of the major tributaries of the Mekong river and has a total basin area of 17,300 km2, and 11,830 km2 inside Vietnam, alone. The basin lies over the Buon Ma Thout highland and the southwestern part of the Plei Ku Highland. The basin is located at coordinates of 11o30' to 13o00'N and 107o30' to 108o30'E as shown in Figure 5.1. The Srepok river is composed of two tributaries of Krong Kno and Krong Ana. The Krong Kno river originates from the Truong Son range along the southern border of Dak Lak province and has a length of 156 km, a basin area of 3,920 km2, an average elevation of 917 m and a basin slope of 17.6 %. The Krong Ana river is composed of three tributaries of Krong Buk, Krong Pak and Krong Bong. The Krong Ana river originates from the Haom Roang range and the East Truong Son range and has a length of 215 km and a basin area of 3,960 km2.

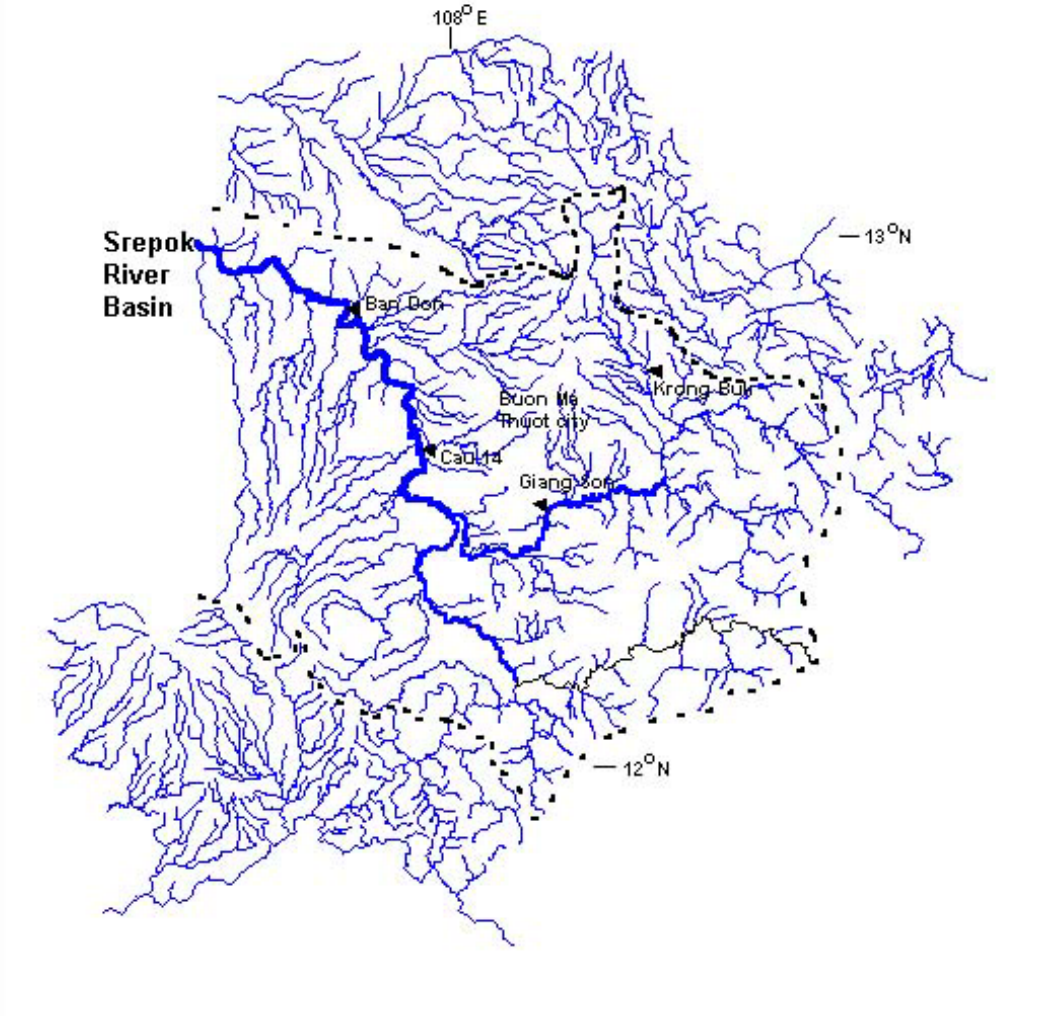


Figure 5.1 Srepok River Basin and Gauging Stations

5.2.3 Basic Meteorological Data

There are twenty-four (24) rainfall stations in the Srepok river basin. The rainfall at thcce Buon Ma Thuot station has been observed since 1928. There are nine (9) rainfall stations with at least ten (10) years of records since 1977 in Dak Lak province as shown in the following table.

Table 5.1 Annual rainfall (mm/year).

Year	Annual rainfall (mm/year)					
	Ban Don	Cau 14	B.M Thuot	Lak	Giang Son	Kr Buk
1977	1427.5	1423.1	1655.8	1654.9	1473.8	1106.6
1978	1658.0	2012.6	1926.9	2207.1	2069.1	1373.8
1979	1779.5	1662.6	1984.4	2017.9	1944.3	1448.8
1980	1571.4	1582.0	1875.6	2431.7	1935.7	1608.9
1981	1498.9	2290.8	2598.0	2331.1	2193.1	1734.8
1982	1521.8	1699.9	1560.5	1887.2	1715.2	1097.9
1983	1515.5	1707.3	1648.3	1357.0	1517.3	1594.6
1984	1723.6	1460.4	2046.4	2035.1	2392.2	1379.5
1985	1671.3	1730.9	1679.1	1773.1	1862.9	1356.0
1986	1563.6	1633.8	1772.1	1604.3	1840.7	1396.4
1987	1928.3	1733.5	1746.5	1873.9	2094.6	1523.3
1988	1487.0	1490.4	2096.7	1939.3	1916.9	1253.6
1989	1491.1	1551.3	1804.7	2880.7	1540.6	1147.7
1990	1721.4	2123.5	2298.0	2569.1	2147.0	1409.4
1991	1302.2	1404.5	1248.9	1277.9	1245.4	1139.8
1992	1551.2	1709.6	2420.4	2748.6	2095.2	1699.7
1993	1735.8	1798.0	1711.1	2064.4	1898.0	1725.2
1994	1091.9	1441.5	1669.8	1535.1	1684.6	1177.2
1995	1540.5	1766.3	1388.3	1645.7	1542.3	1432.5
1996	2166.8	2216.2	2188.4	1607.6	2126.9	1762.2
1997	-	-	1504.9	-	-	1421.9
1998	-	-	2161.5	-	-	1619.5
Average	1597.4	1721.9	1863.4	1972.1	1861.8	1427.7
Standard deviation.	223.7	258.9	335.7	446.0	291.9	213.1
Var. coefficient	0.14	0.15	0.18	0.23	0.16	0.15

(Source:DANIDA)

The rainy season lasts six (6) months from May to October in the north-western part of the Srepok basin and seven (7) months from May to November in the south-eastern part as shown below.

Table 5.2 Average monthly rainfall (mm/month).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Buôn Ho	1	2	24	87	191	222	186	225	248	224	86	22	1487
Krong Buk*	3.6	5.4	39.2	78.3	168.2	157.6	150.4	166.7	227.1	225.2	156.6	49.3	1427.7
Dak Ea Mil	0	5	36	126	218	222	238	231	279	222	73	13	1663
Giang Son	0	4	18	100	215	253	263	300	298	261	103	29	1848
Duc Xuyen	1	2	28	105	227	283	277	308	303	225	75	11	1846
Cau 14	2	4	17	796	261	256	226	267	291	239	72	11	1696
Ban Don	1	4	25	95	200	248	235	242	264	200	60	10	1568
B.M.Thuôt*	3.6	5.1	23.3	85.8	240.5	272.9	257.3	316.5	302.6	244.8	91.4	19.6	1863.4
M'Drak	32	15	31	73	163	111	122	118	207	400	377	158	1825
Lak	0	3	18	72	219	286	307	378	302	272	92	250	1991

Data : 1977-1995 except for Krong Buk (1977-1998) and B.M.Thuot (1977-1998)

During the period 1977-1995, the mean monthly rainfall at Buon Ma Thuot has been a maximum of 311 mm in August, and a minimum of 2.0 mm in February, at

Giang Son 300.0 mm in August and 0.4 mm in January, at Duc Xuyen, 308.0 mm in August and 1.3 mm in January, respectively.

There are three (3) evaporation measurement stations in Dak Lak province as shown below. The evaporation at the Buon Ma Thuot station has been measured since 1977 by a standard Piche tube. In general, actual evaporation values are approximately fifty (50) to seventy (70) % of the values measured by the standard Piche tube in subtropical zones.

Table 5.3 Average monthly Piche Tube evaporation (mm/month)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Buôn Ho	92	123	164	159	134	94	81	71	64	62	62	71	1189
B.M.Thuôt	175	185	220	187	117	74	68	63	53	73	97	129	1441
M'Drak	73	85	116	121	116	144	146	141	88	63	52	57	1201

Data : 1977-1995 except for B.M.Thuot (1977-1998)

There are twenty-nine (29) river gauging stations in Dak Lak province. Out of twenty-nine (29) river gauging stations, there are four (4) key discharge measurement stations for the Srepok river basin at Ban Don, Cau 14, Gian Son and Duc Xuyen as shown below. The discharge data at these key river gauging stations have been measured since 1977.

Table 5.4 River Gauging Stations of Srepok River Basin

No.	Name	River gauging station	Catchment area (km^2)	Aggregate area (km^2)
1	Krong Pac	Krong Pac	256	-
2	Krong Bong	Krong Bong	788	-
3	Upper Krong Buk	Buon Ho	178	-
4	Lower Krong Buk	Cau 42	280	458
5	Upper Krong Ana	Giang Son	1,678	3,180
6	Krong Kno	Duc Xuyen	3,080	-
7	Srepok	Cau 14	2,410	8,670
8	Ea Knir	Doan Ket	224	-
9	Srepok	Ban Don	1,806	10,700
10	Border	None	1,130	11,830

(Source:DANIDA)

The mean annual runoff (1977-1995) of the Srepok river at Ban Don station is 247 m^3/sec, at Giang Son is 64 m^3/sec, and at Duc Xuyen is 97.4 m^3/s as shown below. The maximum annual runoff at Ban Don is 360 m^3/sec in 1981 and minimum is 154 m^3/sec in 1977; at Giang Son it is 118 m^3/sec in 1981 and 39 m^3/sec in 1982, and at Duc Xuyen is 131 m^3/sec in 1990 and 60 m^3/sec in 1977, respectively.

Table 5.5 Mean Annual Discharge of Srepok River (m^3/s)

Year	Measured annual discharge (m^3/sec)		
	Giang Son	Cau 14	Ban Don
1977	44.7	127.9	154.1
1978	61.0	197.8	247.0
1979	64.4	205.6	232.4
1980	73.0	247.6	275.9
1981	118.3	310.5	359.7
1982	38.9	184.5	236.9
1983	44.4	165.0	199.4
1984	61.9	238.5	268.3
1985	56.5	179.4	205.3
1986	57.1	190.6	215.0
1987	47.0	176.8	212.5
1988	65.9	216.3	250.6
1989	64.1	245.0	255.4
1990	92.1	262.2	329.7
1991	40.5	154.4	183.3
1992	89.1	241.2	316.6
1993	90.7	251.2	301.5
1994	57.3	197.5	249.4
1995	49.5	178.2	206.0
Average	64.0	209.0	247.3
Standard deviation	20.77	44.22	52.51
Var. coefficient	0.32	0.21	0.21

(Source:DANIDA)

The lowest mean monthly discharge occurs in April as shown below. The lowest mean monthly discharge values at Ban Don, Cau 14, Gian Son and Duc Xuyen are 61.3, 55.5, 13.6 and 25.1 m^3/sec, respectively.

Table 5.6 Average monthly discharges (m^3/s).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Buôn Ho	3.0	1.9	1.5	1.3	1.8	2.7	2.9	4.5	6.7	8.5	7.2	4.7	3.9
Krong Buk	5.6	3.0	2.1	2.1	3.8	6.2	6.2	10.3	15.9	21.7	17.3	10.4	8.7
Krong Pac	4.9	2.6	1.6	1.3	2.1	3.4	3.5	4.2	7.2	17.3	20.9	12.4	6.8
Krong Bong	14.4	8.4	5.9	5.1	7.0	11.8	12.1	15.0	23.2	45.5	56.6	39.2	20.3
Giang Son	40.1	22.8	15.5	13.6	22.0	39.2	41.9	56.5	82.6	150	161	111	64.0
Duc Xuyen	47.8	32.7	25.6	25.1	38.2	75.7	98.7	172	205	224	137	86.3	97.4
Cau 14	118	76.0	56.7	55.5	86.7	155	204	285	380	468	350	238	209
Ban Don	129	82.9	62.4	61.3	103	196	249	357	483	574	403	267	247
Ea Knir	2.2	1.5	1.3	1.3	2.1	3.9	4.4	6.0	7.9	9.1	6.2	4.3	4.2

Data : 1977-1995 except for Ban Don (1977-1998)

5.2.4 Verification of Simulated Runoff and Water Balance in the Srepok River Basin

The drainage basin of the Srepok river is composed of highlands of basalts and plains of Jurassic sandstone and shale. The discharge of the Srepok river at Ban

Don with a drainage basin area of 10,700 km^2 is selected and verified for the purpose of water balance analysis.

The daily discharge at Ban Don is calculated for twenty-one (21) years from 1978 to 1998. The rainfall data at Buon Ma Thuot and Krong Buk and the evaporation data at Buon Ma Thuot are used in the calculation.

The simulated daily, monthly and annual runoffs of the Srepok river at Ban Don are verified by comparing with the observed runoffs for twenty-one (21) years from 1978 to 1998. The following table shows the identified flow parameters of the tank model and Figure 5.2 describes comparison with the observed and computed monthly discharges of the Srepok river at Ban Don.

Table 5.7 Identified Flow Parameters of Tank Model for Srepok River

Tank	**Parameter**			
First tank	Outflow coefficient	Upper hole	A2	0.1
		Lower hole	A1	0.1
	Infiltration coefficient		A0	0.2
Second tank	Outflow coefficient		B1	0.01
	Infiltration coefficient		B0	0.02
Third tank	Outflow coefficient		C1	0.001
	Infiltration coefficient		C0	0.002
Fourth tank	Outflow coefficient		D1	0.0002
	Infiltration coefficient		D0	0

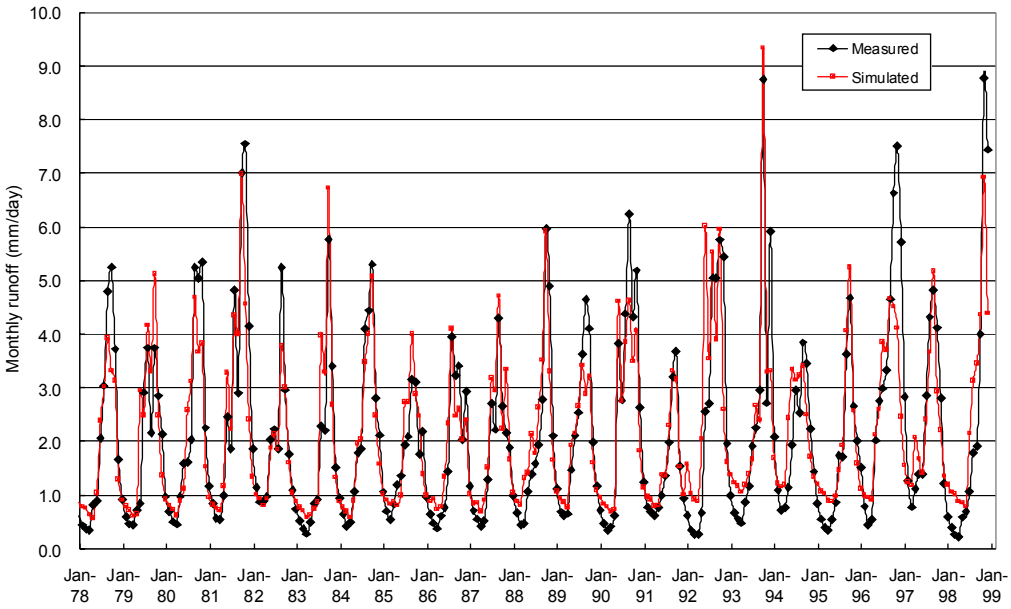


Figure 5.2 Runoff Simulation of Srepok River at Ban Don by Sugawara's Tank Model

The water balance calculation of the Srepok river basin for twenty-one (21) years from 1978 to 1998 at the Ban Don gauging station is summarized as shown below.

Table 5.8 Water Balance of Srepok River Basin for 21 years from 1978 to 1998 at Ban Don (10,700 km^2) identified by Sugawara's Tank Model

Precipitation (mm/year)	Evaporation (mm/year)	Runoff (mm/year)	Groundwater recharge (mm/year)	Groundwater recharge / Precipitation (%)
1658.1	886.1	784.5	535.5	32.3

The recharge in basalt area of the Buon Ma Thuot highland is calculated to exceed more than 30 % of precipitation. The basalt area of the Buon Ma Thuot highland makes a good groundwater aquifer.

5.3 Safe Well Yields

According to the water balance calculation as discussed in section 5.2, the basin-wide (macro-scale) water balance calculation shows that the annual groundwater recharge is estimated as 535.5 mm/year (1.5 mm/day) in the Srepok river basin as shown in Table 5.8 and that the groundwater recharge fluctuates from 437.4 in 1991 to 685.7 mm/year in 1992. The groundwater recharge of 1.5 mm/day is equivalent to an amount of 1500 m^3/day/km^2.

The relationship between discharge and drawdown of the step-drawdown test shows a specific line on a log-log graph as discussed in section 4. The critical yield (discharge) of the test wells is estimated to be more than the maximum discharge of the step-drawdown test. An optimum yield can generally be recognized to be seventy (70) % of the critical yield. The optimum yield of the test wells can be assumed to be nearly equal to the maximum discharge of the step-drawdown test. When the test wells produce an extraction rate of 300 m^3/day for future water supply, the extraction rate can be recognized to be much lower than a groundwater recharge of 1.5 mm/day. From a macroscopic viewpoint of the water balance in the Srepok river basin, several production wells can extract groundwater within 1 km^2.

Therefore, the safe well yield of each test well can be recognized to be equal to the optimum yield. The following table shows the safe well yields of each test well by commune/town.

Table 5.9 Safe Well yield of Each Commune/Town

Target commune/town		Safe well yield (m^3/day) (liter/sec)		Permissible dynamic groundwater level (m below ground surface)
Kon Tum province				
K1	Bo Y	86	1.0	40
K2A	Dak Su	149	1.7	35
K3	Dak Ui	259	3.0	32
K4	Dak Hring	-	-	-
K5	Sa Nghia	-	-	-
K6	Chu Hreng	-	-	-

5.4 Groundwater Level Monitoring

5.4.1 Observation Wells Monitored by the Geological & Mineral Resources Survey of Vietnam

In general, groundwater level monitoring is indispensable to detect problems of groundwater over-exploitation. According to the National Program of Groundwater Monitoring in the central highlands under the Ministry of Industry, the groundwater level monitoring in the three provinces of Dac Lac, Gia Lai and Kon Tum has been conducted since 1993 at 73 monitoring wells. There is no observation well in the target communes of the Kon Tum province.

When groundwater development is planned properly with adequate intervals between wells to avoid local groundwater level lowering (cone effect), it is judged to be sustainable and to contribute to the improvement of the living standards of the people by supplying clean and safe water. Monitoring of groundwater level for the existing and newly constructed wells is essential for management of groundwater resources.

5.4.2 Test Wells

Automatic groundwater level recorders were installed for the 4 successful test wells at June 2001. PCERWASS has been continuing the monitoring work. Figure 5.3 shows the fluctuation of groundwater levels in the test wells from June 2001 to June 2002. It is one hydrological year records including wet and dry seasons. According to the hydro-meteorological station in Buon Ma Thuot, it was a drought

from September 2001 to March 2002.

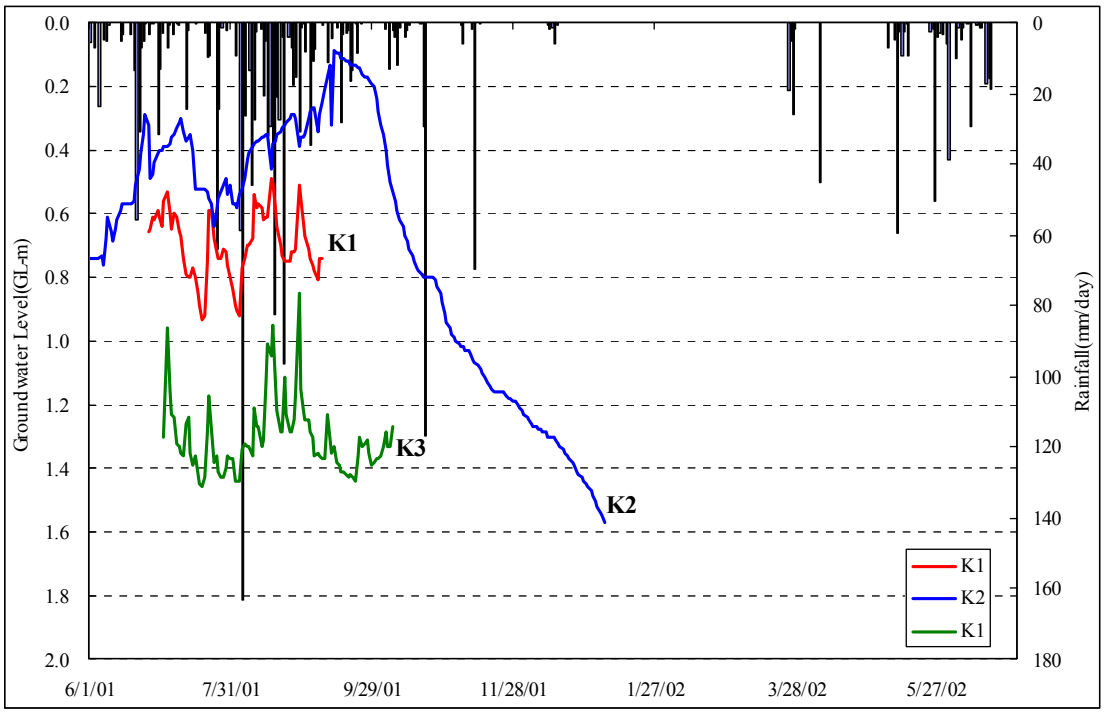


Figure 5.3 Groundwater Levels of Test Wells

The data do not reveal lowering of groundwater levels in the test wells. There is dam reservoirs located the upstream of K1 and K2A test wells and the downstream of K3 test well, respectively. It is conceivable that groundwater levels of the three test wells are controlled by dam reservoirs. The groundwater level of K6 test well had risen from July 2001 to October 2001 with approximately 3 m. The groundwater level had lowered from November 2001 to June 2002.

5.5 Groundwater Potential Map

The most promising areas for wells drilled for future groundwater development of each target commune/town are shown in Appendix 5.3 - 5.5. The most promising areas for the future development of groundwater are circled excluding the present JICA well fields. The results will be reviewed and revised at the F/S phase and feedback to the master plan in consideration of the layout of each water supply system.

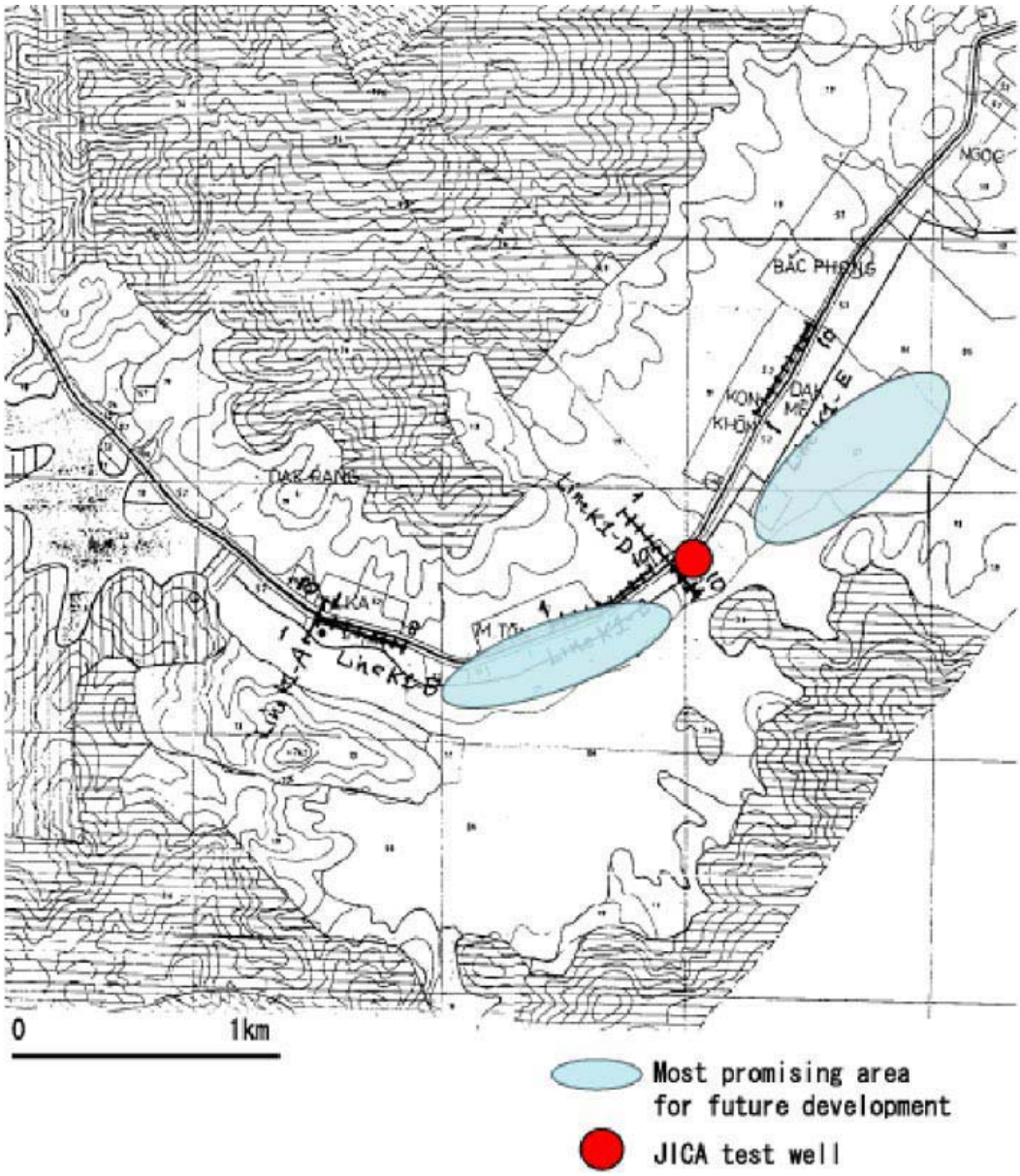


Figure 5.4 Most Promising Area for Future Groundwater Development at Bo Y Commune

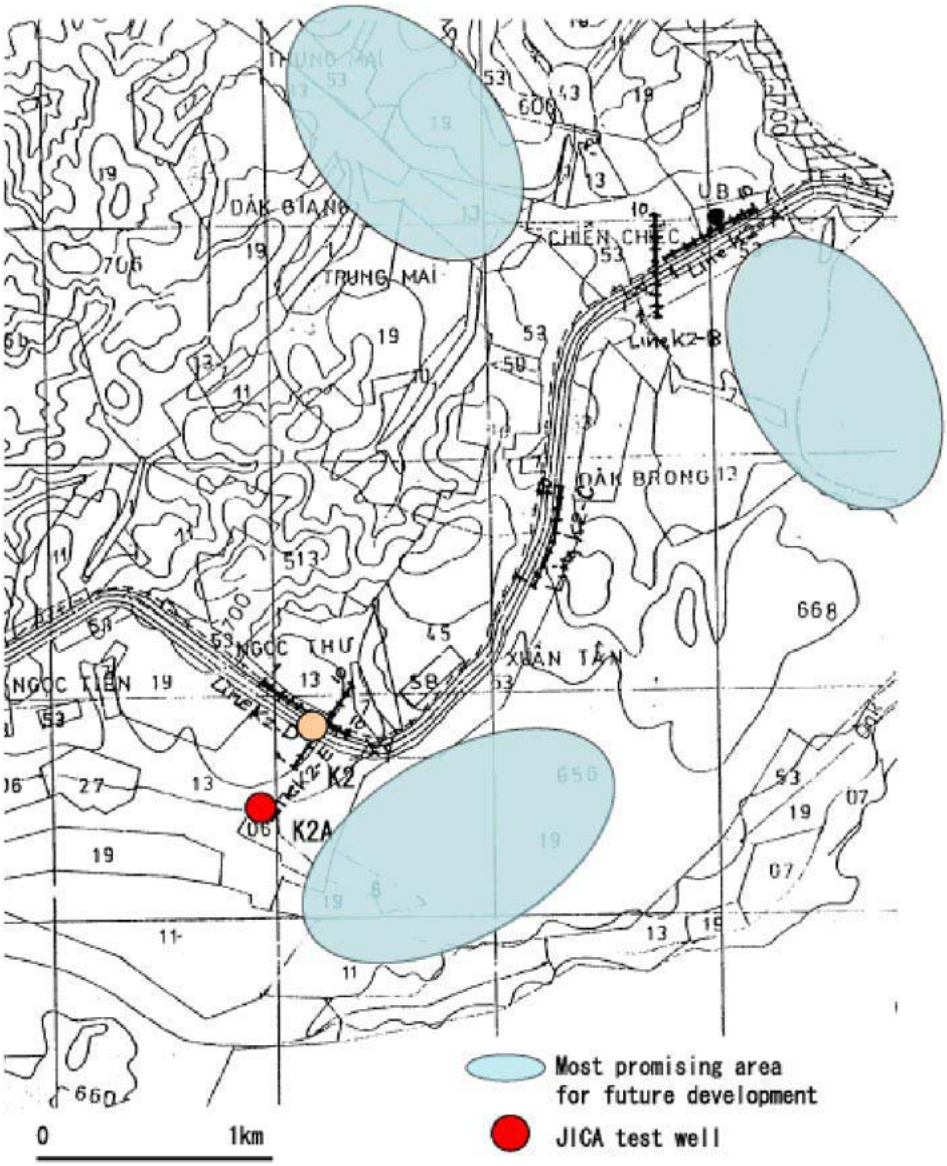


Figure 5.5 Most Promising Area for Future Groundwater Development at Dak Su Commune

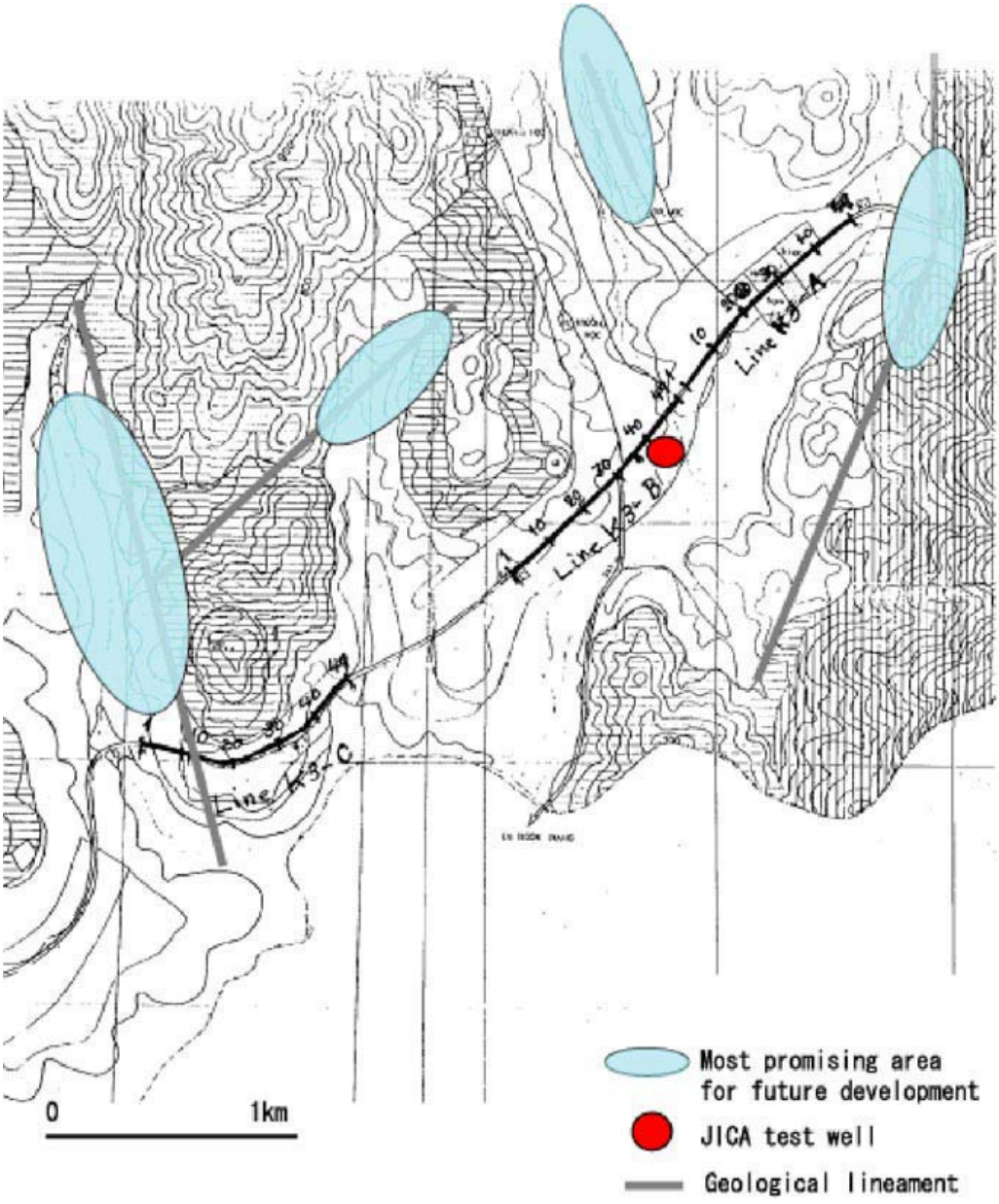


Figure 5.6 Most Promising Area for Future Groundwater Development at Dak Ui Commune

Chapter 6 Water Quality

6.1 Sample Number and Analysis Items

6.1.1 Sample Number

During the field hydrogeological survey, 352 locations were investigated and 36 water samples (6 samples for laboratory analysis and 30 samples for simple water quality test) were collected. The sample for dioxin analysis is taken from K-1 exploratory well and analyzed at Hanoi National University. The sampling locations are shown in Data Book.

6.1.2 Analysis Items

A) Items tested during field measurement

(1) pH
(2) Electric Conductivity (EC) (μ S/cm)
(3) Dissolved Oxygen (DO) (mg/l) (at water sample location)
(4) Water Temperature (℃)
(5) Color and smell

B) Total 18 items for the laboratory analysis

The samples of approx. 2.3 liters by volume for laboratory test were collected during the field survey. The laboratory is the Institute Hygiene and Epidemiology Center in Buon Ma Thuot city under the Ministry of Health. The analysis methods and instruments are shown in Table 6.1.

(1) Total Dissolved Solids (TDS) (mg/l)
(2) Calcium (Ca^{2+}) (mg/l)
(3) Magnesium (Mg^{2+}) (mg/l)
(4) Sodium (Na^{+}) (mg/l)
(5) Potassium (K^{+}) (mg/l)
(6) Bicarbonate (HCO_3^{-}) (mg/l)
(7) Chloride (Cl^{-}) (mg/l)
(8) Sulfate (SO_4^{2-}) (mg/l)
(9) Iron (Σ Fe) (mg/l)
(10) Nitrite (NO_2^{-}) (mg/l)
(11) Nitrate (NO_3^{-}) (mg/l)
(12) Ammonium (NH_4^{+}) (mg/l)

(13) Phosphate (PO_4^{3-}) (mg/l)

(14) Chemical oxygen demand (COD) (mg/l)

(15) Fluoride (F) (mg/l)

(16) Arsenic (As) (mg/l)

(17) Manganese (Mn^{2+}) (mg/l)

(18) Coliform (MPN/100ml)

Table 6.1 Analysis Methods and Instruments of IHE Laboratory

Item	Method	Instrument Name, No.	Measuring Limit
TDS (mg/l)	Total Cation +Anion		0.001 mg/l
Ca^{2+} (mg/l)	Titration by Manual	Automatic Buret	0.01 mg/l
Mg^{2+} (mg/l)	Titration by Manual	Automatic Buret	0.001 mg/l
Na^{+} (mg/l)	Flame photometer	Jenway flame photometer (ENGLAND) Model PEP7 - Serial No.6721	0.01 mg/l
K^{+} (mg/l)	Flame photometer	Jenway flame photometer (ENGLAND) Model PEP7 - Serial No.6721	0.001 mg/l
HCO_3^{-} (mg/l)	Titration by Manual	Automatic Buret	0.001 mg/l
Cl^{-} (mg/l)	Ion chromatography	Automatic Buret	0.01 mg/l
SO_4^{2-} (mg/l)	Ion chromatography	Automatic Buret	0.01 mg/l
Total Fe (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.01 mg/l
NO_2-N (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.001 mg/l
NO_3-N (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.01 mg/l
NH_4^{+} (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.001 mg/l
PO_4^{3-} (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.01mg/l
COD/$KmnO_4$ (mg/l)	Titration by Manual	Automatic Buret	0.001 mg/l
F (mg/l)	Neutron activation Analyse method	The Gamma Spectrometer System with Detector Ge(Li), HP	0.0001 mg/l
As (mg/l)	Neutron activation Analyse method	The Gamma Spectrometer System with Detector Ge(Li), HP	0.0001 mg/l
Mn^{2+} (mg/l)	Neutron activation Analyse method	The Gamma Spectrometer System with Detector Ge(Li), HP	0.0001 mg/l
Coliform (MPN/100ml)	MPN	Mac conky medium	-

C) Dioxin Analysis by Hanoi National University

Water volume of approximately 20 liters from K-1, G-3 and D-6 exploratory wells are transported and analyzed at the Hanoi National University.

D) Simple Water Quality Test

Simple water quality tests were carried out by the pack test, coliform paper test and Hironaka's arsenic field Kit test, in order to make a check on preliminary the quality. The following 11 items were tested.

(1) Magnesium (Mg^{2+}) (mg/l)
(2) Iron (Fe^{2+}, Fe^{3+}) (mg/l)
(3) Nitrite (NO_2^-) (mg/l)
(4) Nitrate (NO_3^-) (mg/l)
(5) Ammonium (NH_4^+) (mg/l)
(6) Phosphate (PO_4^{3-}) (mg/l)
(7) Chemical oxygen demand (COD) (mg/l)
(8) Fluoride (F) (mg/l)
(9) Arsenic (As) (mg/l)
(10) Manganese (Mn^{2+}) (mg/l)
(11) Coliform (MPN/100ml)

6.1.3 Water Quality Standards

The Vietnamese water quality standards of groundwater source are shown in Table 6.2 and for surface water resource in Table 6.3. The sources are classified into the following 3 classes for water supply according to the regulation of TCXD233 (1999), which was regulated by the Ministry of Health.

- Class A: water source with good quality, requiring only simple treatment prior to supply for domestic use.
- Class B: water with normal quality, which should be extracted and treated for domestic use.
- Class C: water with bad quality, which should be treated with special technology for domestic use and its quality must be strictly and regularly monitored.

Table 6.2 Vietnamese Water Quality Standards of Groundwater Source

No.	Parameter		Unit	Water Class		
				Class A*	Class B*	Class C*
1	pH value			6.8 to 7.5	6.0 to 8.0	4.5 to 8.5
2	Dissoleved Oxygen		mg/l O_2	<0.5	0.5 - 2.0	<10
3	Total Hardness		°dH	4 to 8	<4, or 8 to 13	<28
4	Hydrogen Sulfide	H_2S	mg/l	0	0	<0.5
5	Chloride	Cl^-	mg/l	<25	<200	<400
6	Sulphate	SO_4^{2-}	mg/l	<25	<250	<400
7	Nitrite	NO_2^-	mg/l	<0	<0.1	<2
8	Nitrate	NO_3^-	mg/l	0	<6	<10
9	Phosphate	PO_4^{3-}	mg/l	0	<1.5	<2
10	Total Iron	Fe	mg/l	<0.3	<10	<50
11	Manganese	Mn	mg/l	<0.05	<2	<3
12	Ammonium	NH_4^+	mg/l	<0	<3	<30
13	Fluoride	F^-	mg/l	0.5 to 1.0	0 to 0.5, or 1.0 to 1.5	<2
14	Cyanide	CN^-	µg/l	0	<50	<100
15	Phenol		µg/l	0	0.5	<100
16	Arsenic	As	µg/l	0	50	<100
17	Cadmium	Cd	µg/l	0	<1	<5
18	Total Chromium	Cr	µg/l	0	<10	<50
19	Selenium	Se	µg/l	0	<5	<10
20	Mercury	Hg	µg/l	0	0	<1
21	Copper	Cu	µg/l	<50	<1,000	<3,000
22	Lead	Pb	µg/l	0	<10	<50
23	Zinc	Zn	µg/l	<50	<1,000	<5,000
24	E. Coli		MPN/100ml	0	<20	<100

Table 6.3 Vietnamese Water Quality Standards of Surface Water Source

No.	Parameter		Unit	Water Class		
				Class A*	Class B*	Class C*
1	pH value			6.5 to 8.5	6.0 to 9.0	pH>9 or pH<6
2	Turbidity		NTU	<20	<500	<1,000
3	Color		mg/l Pt	<10	<100	<200
4	Dissoleved Oxygen		mg/l O_2	<2.0	2 - 5	<10
5	Total Hardness		°dH	4 to 8	<4, or 8 to 13	<28
6	Hydrogen Sulfide	H_2S	mg/l	0	0	<0.5
7	Chloride	Cl^-	mg/l	<25	<200	<400
8	Sulphate	SO_4^{2-}	mg/l	<25	<250	<400
9	Nitrite	NO_2^-	mg/l	<0.1	<1	<2
10	Nitrate	NO_3^-	mg/l	0	<6	<10
11	Phosphate	PO_4^{3-}	mg/l	0	<1.5	<2
12	Total Iron	Fe	mg/l	<0.3	<1	<2
13	Manganese	Mn	mg/l	<0.2	<0.5	<1
14	Ammonium	NH_4^+	mg/l	<0.2	<0.5	<1
15	Fluoride	F^-	mg/l	0.5 to 1.0	<1.5	<2
16	Cyanide	CN^-	µg/l	0	<50	<100
17	Phenol		µg/l	0	0.5	<100
18	Arsenic	As	µg/l	0	50	<100
19	Cadmium	Cd	µg/l	0	<1	<5
20	Total Chromium	Cr	µg/l	0	<10	<50
21	Selenium	Se	µg/l	0	<5	<10
22	Mercury	Hg	µg/l	0	0	<1
23	Copper	Cu	µg/l	<50	<1,000	<3,000
24	Lead	Pb	µg/l	0	<10	<50
25	Zinc	Zn	µg/l	<50	<1,000	<5,000
26	E. Coli		MPN/100ml	<20	<100	<200
27	Total pesticides (except DDT)		mg/l	0	<0.15	<0.15
28	DDT		mg/l	0	<0.01	<0.01
29	Gross alpha activity		Bq/l	<0.1	<0.1	<0.1
30	Gross beta activity		Bq/l	<1	<1	<1

6.1.4 Main Findings from Water Quality of Existing Water Sources

(1) pH Value

The pH values range from 4.55 to 8.46, with an average value of 5.96. The two communes (Bo Y and Dak Hring) are relatively acidic at around 5.0 to 5.5.

Table 6.4 pH of Existing Water Sources

Type		K-1	K-2	K-3	K-4	K-5	K-6	Kon Tum
Surface Water	nos.	7	2	4	6	7	5	31
	Max	7.89	6.35	8.26	7.13	7.69	7.19	8.26
	Min	6.94	6.27	7.30	5.75	6.55	6.55	5.75
	Average	7.41	6.31	7.84	6.50	6.87	6.95	7.02
Spring Water	nos.	-	-	-	2	-	2	4
	Max	-	-	-	6.81	-	6.12	6.81
	Min	-	-	-	6.00	-	5.76	5.76
	Average	-	-	-	6.41	-	5.94	6.17
Shallow Well (Dug Well)	nos.	75	27	90	29	29	27	277
	Max	6.99	6.63	6.99	6.57	6.48	8.03	8.03
	Min	4.79	4.58	4.93	4.55	4.67	4.88	4.55
	Average	5.81	5.67	5.91	5.32	5.65	5.93	5.77
Shallow Well (Unicef Hand Pump Well)	nos.	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Deep Well (Dug Well + Drilling Well)	nos.	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Deep Well (Drilling Well)	nos.	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Existing Water Supply System	nos.	6	-	3	1	-	-	10
	Max	8.46	-	7.59	5.76	-	-	8.46
	Min	7.20	-	7.53	5.76	-	-	5.76
	Average	8.17	-	7.57	5.76	-	-	7.75
Total	nos.	88	29	97	38	36	34	322
	Max	8.46	6.63	8.26	7.13	7.69	8.03	8.46
	Min	4.79	4.58	4.93	4.55	4.67	4.88	4.55
	Average	6.10	5.71	6.04	5.57	5.89	6.08	5.96

<pH values of water samples from existing water sources>

There is a trend forward higher pH values in order of shallow well (dug well), spring water, shallow well (UNICEF hand pump well), deep well (dug well + drilling well), surface water, deep well (drilling well), and water supply

systems as shown in Figures 6.1 to 6.4.

<Comparison with the drinking water standards>

According to the standard "The parameters using for selection of the surface and ground water resources in water supply system" (TCXD 233: 1999), it is mentioned that pH value of class A should be in the range from 6.8 to 7.5 (groundwater) and 6.5 to 8.5 (surface water).

(2) Electric Conductivity (EC)

The values become higher in order of surface water, spring water, shallow well (dug well), deep well (drilling well), water supply systems, shallow well (UNICEF hand pump well), and deep well (dug well + drilling well) as shown in Figures 6.5 to 6.8.

Table 6.5 Electric Conductivity of Existing Water Sources

Type		K-1	K-2	K-3	K-4	K-5	K-6	Sub Total
Surface Water	nos.	7	2	4	6	7	5	31
	Max	118.9	29.2	165	82.2	70.8	103.5	164.7
	Min	44.8	24.8	82.4	11.40	21.9	68.8	11.40
	Average	73.8	27.0	130.2	46.1	45.5	84.8	68.1
Spring Water	nos.	-	-	-	2	-	2	4
	Max	-	-	-	26.3	-	56.7	56.7
	Min	-	-	-	11.88	-	53.3	11.88
	Average	-	-	-	19.09	-	55.0	37.0
Shallow Well (Dug Well)	nos.	75	27	90	29	29	27	277
	Max	427	162.5	345	135.9	480	424	480
	Min	13.39	11.16	13.00	12.80	21.4	29.9	11.16
	Average	53.6	49.0	67.9	35.99	123.2	143.7	72.0
Shallow Well (Unicef Hand Pump Well)	nos.	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Deep Well (Dug Well + Drilling Well)	nos.	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Deep Well (Drilling Well)	nos.	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-
Existing Water Supply System	nos.	6	-	3	1	-	-	10
	Max	130.90	-	220	6.53	-	-	220
	Min	45.30	-	139.3	6.53	-	-	6.53
	Average	115.12	-	167.2	6.53	-	-	119.9
Total	nos.	88	29	97	38	36	34	322
	Max	427	162.5	345	135.9	480	424	480
	Min	13.39	11.16	13.00	6.53	21.4	29.9	6.53
	Average	59.4	47.5	73.5	35.9	108.1	129.8	72.7

(3) Total Dissolved Solids (TDS)

Values are in the ranged from 3.981 to 171.641 mg/l. The average is 50.911 mg/l and dominant values are in the range of 0 - 50 mg/l as shown in Figures 6.9 to 6.10.

(4) Total Iron (Fe)

The values in Kon Tum province ranged from 0.13 to 1.05 mg/l with an average of 0.37 mg/l as shown in Figures 6.11. The dominant values are in the range of 0.3 - 1 mg/l. The average value is lower than that of the other two provinces. The values in Bo Y (K-1), Dak Hring (K-4), and Sa Nghia (K-5) communes are higher than those of other communes.

<Relationship between total Fe contents and water sources>

The values of the samples from each water source are about average for UNICEF hand pump wells and slightly higher for deep drilling wells than other water resources.

Table 6.6 Iron of Existing Water Sources

Type	Total Fe (mg/l)	Average (mg/l)
Surface water	0.16 - 1.05	**0.49**
Spring water	0.15 - 0.28	**0.24**
Shallow well (dug well)	0.06 - 7.10	**0.78**
Shallow well (UNICEF hand pump well)	0.92 - 1.90	**1.41**
Deep well (Dug + drilling well)	0.09 - 0.39	**0.26**
Deep well (drilling well)	0.01 - 3.50	**1.02**

<Comparison with Drinking Water Standards>

According to the Vietnamese standard (TCXD 233: 1999), most of the observed values are classified as either class A or B.

(5) Manganese (Mn^{2+})

The values in Kon Tum province ranged from 0.0302 to 0.4070 mg/l with an average of 0.0783 mg/l as shown in Figures 6.12 to 6.13. The dominant values are in the range of 0 - 0.1 mg/l. The average value in Chu Hreng commune (K-6) is higher than that of the other communes.

<Relationship between Mn^{2+} and existing water sources>

The average value of shallow well (dug well) is higher than that of the other water sources.

Table 6.7 Manganese of Existing Water Sources

Type	Mn^{2+} (mg/l)	Average (mg/l)
Surface water	0.0302 - 0.1411	**0.0589**
Spring water	0.0375 - 0.0877	**0.0636**
Shallow well (dug well)	0.0010 - 3.2851	**0.1396**
Shallow well (UNICEF hand pump well)	0.0457 - 0.0785	**0.0632**
Deep well (dug + drilling well)	0.0230 - 0.0370	**0.0230**
Deep well (drilling well)	0.0020 - 0.1716	**0.0401**

<Comparison with drinking water standards>

According to the Vietnamese standard (TCXD 233: 1999), manganese value of class A is less than 0.05 mg/l for ground water and less than 0.2 mg/l for surface water. Most of the measured values are classified as either class A or B.

(6) Arsenic (As)

<Comparison with drinking water standards>

According to the Vietnamese standard (TCXD 233: 1999), arsenic value of class A is 0 mg/l, and class B should be less than 0.05 mg/l. All of the measured values are classified into class B as shown in Figures 6.12 to 6.14.

(7) Fluoride (F)

<Comparison with drinking water standards>

According to the Vietnamese standard (TCXD 233: 1999), fluoride value of class A is 0 mg/l and class B is less than 0.05 mg/l. Most of the measured values are classified into class as shown in Figures 6.15 to 6.16.

(8) Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-}

Table 6.8 shows the laboratory result of water quality analysis of existing water sources. According to the trilinear diagrams and stiff diagrams as shown in Figures 6.17 to 6.20, geo-chemical types are summarized as shown Table 6.9;

Table 6.8 Result of Water Quality Analysis of Existing Water Sources

Commune No.	Type	Parameter	Temp. (℃)	pH	Ec (μ S/cm)	DO (mg/l)	TDS (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	HCO_3^{-} (mg/l)	Cl (mg/l)	SO_4^{2-} (mg/l)	Total Fe (mg/l)	NO_3-N (mg/l)	NO_2-N (mg/l)	NH_4^{+} (mg/l)	PO_4^{3-} (mg/l)	COD(KMnO$_4$) (mg/l)	F (mg/l)	As (mg/l)	Mn^{2+} (mg/l)	Coliform (MPN/100ml)
K-1	Surface Water (+Gravity Flow System)	Nos.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		Max.	24.7	8.23	126.9	3.59	111.850	13.14	8.080	2.76	2.418	83.51	0.426	3.84	0.53	<0.001	0.03	0.058	0.05	3.390	0.1808	0.0050	0.1411	5,400
		Min.	23.6	6.59	42.1	2.38	38.800	3.10	2.940	1.15	0.546	25.50	0.142	3.02	0.16	<0.001	0.01	0.044	<0.01	1.260	0.0659	0.0029	0.0302	920
		Av.	24.2	7.66	98.6	3.10	74.815	8.21	5.840	1.99	1.339	53.68	0.284	3.47	0.38	<0.001	0.02	0.051	-	2.627	0.1058	0.0038	0.0688	2,413
	Shallow Well (Dug Well)	Nos.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
		Max.	24.7	6.79	168.4	2.69	123.957	17.84	2.685	3.68	11.310	81.80	0.497	6.14	0.52	0.010	0.19	0.070	0.05	0.551	0.2081	0.0026	0.0735	1,600
		Min.	24.6	5.32	84.6	2.06	33.465	2.82	0.571	3.68	5.460	1.28	3.621	16.03	0.68	<0.001	5.82	0.040	<0.01	1.180	0.1373	0.0033	0.0375	280
		Av.	24.65	6.06	126.5	2.38	78.711	10.33	1.628	3.68	8.385	41.54	2.059	11.09	0.60	-	3.00	0.055	-	0.866	0.1727	0.0029	0.0555	940
K-2	Shallow Well (Dug Well)	Nos.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		Max.	25.4	6.07	61.1	3.37	50.219	8.38	1.276	1.61	1.326	30.20	1.775	7.97	0.29	0.010	2.43	0.081	<0.01	0.787	0.1006	0.0039	0.2201	1,600
		Min.	23.7	4.93	13.14	2.56	7.374	0.78	0.389	0.46	0.195	0.61	0.284	4.32	0.13	<0.001	0.09	0.006	<0.01	0.236	0.0420	0.0028	0.0318	540
		Av.	24.5	5.38	32.7	2.86	19.297	2.76	0.775	0.97	0.710	7.08	0.611	6.40	0.17	-	0.81	0.056	<0.01	0.504	0.0733	0.0035	0.0729	1,116
K-3	Surface Water (+Gravity Flow System)	Nos.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
		Max.	24.4	7.59	142.3	3.85	125.694	14.88	8.602	4.83	1.911	91.74	0.213	6.96	1.05	<0.001	0.02	0.070	0.09	1.810	0.0851	0.0033	0.0455	3,500
		Min.	24.1	7.59	132.2	3.78	119.951	13.88	7.679	3.68	1.209	84.18	0.213	5.66	0.28	<0.001	0.02	0.031	<0.01	1.259	0.0677	0.0031	0.0427	2,400
		Av.	24.3	7.59	137.3	3.82	122.823	14.38	8.141	4.26	1.560	87.96	0.213	6.31	0.67	<0.001	0.02	0.051	-	1.535	0.0764	0.0032	0.0441	2,950
	Shallow Well (Dug Well)	Nos.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		Max.	25.4	5.88	68.0	2.95	48.309	2.90	4.398	4.37	2.340	30.93	3.550	6.10	0.22	<0.001	0.74	0.060	<0.01	0.630	0.0843	0.0034	0.1505	1,600
		Min.	25.3	5.57	45.3	1.58	23.230	2.16	0.437	2.07	1.053	11.59	0.213	4.75	0.14	<0.001	0.16	0.044	<0.01	0.551	0.0647	0.0026	0.0375	540
		Av.	25.3	5.72	54.7	2.25	34.175	2.60	1.774	3.07	1.716	18.42	1.349	5.25	0.19	<0.001	0.42	0.050	<0.01	0.577	0.0716	0.0031	0.0752	1,020
K-4	Shallow Well (Dug Well)	Nos.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		Max.	26.7	5.54	33.7	3.26	28.419	5.42	0.705	1.61	1.170	17.69	0.852	7.49	0.99	<0.001	1.11	0.110	<0.01	0.787	0.1000	0.0039	0.0529	350
		Min.	24.4	4.55	13.10	2.55	3.981	0.22	0.267	0.23	0.195	0.67	0.071	2.26	0.18	<0.001	0.20	0.041	<0.01	0.236	0.0452	0.0035	0.0305	140
		Av.	25.4	5.22	22.7	2.95	14.040	1.85	0.527	0.83	0.616	5.31	0.398	4.51	0.42	<0.001	0.51	0.064	<0.01	0.472	0.0734	0.0037	0.0412	234
K-5	Shallow Well (Dug Well)	Nos.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		Max.	25.9	5.99	108.8	2.58	62.517	8.10	2.491	6.44	6.630	40.20	11.786	11.52	0.71	0.010	9.58	0.072	0.06	0.866	0.1007	0.0048	0.1070	920
		Min.	25.3	4.67	23.3	1.65	9.824	0.44	0.255	1.61	0.624	0.73	0.213	4.66	0.20	<0.001	8.22	0.017	0.04	0.315	0.0452	0.0036	0.0427	280
		Av.	25.7	5.18	69.8	2.29	38.810	4.14	1.419	3.96	2.543	13.22	5.112	8.42	0.48	-	8.96	0.034	0.04	0.567	0.0783	0.0040	0.0719	640
K-6	Spring Water	Nos.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Max.	25.0	6.12	56.7	3.39	30.623	2.16	2.479	1.43	3.354	6.16	0.355	14.69	0.27	0.020	4.34	0.020	0.04	0.391	0.0853	0.0038	0.0375	920
		Min.	25.0	6.12	56.7	3.39	30.623	2.16	2.479	1.43	3.354	6.16	0.355	14.69	0.27	0.020	4.34	0.020	0.04	0.391	0.0853	0.0038	0.0375	920
		Av.	25.0	6.12	56.7	3.39	30.623	2.16	2.479	1.43	3.354	6.16	0.355	14.69	0.27	0.020	4.34	0.020	0.04	0.391	0.0853	0.0038	0.0375	920
	Shallow Well (Dug Well)	Nos.	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		Max.	25.8	6.27	254	3.46	171.641	24.06	4.787	14.72	7.410	115.29	27.868	30.14	0.37	0.080	9.56	0.017	0.18	0.787	0.1888	0.0082	0.4070	920
		Min.	25.2	5.82	80.8	1.75	12.600	0.86	0.158	0.69	3.198	0.67	1.420	2.98	0.25	<0.001	1.74	0.012	0.04	0.708	0.0707	0.0041	0.1100	240
		Av.	25.5	6.02	162.2	2.50	101.483	13.69	2.858	9.09	4.407	48.01	8.795	14.64	0.30	-	7.33	0.015	0.08	0.748	0.1293	0.0052	0.1880	485
Kon Tum	Surface Water	Nos.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		Max.	24.7	8.23	142.3	3.85	125.694	14.88	8.602	4.83	2.418	91.74	0.426	6.96	1.05	<0.001	0.03	0.070	0.09	3.390	0.1808	0.0050	0.1411	5,400
		Min.	23.6	6.59	42.1	2.38	38.800	3.10	2.940	1.15	0.546	25.50	0.142	3.02	0.16	<0.001	0.01	0.031	<0.01	1.259	0.0659	0.0029	0.0302	920
		Av.	24.2	7.63	114.1	3.38	94.018	10.68	6.760	2.90	1.427	67.39	0.256	4.606	0.49	<0.001	0.02	0.051	-	2.190	0.0940	0.0036	0.0589	2,628
	Spring Water	Nos.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Max.	25.0	6.12	56.7	3.39	30.623	2.16	2.479	1.43	3.354	6.16	0.355	14.69	0.27	0.020	4.34	0.020	0.04	0.391	0.0853	0.0038	0.0375	920
		Min.	25.0	6.12	56.7	3.39	30.623	2.16	2.479	1.43	3.354	6.16	0.355	14.69	0.27	0.020	4.34	0.020	0.04	0.391	0.0853	0.0038	0.0375	920
		Av.	25.0	6.12	56.7	3.39	30.623	2.16	2.479	1.43	3.354	6.16	0.355	14.69	0.27	0.020	4.34	0.020	0.04	0.391	0.0853	0.0038	0.0375	920
	Shallow Well (Dug Well)	Nos.	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
		Max.	26.7	6.79	254	3.46	171.641	24.06	4.787	14.72	11.310	115.29	27.868	30.14	0.99	0.080	9.58	0.110	0.18	1.180	0.2081	0.0082	0.4070	1,600
		Min.	23.7	4.55	13.10	1.58	3.981	0.22	0.158	0.23	0.195	0.61	0.071	2.26	0.13	<0.001	0.09	0.006	<0.01	0.236	0.0420	0.0026	0.0305	140
		Av.	25.2	5.51	70.5	2.58	42.776	5.29	1.401	3.40	2.454	19.10	3.081	8.05	0.35	-	3.67	0.045	-	0.590	0.0918	0.0038	0.0841	781
	Total	Nos.	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
		Max.	26.7	8.23	254	3.85	171.641	24.06	8.602	14.72	11.310	115.29	27.868	30.14	1.05	0.080	9.58	0.110	0.18	3.390	0.2081	0.0082	0.4070	5,400
		Min.	23.6	4.55	13.10	1.58	3.981	0.22	0.158	0.23	0.195	0.61	0.071	2.26	0.13	<0.001	0.01	0.006	<0.01	0.236	0.0420	0.0026	0.0302	140
		Av.	25.0	5.89	77.3	2.74	50.911	6.08	2.330	3.25	2.313	26.72	2.519	7.70	0.37	-	3.08	0.045	-	0.850	0.0919	0.0038	0.0783	1,030
Water Quality Standard (TCXD 233 : 1999)	Class A		-	6.8-7.5 (6.5-8.5)									<25 (<25)	<25 (<25)	<0.3 (<0.3)	0 (<0.1)	0 (0)	0 (<0.2)	0 (0)		0.5-1.0 (0.5-1.0)	0 (0)	<0.05 (<0.2)	0 (<20)
	Class B			6.0-8.0 (6.0-9.0)									<200 (<200)	<250 (<250)	<10 (<1)	<0.1 (<1)	<6 (<6)	<3 (<0.5)	<1.5 (<1.5)		0-0.5or1.0-1.5 (<1.5)	<0.050 (<0.050)	<2 (<0.5)	<20 (<100)
	Class C			4.5-8.5 (>9 or <6)									<400 (<400)	<400 (<400)	<50 (<2)	<2 (<2)	<10 (<10)	<30 (<1)	<2 (<2)		<2 (<2)	<0.100 (<0.100)	<3 (<1)	<100 (<200)
	Exceeding Class C																							1000≤ (2000≤)
WHO Guideline			-	-			1,000						250	250	0.3	3	50	1.5			1.5	0.01	0.5, 0.1	0

Table 6.9 Geo-chemical Types of Existing Water Sources

Type	Water Type	Nos.
Surface water	$Mg\text{-}Ca\text{-}HCO_3$	4
	$Ca\text{-}Mg\text{-}HCO_3$	1
Spring water	$Mg\text{-}Ca\text{-}HCO_3$	2
	$Mg\text{-}SO_4\text{-}HCO_3$	1
	$FMg\text{-}Ca\text{-}SO_4$	1
Shallow well (dug well)	$Mg\text{-}Ca\text{-}HCO_3$	8
	$Mg\text{-}Ca\text{-}SO_4$	6
	$Ca\text{-}Mg\text{-}HCO_3$	5
	Ca-HCO3	4
	Ca-Na-Mg	4
Sallow well (Dug well)	$Ca\text{-}Na\text{-}SO4\text{-}HCO_3$	1
	$Ca\text{-}Mg\text{-}Na\text{-}SO_4\text{-}HCO_3$	1
	Ca-Mg-HCO3-Cl	1
Deep well (dug + drilling wells)	$Ca\text{-}Mg\text{-}HCO_3$	2
	$Ca\text{-}Mg\text{-}Na\text{-}HCO_3$	1
Deep well (drilling well)	$Ca\text{-}Mg\text{-}HCO_3$	5
	$Na\text{-}Ca\text{-}HCO_3$	4
	$Ca\text{-}Mg\text{-}Na\text{-}HCO_3$	2

<Comparison with drinking water standards>

The standard value of chloride for class A is less than 25 mg/l and class B is less than 200 mg/l by the Vietnamese standard. All data of chloride show less than 200 mg/l and classified as either class A or B.

The standard value of sulphate for class A is less than 25 mg/l and class B is less than 250 mg/l by the Vietnamese standard. All data of sulphate show less than 250 mg/l and classified as either class A or B.

(9) Nitrite (NO_2^-), Ammonium (NH_4^-)

<Comparison with drinking water standards>

The standard value of nitrite for class A is 0 mg/l (groundwater) and less than 0.1 mg/l (surface water). The value for class B is less than 0.1 mg/l (groundwater) and less than 1 mg/l (surface water) by the Vietnamese standard. All data of nitrite show less than 0.1 mg/l and classified as either class A or B. The highest value was from the dug well of Chu Hreng commune (K-6, 0.080mg/l).

Table 6.10 Nitrite of Existing Water Sources

Type	Class A	Class B	Class C
Surface water	100.0%	0%	0%
Spring water	75.0%	25.0%	0%
Shallow well (dug well)	76.9%	23.1%	0%
Shallow well (UNICEF hand pump well)	100.0%	0%	0%
Deep well (dug + drilling well)	66.7%	33.3%	0%
Deep well (drilling well)	85.0%	15.0%	0%
Total	80.0%	20.0%	0%

The standard value of ammonium for class A is 0 mg/l (groundwater) and less than 0.2 mg/l (surface water). The value for class B is less than 3 mg/l (groundwater) and less than 0.5 mg/l (surface water) by the Vietnamese standard. All data of Ammonium show less than 3 mg/l and are classified into class A and B. The ammonium values of each water source are classified as follows;

Table 6.11 Ammonium of Existing Water Sources

Type	Class A	Class B	Class C
Surface water	100.0%	0%	0%
Spring water	100.0%	0%	0%
Shallow well (dug well)	0%	100.0%	0%
Shallow well (UNICEF hand pump well)	0%	100.0%	0%
Deep well (dug + drilling well)	0%	100.0%	0%
Deep well (drilling well)	0%	100.0%	0%
Total	9.0%	91.0%	0%

(10) Coliform

<Comparison with drinking water standards>

The standard value of coliform for class A is 0 MPN/100ml (groundwater) and less than 20 MPN/100ml (surface water). The value for class B is less than 20 MPN/100ml (groundwater) and less than 100 mg/l (surface water) by the Vietnamese standard. More than 82% of all data exceeded class C, and even for deep wells, 33% and 45% of data exceeded class C. The coliform values of each water resource are classified as follows;

Table 6.12 Coliform of Existing Water Sources

Type	Class A	Class B	Class C	Exceeding Class C
Surface water	0%	0%	0%	100.0%
Spring water	0%	0%	0%	100.0%
Sallow well (dug well)	1.5%	1.5%	4.6%	92.3%
Shallow well (UNICEF hand pump well)	0%	0%	0%	100.0%
Deep well (dug + drilling well)	0%	0%	66.7%	33.3%
Deep well (drilling well)	30.0%	15.0%	10.0%	45.0%
Total	7.0%	4.0%	7.0%	82.0%

6.1.5 Water Quality of Test Wells

Groundwater samples from the test well were collected at the pumping test stage. The samples were brought to the laboratory as soon as possible. The analysis results are shown in Figures 6.13. It is noted that the well of JICA K-4 and K-5 were abandoned or used for observation purposes only (K-6), because the well capacity is too small for a production well. The measured chemical parameters for the laboratory test and its methods are the same as mentioned in Chapter 5. In addition, the re-test for coliform for all the wells and the 2 re-test for all the items carried out in the pumping test stage in K3-1 well were carried out in the second field work at November 2001 and the third field work at May 2002. For the pilot model plant of K3-1 periodical in-site water quality check has been carrying out by the water supply unit (WSU) by weekly base.

(1) pH

The 17 data show that pH values ranged from 6.23 to 8.85 with an average of 7.15. The dominant values range from 7.0 to 7.5 (Figures 6.21). There were no definite differences with existing deep well water.

Table 6.13 Result of Water Quality Analysis of Test Wells and Alternative Water Sources

Sampl. No.	Type	Temp.	pH	EC	DO	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	Total Fe	$NO_2^{-}N$	$NO_3^{-}N$	NH_4^{+}	PO_4^{3-}	COD/K MnO_4	F	As	Mn^{2+}	Coliform*
		(℃)		(μS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(MPN/100m
K-1-0	Well	26.8	7.25	183.6	2.23	151.457	16.20	7.557	9.89	2.028	111.75	0.142	3.897	3.55	<0.001	0.01	0.028	0.09	0.315	0.0300	0.0010	0.1000	11
K-2-0	Well	24.1	7.23	178.7	1.75	151.873	16.28	8.432	9.66	1.950	112.61	1.985	0.96	2.64	<0.001	0.01	0.031	0.07	0.157	0.0100	0.0010	0.0650	17
K-3-0	Well	24.7	7.19	864	1.17	597.608	151.38	10.753	6.44	0.663	184.71	0.496	243.18	3.49	0.005	0.03	0.046	0.04	0.630	1.3200	0.0050	0.1211	33
K-4-0	River	26.7	7.13	66.6	3.15	50.979	5.12	3.074	2.30	1.833	36.66	0.071	1.92	1.88	0.002	0.11	0.035	<0.01	3.226	0.2100	0.0010	0.0050	130
K-5-0	River	25.6	7.15	68.8	3.64	51.037	4.62	2.151	3.45	4.095	33.49	0.496	2.75	4.58	0.005	0.12	0.059	<0.01	7.082	0.1900	0.0010	0.0150	180
K-6-0	River	33.2	7.60	89.4	3.04	68.223	2.46	5.346	5.06	3.822	48.25	0.351	2.94	3.02	0.005	0.06	0.073	<0.01	2.518	0.0800	0.0010	0.0210	2800
G-1-0	Well	27.5	7.32	198.7	1.16	170.062	4.34	2.807	31.97	2.535	124.32	0.915	3.19	0.82	0.030	0.06	0.052	0.03	0.157	0.6600	0.0010	0.0130	33
G-2-0	Well	28.1	7.00	338	3.04	211.444	24.72	12.758	12.65	4.062	142.62	0.993	13.10	0.21	0.002	0.19	0.074	0.10	0.157	0.2900	0.0032	0.1950	0
G-3-0	Well	27.0	7.20	61.7	2.56	166.645	14.38	11.900	7.13	2.964	126.88	0.213	3.89	0.40	<0.001	0.05	0.029	0.14	0.236	0.1007	0.0040	0.0975	34
G-4-0	Well	29.2	7.59	273	5.55	225.997	10.80	13.171	22.43	4.095	155.18	0.355	19.97	0.36	0.010	0.01	0.179	0.07	0.079	0.8000	0.0022	0.1740	5
G-5-0	Well	28.6	7.29	656	2.28	568.373	24.20	20.679	94.30	17.550	410.47	0.071	1.10	0.47	0.001	0.01	0.147	0.06	0.079	0.2900	0.0026	0.0630	23
G-6-0	Well	27.3	6.98	775	1.25	195.322	40.40	13.940	34.96	1.521	57.26	158.350	7.28	3.10	<0.001	9.09	0.138	0.04	0.779	0.0870	0.0034	0.0672	46
G-7-0	Well	27.0	7.18	501	1.42	426.749	42.12	23.219	28.75	1.989	311.34	15.775	3.55	2.07	0.002	0.01	0.098	0.05	0.866	0.2200	0.0010	0.2860	43
D-1-0	Well	25.3	6.43	153.0	2.63	125.028	8.80	7.946	9.66	1.833	93.88	1.407	1.50	0.11	0.001	0.06	0.035	0.06	0.079	0.1300	0.0010	0.0111	31
D-2-0	Well	26.4	6.42	100.6	2.56	64.614	4.92	3.900	5.29	1.599	39.10	0.780	9.02	0.39	0.002	0.02	0.049	0.12	0.157	<0.0001	0.0010	0.0410	11
D-3-0	Well	26.5	7.99	553	1.77	495.166	3.98	3.159	126.50	1.443	309.88	0.284	13.92	0.12	<0.001	0.60	0.103	0.08	0.551	0.2800	0.0060	0.0120	22
D-4-0	Well	25.9	7.85	401	1.59	335.710	2.52	0.620	94.30	3.354	215.70	3.332	15.90	3.76	0.080	0.12	0.071	0.14	0.630	0.6700	0.0010	0.0390	33
D-5-0	Well	27.7	6.93	558	2.35	340.127	70.96	6.051	12.88	1.356	240.65	0.355	7.87	0.82	0.020	0.06	0.233	0.06	0.236	<0.0001	0.0040	1.1110	8
D-6-0	Well	28.0	6.23	145.6	1.92	208.916	21.60	11.676	9.20	2.652	155.37	0.213	8.21	0.65	0.010	0.02	0.072	<0.01	0.630	0.0857	0.0046	0.0755	0
D-7-0	Well	28.1	6.54	186.0	2.02	126.073	9.04	6.282	11.96	3.042	86.56	0.071	9.12	4.09	0.011	0.01	0.293	0.03	0.236	0.0500	0.0010	0.3590	43
Total	nos.	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	max	33.2	7.99	864	5.55	597.608	151.38	23.219	126.50	17.550	410.47	158.350	243.18	4.58	0.080	9.09	0.293	0.14	7.082	1.3200	0.0060	1.1110	2800
	min	24.1	6.23	61.7	1.16	50.979	2.46	0.620	2.30	0.663	33.49	0.071	0.96	0.11	<0.001	0.01	0.028	<0.01	0.079	<0.0001	0.0010	0.0050	0
	average	27.2	7.13	318	2.35	236.570	23.94	8.771	26.94	3.219	149.83	9.333	18.66	1.83	0.009	0.53	0.092	0.059	0.940	0.2752	0.0023	0.1436	175
Standard 505 of MOH		-	-			1,000						250	400	0.5	0	10	3.0			1.5	0.05	0.1	

*tests were conducted in the first field survey and F/S. Source: Study Team

<Comparison with drinking water standards>
According to the Vietnamese standard (TCXD 233: 1999), pH value of groundwater for class A should be in the range from 6.8 to 7.5 and class B should be in the range from 6.0 to 8.0. All of the measured values are classified as either class A or B.

Table 6.14 pH of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	10nos.	7nos.	0nos.
	58.8%	41.2%	0%

(2) EC

The EC values ranged from 61.7 to 864 μS/cm, with an average of 360 μS/cm. The dominant values are in the two groups of 100 - 200 μS/cm and 400 to 800 μS/cm (Figures 6.21).The EC values are slightly higher than that of the existing deep well samples (Figures 6.13).

(3) Total Dissolved Solids (TDS)

The values ranged from 64.614 to 597.608 mg/l, with an average of 268.304 mg/l. The dominant values are in the range of 150 to 200 mg/l (Figures 6.21). They are slightly higher than that of the existing deep well samples (Table 6.13)

(4) Total Iron (Fe)

The values ranged from 0.11 to 4.09 mg/l, with average of 1.59 mg/l. Two dominant groups are detected as 0.3 to 1 mg/l and 2 to 4 mg/l (Figures 6.21). These results are slightly higher than that of existing deep well samples (Table 6.13)

<Comparison with drinking water standards>
The standard value of total iron for class A is less than 0.3 mg/l and for class B is less than 10 mg/l as shown in the following table. The total Iron values of test well water are classified as follows;

Table 6.15 Iron of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	3nos.	14nos.	0nos.
	17.6%	82.4%	0%

All of the measured values are classified as either class A or B. The highest value was from the JICA D-7 (Krong Kmar, 4.09 mg/l). JICA D-4 (Ea Drong, 3.76 mg/l) was the second highest value. The other data that exceeding 2 mg/l are, JICA K-1 (Bo Y, 3.55 mg/l), JICA K-2 (Dak Su, 2.64 mg/l), JICA K-3 (Dak Ui, 3.49 mg/l), JICA G-6 (Ia Rsiom, 3.10 mg/l), and JICA G-7 (Kong Yang, 2.07 mg/l) well.

(5) Manganese (Mn^{2+})

The values ranged from 0.0111 to 1.1110 mg/l, with an average of 0.1665 mg/l. The dominant values ranged from 0 to 0.1 mg/l (Figures 6.21). They are higher than that of existing deep well samples (Table 6.13).

<Comparison with drinking water standards>

The manganese values of test well water are classified as either class A or B;

Table 6.16 Manganese of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	5nos.	12nos.	0nos.
	29.4%	70.6%	0%

The other data exceeding 0.1 mg/l are JICA K-1 (Bo Y, 0.1000 mg/l) and JICA K-3 (Dak Ui, 0.1211 mg/l) well.

(6) Arsenic (As)

The values ranged from 0.0010 to 0.0060 mg/l, with an average of 0.0025 mg/l. The dominant values range from 0 to 0.002 mg/l (Fugure 6.21). There is no definite difference in the values with the existing deep well samples (Table 6.13).

<Comparison with drinking water standards>

The standard value of arsenic for class A is 0 mg/l, for class B is less than 0.05 mg/l, and for class C is less than 0.1 mg/l as shown in the following table. All of the measured values are classified into class B.

Table 6.17 Arsenic of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	0nos.	17nos.	0nos.
	0%	100.0%	0%

All of the measured values are classified into class B.

(7) Fluoride (F)

The values ranged from <0.0001 to 1.3200 mg/l. The dominant values ranged from 0 to 0.2 mg/l (Figure 6.21). There is no definite difference in the values with the existing deep well data (Table 6.13).

<Comparison with drinking water standards>

The standard value of fluoride for class A is should be in the range from 0.5 mg/l to 1.0 mg/l, for class B is range from 0 to 0.5 mg/l and range from 1.0 to 1.5 mg/l. The fluoride values of test well water are classified as follows;

Table 6.18 Fluoride of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	3nos.	14nos.	0nos.
	17.6%	82.4%	0%

All of the measured values are classified as either class A or B.

(8) Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-} of Test Wells

According to the trilinear diagrams as shown in Figures 6.21 to 6.24, most results plotted in the lower left field of the diamond-shape diagram, and SO_4^{2+} + NO_3^{-} + Cl^{-} is less than 20 % in total meq/l. The values of Cl^{-} are less than 20 % in total meq/l. Sodium, chloride, sulphate, and nitrate from the test wells are higher than that of existing deep well data (Table 6.13). The geo-chemical types of the test wells are summarized as follows;

Table 6.19 Geo-chemical Types of Test Wells

Water Type	Nos.
Na-HCO_3	4
Ca-Mg-Na-HCO_3	3
Ca-Mg-HCO_3	2

<Comparison with drinking water standards>

The standard value of chloride for class A is less than 25 mg/l and for class B is less than 200 mg/l. The chloride values of test well water are classified as follows;

Table 6.20 Chloride of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	16nos.	1nos.	0nos.
	94.1%	5.9%	0%

Only one value classified into class B and the others classified into class

The standard value of Sulphate for class A is less than 25 mg/l and for class B is less than 250 mg/l. The Sulphate values of test well water are classified as follows;

Table 6.21 Sulphate of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	16nos.	1nos.	0nos.
	94.1%	5.9%	0%

Only one (1) value classified into class B and this value is from JICA K-3 (Dak Ui, 243.18 mg/l). Except this value, the others classified into class

The standard value of nitrate for class A is 0 mg/l, for class B is less than 6 mg/l, and for class C is less than 10 mg/l. The nitrate values of test well water are classified as follows;

Table 6.22 Nitrate of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	0nos.	16nos.	1nos.
	0%	94.1%	5.9%

Only one (1) value classified into class C and this value was from JICA G-6 (Ia Rsiom, 9.09 mg/l). Except this value, the others classified into class B.

(9) Nitrite (NO_2^-) and Ammonium (NH_4^-)

<Comparison with drinking water standards>

The standard value of nitrite for class A is 0 mg/l, for class B is less than 0.1 mg/l, and for class C is less than 2 mg/l. The nitrite values of test well water are classified as follows;

Table 6.23 Nitrite of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	5nos.	12nos.	0nos.
	29.4%	70.6%	0%

All of the measured values are classified as either class A or B. The highest value was from JICA D-4 (Thang Hung, 0.080 mg/l).

The standard value of ammonium for class A is 0 mg/l, for class B is less than 3 mg/l, and for class C is less than 30 mg/l. The ammonium values of test well water are classified as follows;

Table 6.24 Ammonium of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	0nos.	17nos.	0nos.
	0%	100.0%	0%

All of the measured values are classified into class B. The highest value was from JICA D-7 (Krong Kmar, 0.293 mg/l).

(10) Coliform

<Comparison with drinking water standards>

The standard value of coliform for class A is 0 MPN/100ml, for class B is less than 20 MPN/100ml, and for class C is less than 100 MPN/100ml. Detailed measurement of coliform was carried out at the F/S phase. All the surface water samples contained a high level of coliform indicating severe biological contamination. The level of coliform was so high (130 MPN/100ml) that alternative water sources need intensive treatment for coliform.

(11) Dioxin Analysis

Dioxin analysis was made at Hanoi National University. The 3 samples were taken from JICA K-1, JICA G-3 and JICA D-6 exploratory wells in the time for pumping test or preliminary pumping test. The total 20 liters of each sample were transported to the laboratory.

The appearance of dioxin is inferred that it is by chemical reaction from artificial materials such as agricultural chemical, burning of poly-vinyl chemical materials under low temperature, and deforestation chemicals. The most probable area of serious deforestation by Vietnam War is located near the border of Cambodia. Therefore, the samples were selected as K1, G3 and D6 communes. No dioxin was detected by the laboratory test (Data Book).

6.1.6 Water Quality of Alternative Water Sources

In the Dak Hring commune (K-4), Sa Nghia commune (K-5), and Chu Hreng commune (K-6), the drilling result showed that a capacity and/or groundwater potential is too small for production well to supply water. Therefore, in these communes 3 river water samples were collected as alternative sources.

(1) pH

The data ranged from 7.13 to 7.60 with an average of 7.29 as shown in Table 6.25 and Figure 6.23.

Table 6.25 Result of Water Quality Analysis of Surface Water Sources

Parameter	pH		EC (μ S/cm)		DO (mg/l)		TDS (mg/l)	
Type	A	B	A	B	A	B	A	B
nos.	60	3	60	3	5	3	5	3
Max	8.26	7.60	467	89.4	3.85	3.64	125.694	68.223
Min	5.54	7.13	11.40	66.6	2.38	3.04	38.800	50.979
Average	7.04	7.29	90.2	74.9	3.38	3.28	94.018	56.746
Parameter	TotalFe(mg/l)		Mn^{2+} (mg/l)		As (mg/l)		F (mg/l)	
Type	A	B	A	B	A	B	A	B
nos.	5	3	5	3	5	3	5	3
Max	1.05	4.58	0.1411	0.0210	0.0050	0.0010	0.1808	0.2100
Min	0.16	1.88	0.0302	0.0050	0.0029	0.0010	0.0659	0.0800
Average	0.49	3.16	0.0589	0.0137	0.0036	0.0010	0.0940	0.1600
Parameter	Ca^{2+} (mg/l)		Mg^{2+} (mg/l)		Na^{+} (mg/l)		K^{+} (mg/l)	
Type	A	B	A	B	A	B	A	B
nos.	5	3	5	3	5	3	5	3
Max	14.88	5.12	8.602	5.346	4.83	5.06	2.418	4.095
Min	3.10	2.46	2.940	2.151	1.15	2.30	0.546	1.833
Average	10.68	4.07	6.760	3.524	2.90	3.60	1.427	3.250
Parameter	HCO_3^- (mg/l)		Cl^- (mg/l)		SO_4^{2-} (mg/l)		NO_3^-N (mg/l)	
Type	A	B	A	B	A	B	A	B
nos.	5	3	5	3	5	3	5	3
Max	91.74	48.25	0.426	0.496	6.96	2.94	0.03	0.12
Min	25.50	33.49	0.142	0.071	3.02	1.92	0.01	0.06
Average	67.39	39.47	0.256	0.306	4.61	2.54	0.02	0.10
Parameter	NO_2^-N (mg/l)		NH_4^- (mg/l)		PO_4^{3+} (mg/l)		Coliform(MPN/100ml)	
Type	A	B	A	B	A	B	A	B
nos.	5	3	5	3	5	3	5	3
Max	<0.001	0.005	0.070	0.073	0.09	<0.01	5,400	16,000
Min	<0.001	0.002	0.031	0.035	0.05	<0.01	920	2,800
Average	<0.001	0.004	0.051	0.056	0.07	<0.01	2,628	8,067

* A: Existing water source B: Alternative water source

<Comparison with drinking water standards>
According to the Vietnamese standard (TCXD 233: 1999), it is mentioned that pH value of surface water for class A should be in the range from 6.5 to 8.5 and class B should be in the range from 6.0 to 9.0 (Table 5.14). The pH values of surface water are classified as follows;

Table 6.26 pH of Alternative Water Sources

Type	Class A	Class B	Class C
Surface Water	3nos.	0nos.	0nos.
	100.0%	0%	0%

All of the measured values are classified into class

(2) EC

The data ranged from 66.6 to 89.4 μS/cm, with an average of 74.9 μS/cm (Figure 5.55). The values of the three alternative water samples are slightly lower than that of the other surface water data (Table 5.25).

(3) Total Dissolved Solids (TDS)

The data ranged from 50.979 to 68.223 mg/l, with an average of 56.746 mg/l (Figure 5.55). The data of three alternative samples are lower than that of the other surface water samples (Table 5.25).

(4) Total Iron (Fe)

The data ranged from 1.88 to 4.58 mg/l, with an average of 3.16 mg/l (Figure 5.55). The values of three alternative resources are higher than that of existing surface water samples (Table 5.25).
<Comparison with drinking water standards>
The standard value of total iron for class A is less than 0.3 mg/l, for class B is less than 1 mg/l, and for class C is less than 2 mg/l (Table 5.14). The total Iron values of surface water are classified as follows;

Table 6.27 Iron of Alternative Water Sources

Type	Class A	Class B	Class C	Exceeding Class C
Surface Water	0nos.	0nos.	1nos.	2nos.
	0%	0%	33.3%	66.7%

All of the measured values are classified as either class C or exceeding class C. These three alternative water resource samples are exceeding 1 mg/l. The highest value was from the river in Nghia Hoa commune (K-5, 4.58 mg/l).

(5) Manganese (Mn^{2+})

The data range from 0.0050 to 0.0210 mg/l, and average is 0.0137 mg/l (Figure 5.55). The values of three alternative water resource samples are lower that of existing water resources (Table 5.25).

<Comparison with drinking water standards>

The standard value of manganese for class A is less than 0.2 mg/l, for class B is less than 0.5 mg/l, and for class C is less than 1 mg/l (Table 5.14). The manganese values of surface water are classified as follows;

Table 6.28 Manganese of Alternative Water Sources

Type	Class A	Class B	Class C
Surface Water	3nos.	0nos.	0nos.
	100.0%	0%	0%

All of the measured values are classified into class The highest value was from the river in Chu Hreng commune (K-6, 0.0210 mg/l).

(6) Arsenic (As)

The data for arsenic of 3 samples are 0.0010mg/l (Figure 5.55). As contents in three alternative water resources samples are lower than that of the other surface water samples (Table 5.25).

<Comparison with drinking water standards>

The standard value of arsenic for class A is 0 mg/l, for class B is less than 0.05 mg/l, and for class C is less than 0.1 mg/l (Table 5.14). The arsenic values of surface water are classified as follows;

Table 6.29 Arsenic of Alternative Water Sources

Type	Class A	Class B	Class C
Surface Water	0nos.	3nos.	0nos.
	0%	100.0%	0%

All of the measured values are classified into class B.

(7) Fluoride (F)

The data for fluoride contents range from 0.0800 to 0.2100 mg/l, and average is 0.1600 mg/l (Figure 5.55). The fluoride contents of three alternative water resource samples are higher than that of the other surface water samples (Table 5.25.)

<Comparison with Drinking Water Standards>

The standard value of fluoride for class A is should be in the range from 0.5 mg/l to 1.0 mg/l, for class B is less than 1.5 mg/l, and for class C is less than 2 mg/l (Table 5.14). The fluoride values of surface water are classified as follows;

Table 6.30 Fluoride of Alternative Water Sources

Type	Class A	Class B	Class C
JICA Test Well	0nos.	3nos.	0nos.
	0%	100.0%	0%

All of the measured values are classified into class B. The highest value was from the river in Dak Hring commune (K-4, 0.210 mg/l).

(8) Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-}

The data are plotted on the trilinear diagram in Figure5.56. The three data are plotted in the lower left field of the diamond-shape diagram, and $SO_4^{2+} + NO_3^{-} + Cl^{-}$ is less than 10 % in total meq/l. Cl^{-} is less than 10 % in total meq/l.

The water chemical types of the three alternative water resources are summarized as follows;

Table 6.31 Geo-chemical Types of Alternative Water Sources

Water Type	Nos.
Ca-Mg-HCO_3	1
Ca-Mg-Fe	1
Mg-Na-HCO_3	1

<Comparison with drinking water standards>

The standard value of chloride for class A is less than 25 mg/l and for class B is less than 200 mg/l (Table 5.14). All measured values are classified into class A, and the highest value was from the river in Sa Nghia commune (K-5, 0.351 mg/l).

The standard value of Sulphate for class A is less than 25 mg/l and for class B is less than 250 mg/l (Table 5.14). All of the measured values are classified into class A, and the highest value was from the river in Chu Hreng commune (K-6, 2.94 mg/l).

The standard value of nitrate for class A is 0 mg/l, for class B is less than 6 mg/l, and for class C is less than 10 mg/l (Table 5.14). All of the measured values are classified into class B, and the highest value was from the river in Sa Nghia commune (K-5, 0.12 mg/l).

(9) Nitrite (NO_2^-), Ammonium (NH_4^-)

<Comparison with Drinking Water Standards>
The standard value of nitrite for class A is less than 0.1 mg/l, for class B is less than 1 mg/l, and for class C is less than 2 mg/l (Table 5.14). The measured three values are classified into class A, and the highest value was from the river in Sa Nghia commune (K-5, 0.005 mg/l) and Chu Hreng commune (K-6, 0.005 mg/l).

The standard value of ammonium for class A is 0.2 mg/l, for class B is less than 0.5 mg/l, and for class C is less than 1 mg/l (Table 5.14). The measured three values are classified into class A, and the highest value was from the river in Chu Hreng commune (K-6, 0.073 mg/l).

(10) Coliform

<Comparison with Drinking Water Standards>
The standard value of coliform for class A is less than 20 MPN/100ml, for class B is less than 100 MPN/100ml, and for class C is less than 200 MPN/100ml (Table 5.14). The measured three values exceeded class C, and the highest value was from the river in Sa Nghia commune (K-5, 16,000 MPN/100ml)

6.1.7 Evaluate of the Water Quality

(1) Existing Water Resources

Except for the parameter of coliform levels, these existing water resources are mostly classified into class B to C. Because of low pH and high contents of nitrate contents, many water samples were classified into class C.
The following points are of the importance for future improvement of water quality.

- High values of coliform
- Low pH
- High contents of nitrate
- High contents of manganese
- High contents of iron

(2) JICA Test Wells

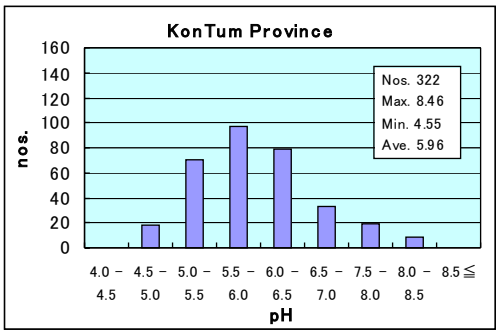
Except the water samples which show a high coliform value, these test well water are mostly classified into class A and B. Because of low coliform value by the re-test at F/S stage, many water samples were classified into class B.
The following points are the most important considerations for using these water resources for a water supply.

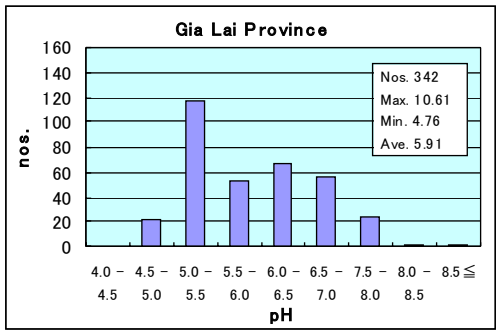
- High contents of iron

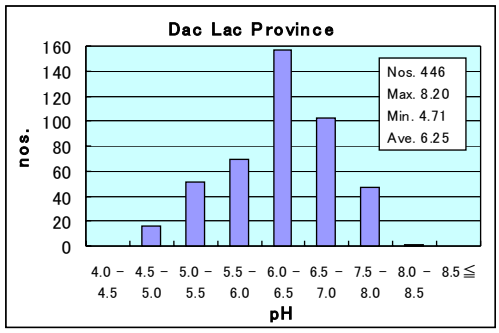
(3) Alternative Water Resources

The analyzed surface water samples are mostly classified into class B.
The following points are the most important considerations for using these water resources for water supply.

- High values of Coliform
- High contents of Iron







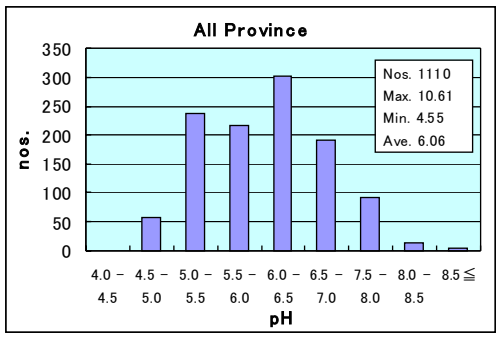
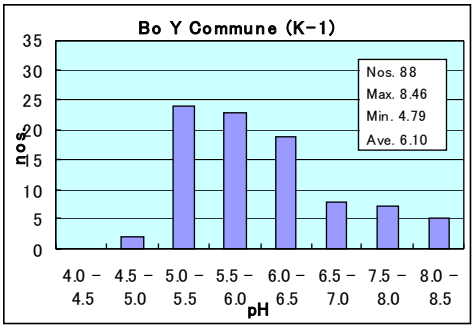
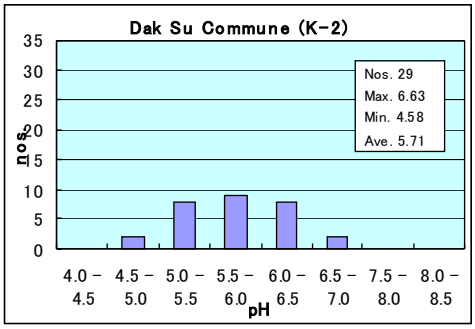
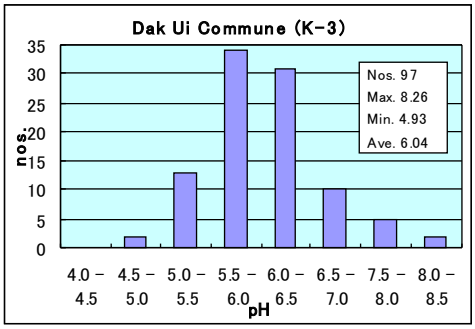
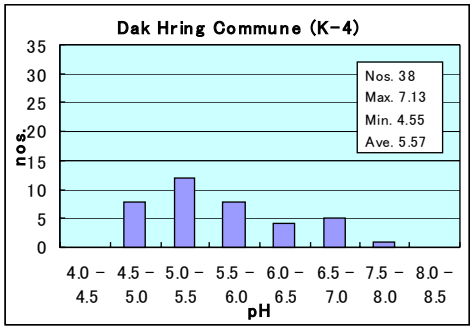


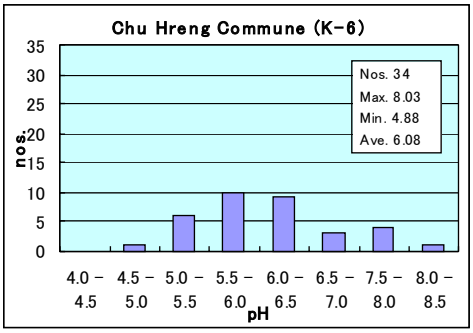
Figure 6.1 pH Value of Existing Water Sources in Three Provinces











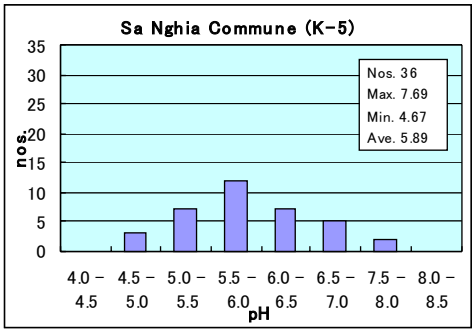
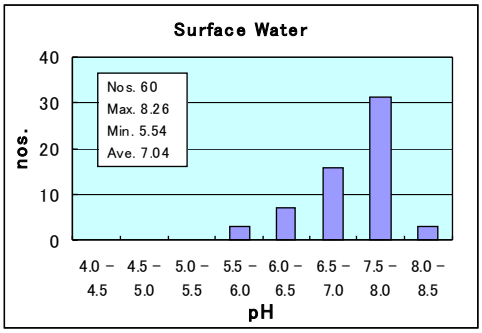
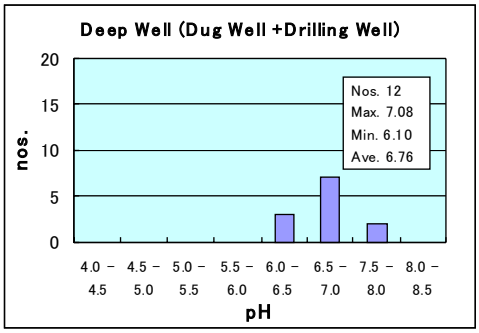
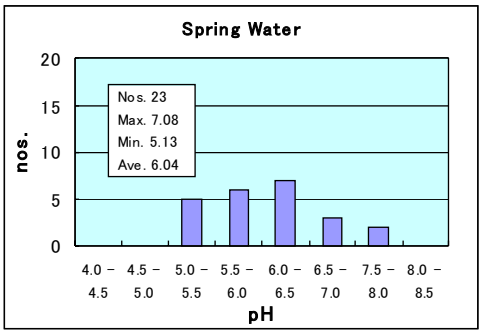
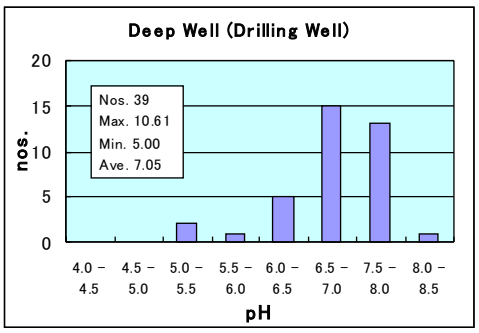


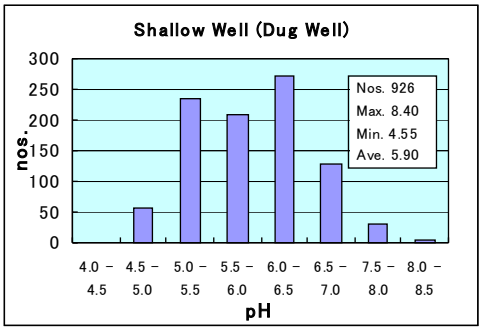
Figure 6.2 pH Value of Existing Water Sources in Kon Tum Province

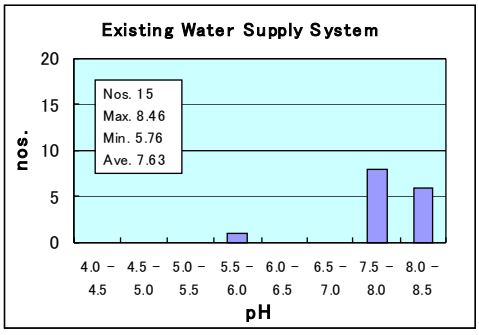


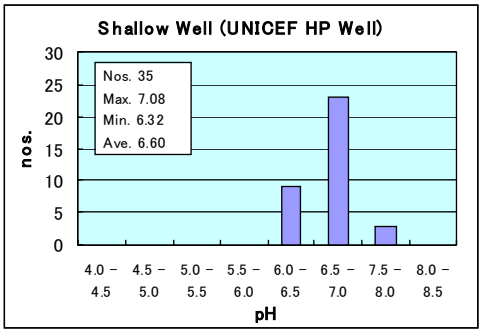












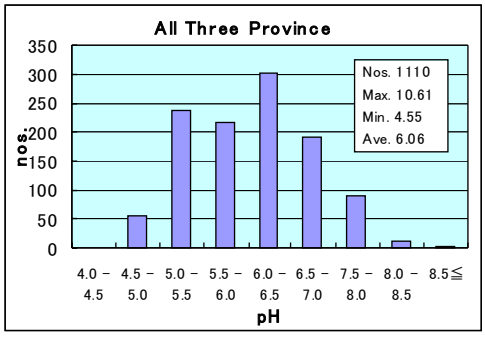
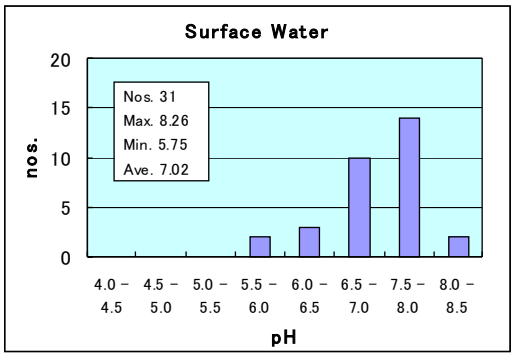
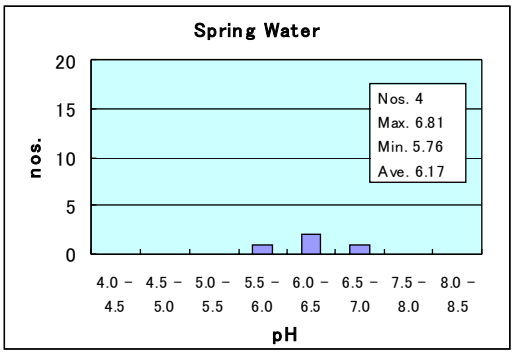
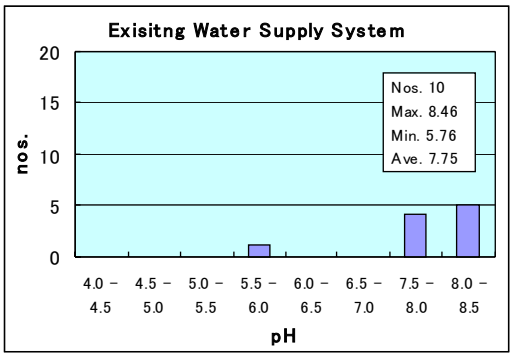
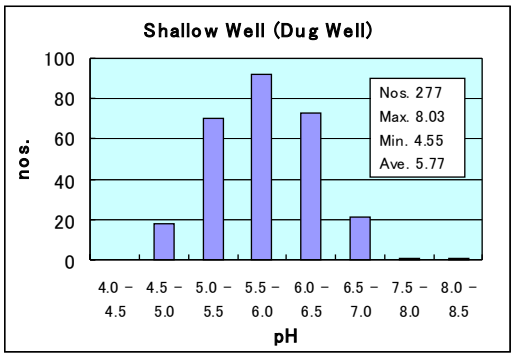


Figure 6.3 pH Value of Existing Water Sources in Three Provinces









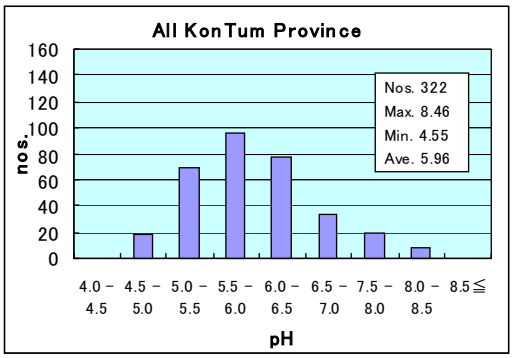


Figure 6.4 pH Value of Existing Water Sources in Kon Tum Province

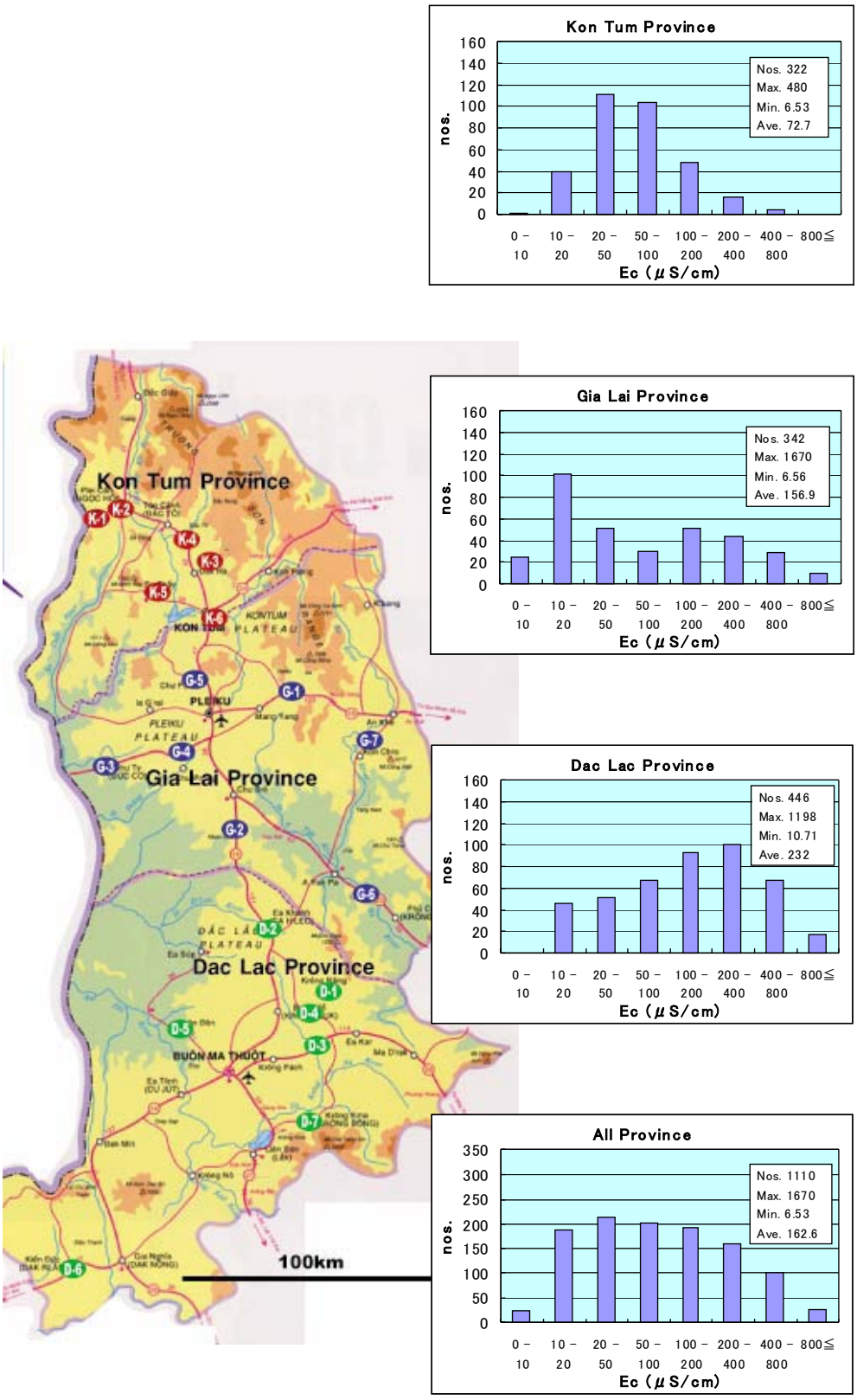
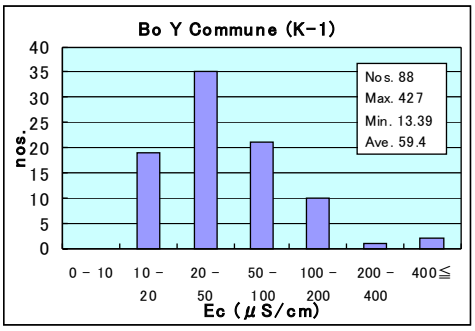
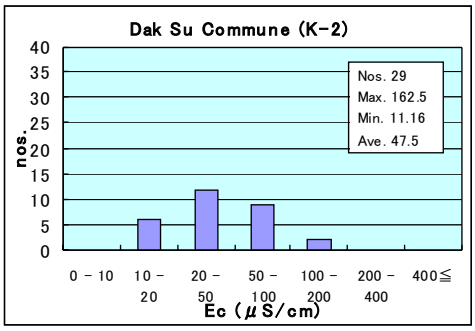
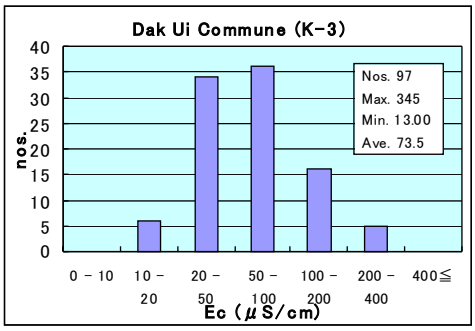
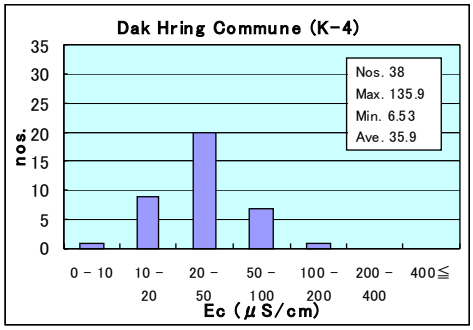


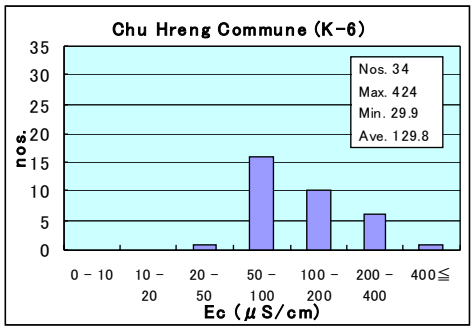
Figure 6.5 EC Value of Existing Water Sources in Three Provinces











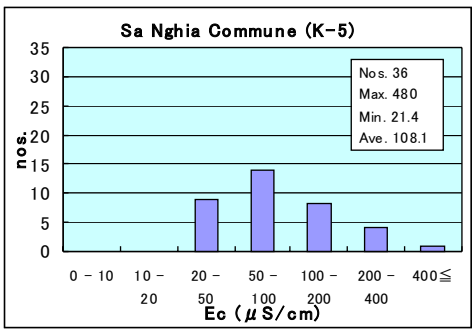
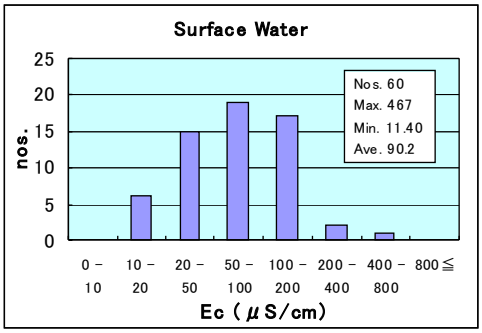
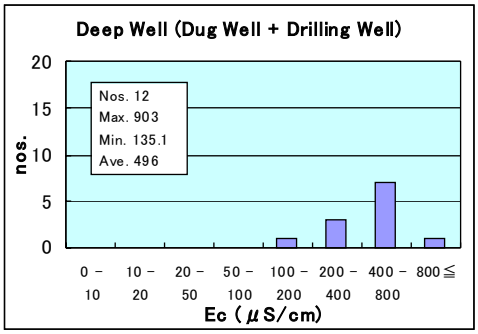
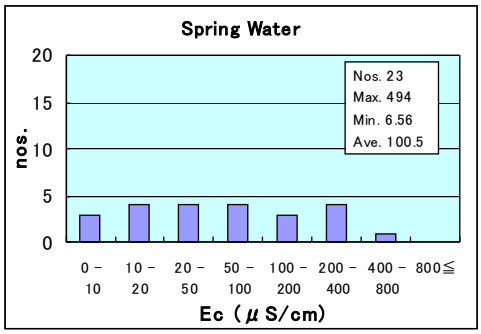
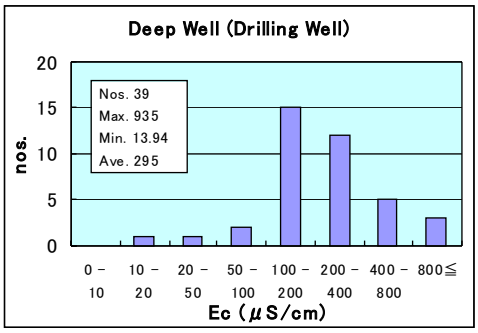


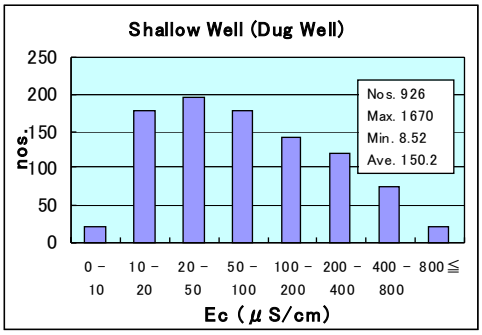
Figure 6.6 EC Value of Existing Water Sources in Kon Tum Provinces

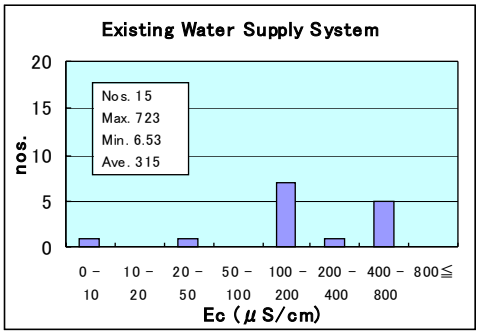


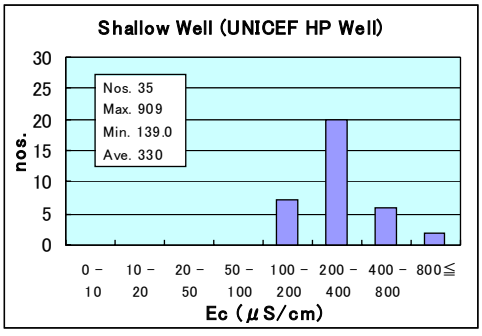












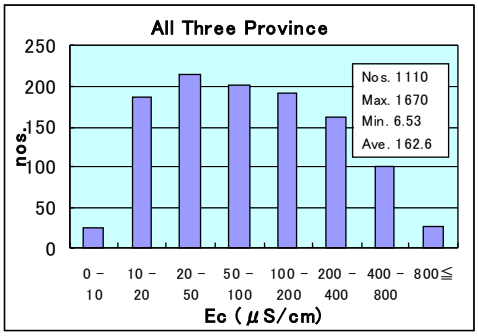
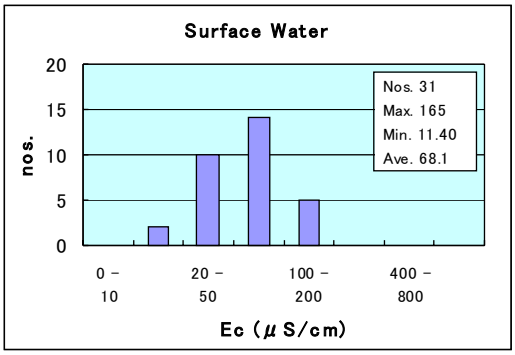
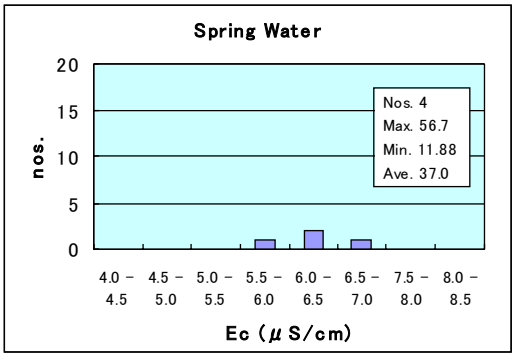
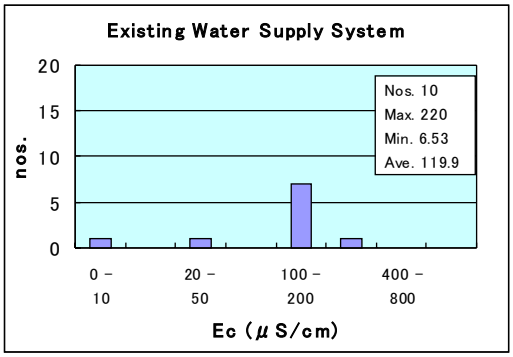
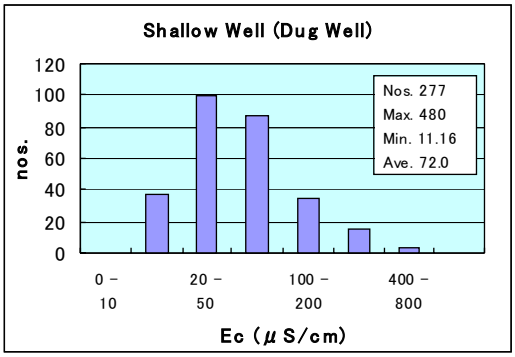


Figure 6.7 EC Value of Existing Water Sources in Three Provinces









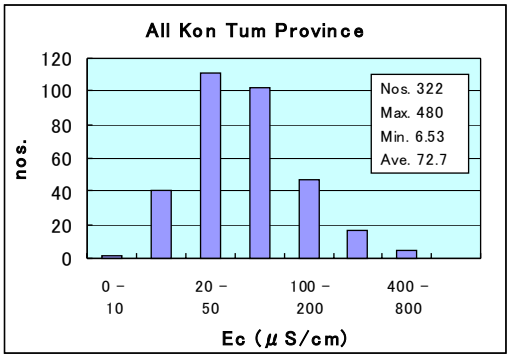
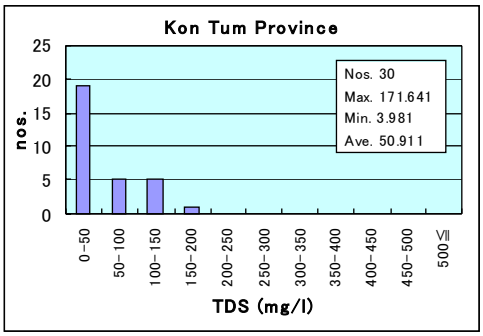
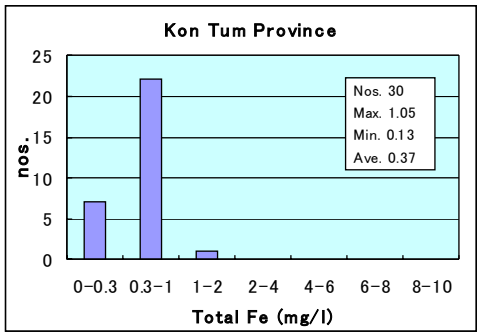
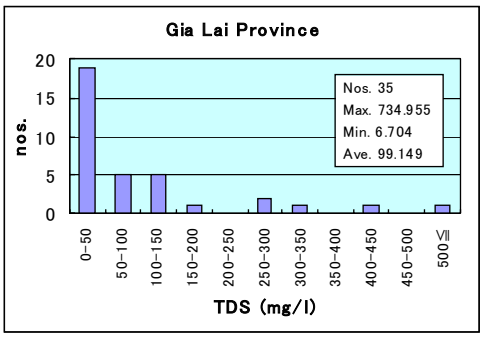
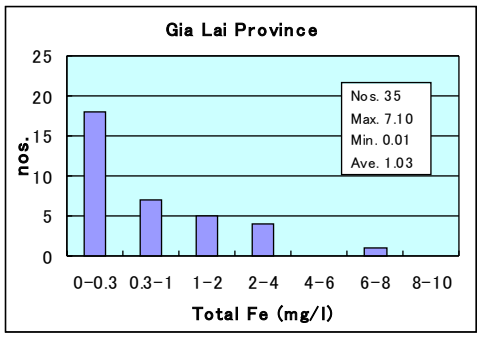


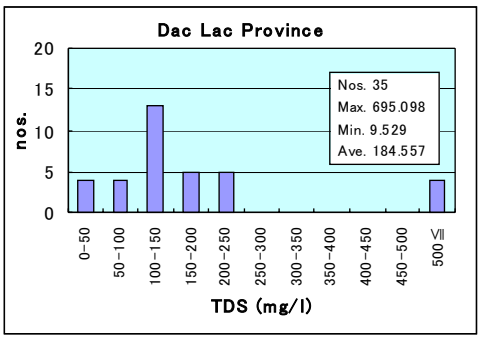
Figure 6.8 EC Value of Existing Water Sources in Dac Lac Province

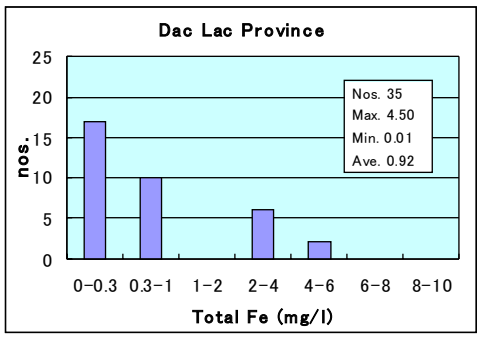


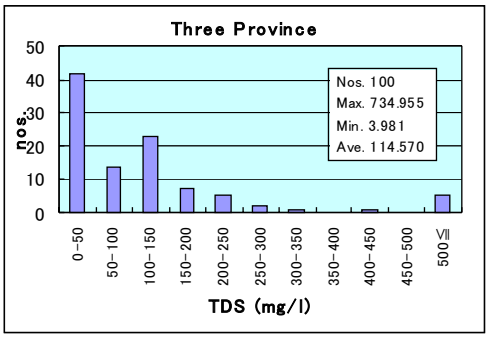












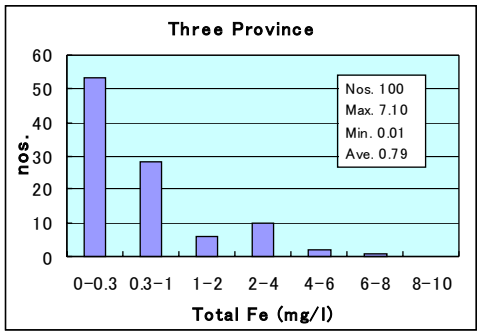
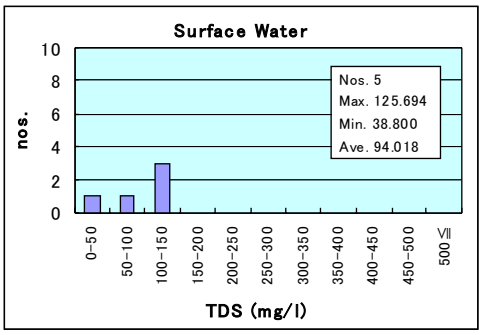
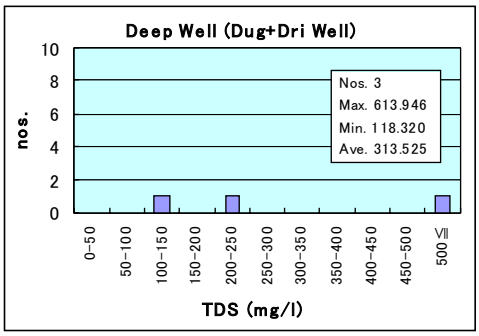
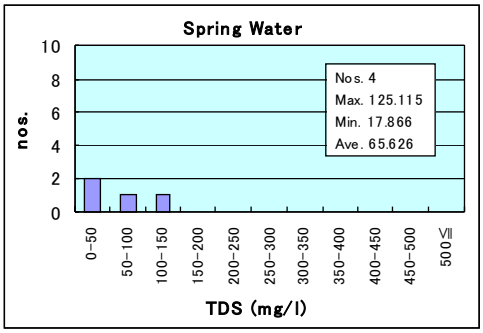
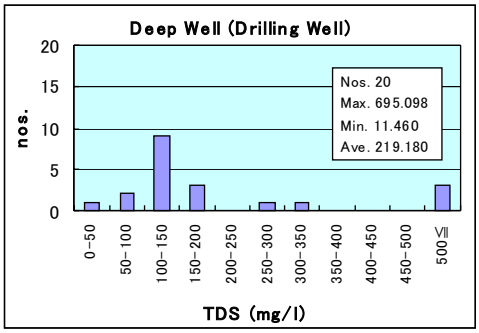


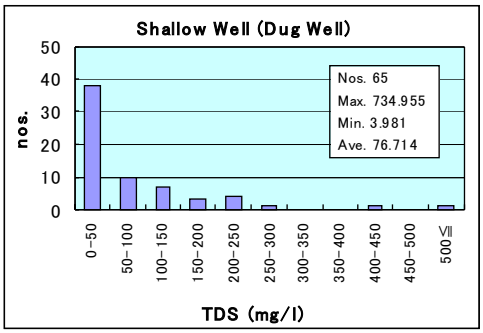
Figure 6.9 Measured TDS and Total Fe-Province

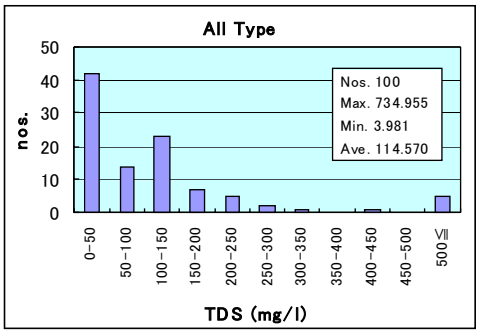












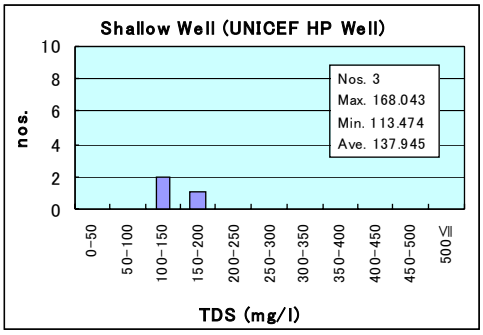
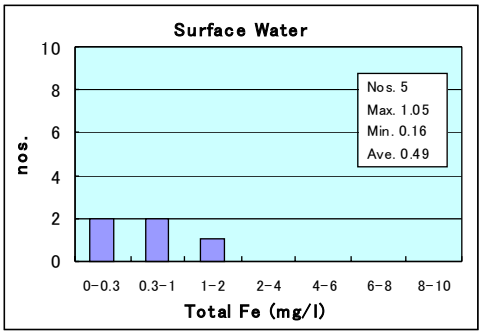
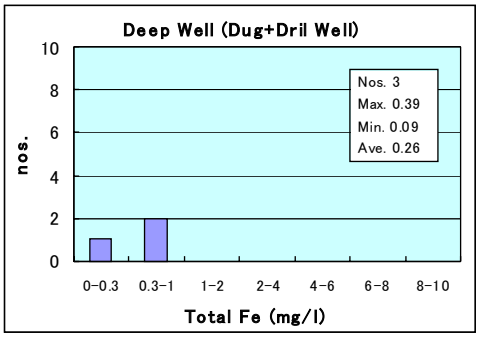
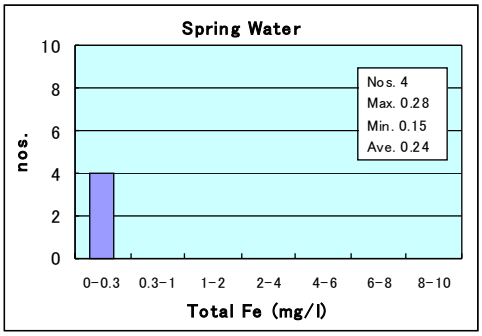
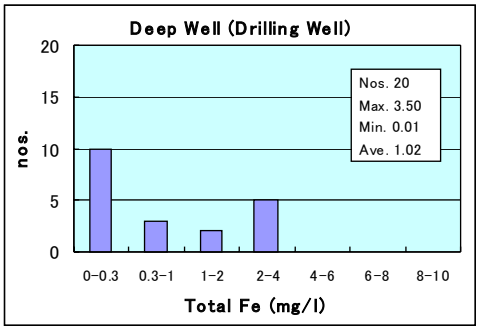


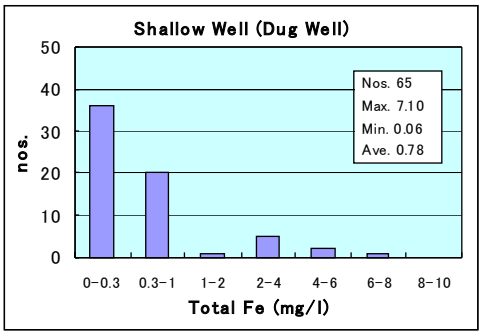
Figure 6.10 Measured TDS Concentration - Each Water Source

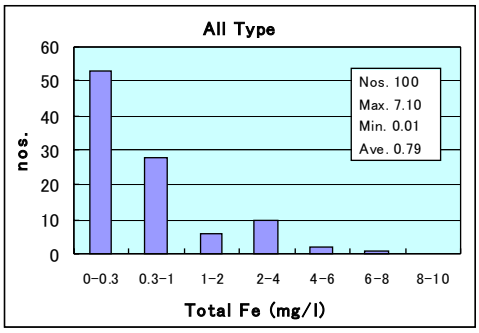












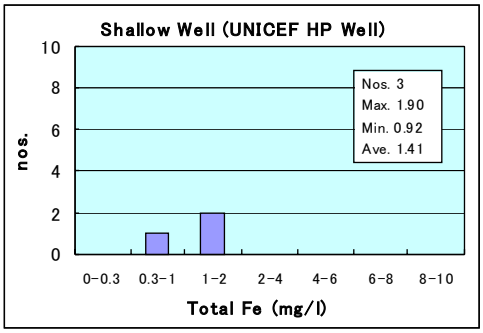
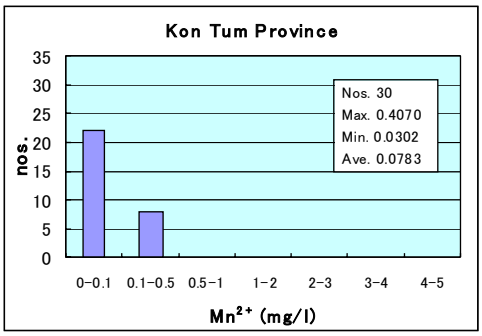
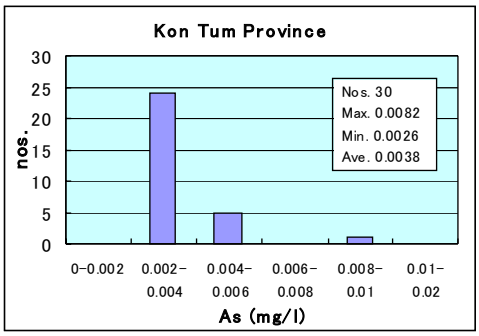
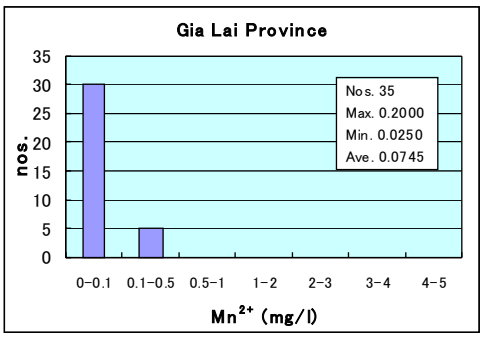
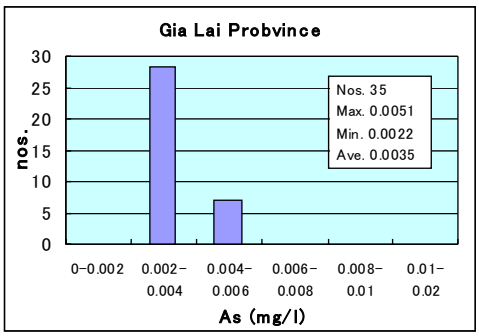


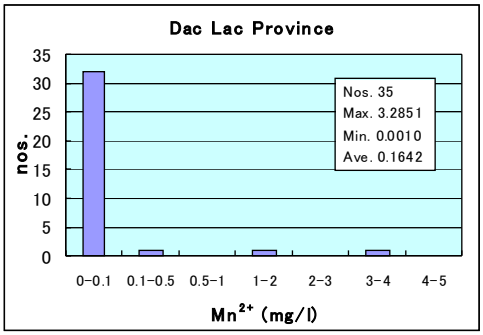
Figure 6.11 Measured Total Iron Concentration - Each Water Source

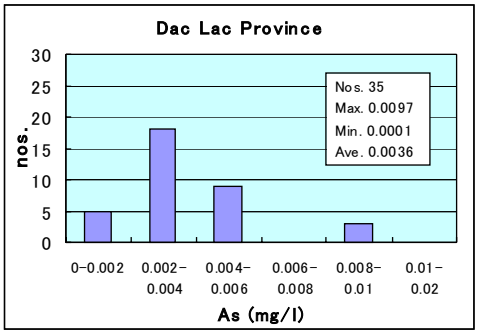


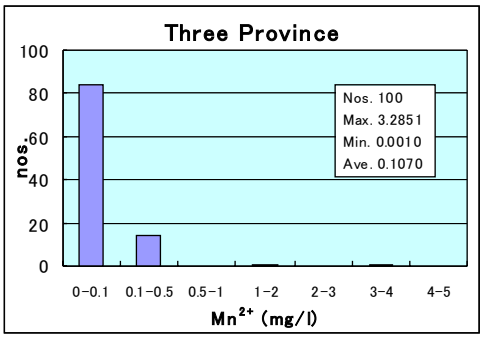












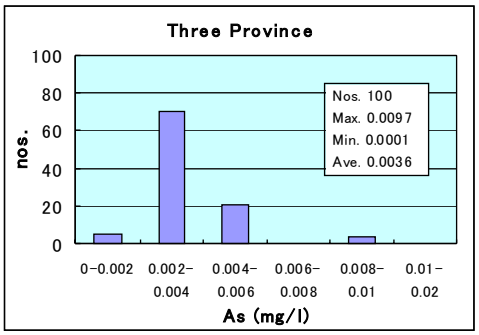
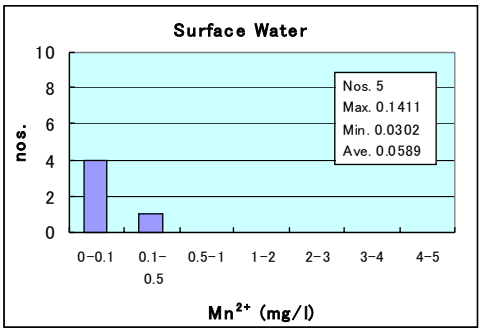
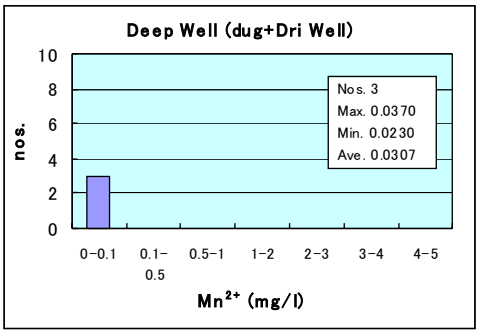
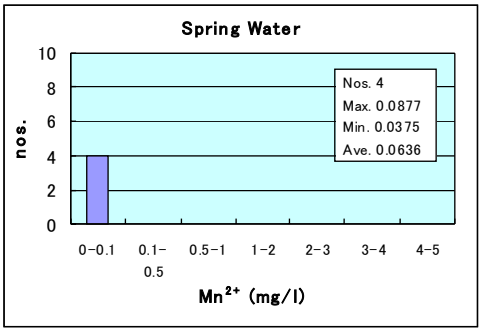
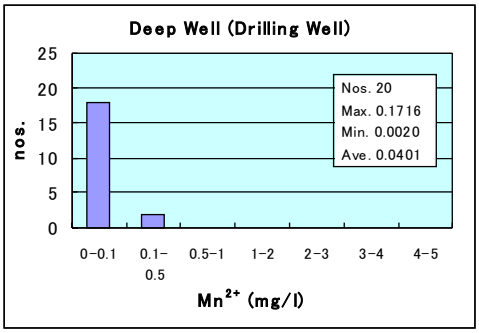


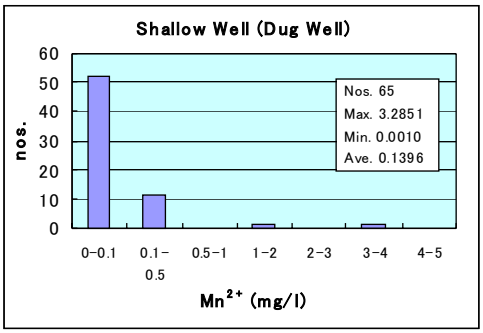
Figure 6.12 Measured Mn2+ and As – Province

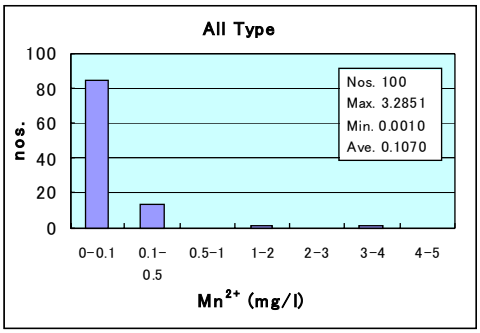












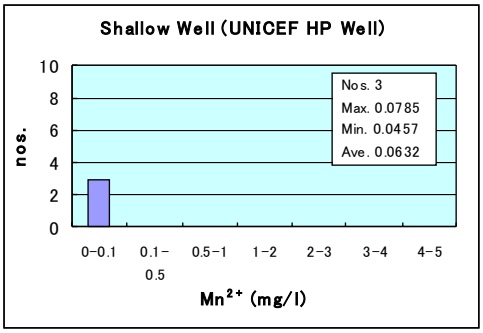
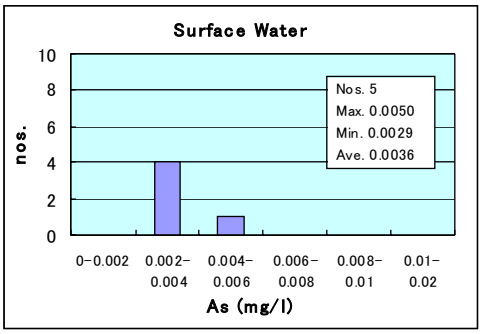
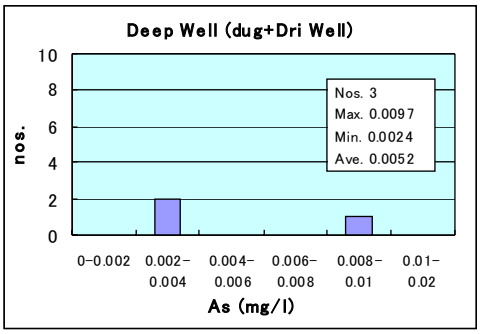
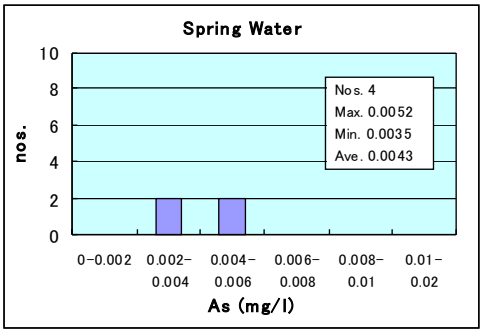
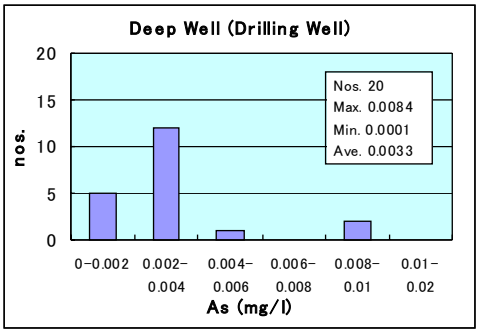


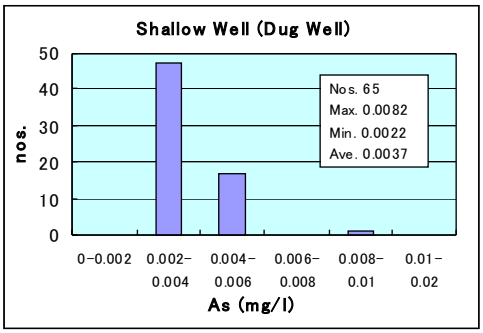
Figure 6.13 Measured Mn2+ Concentration-Each Water Source

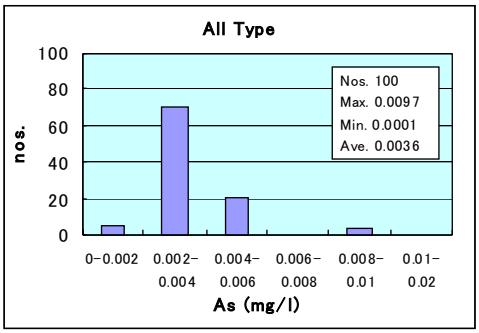












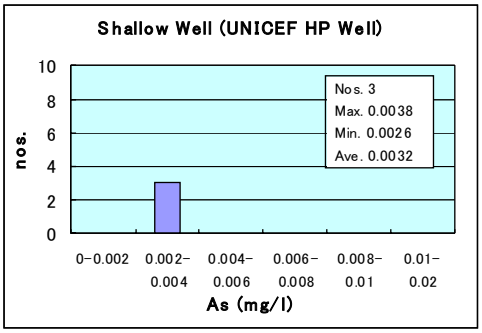
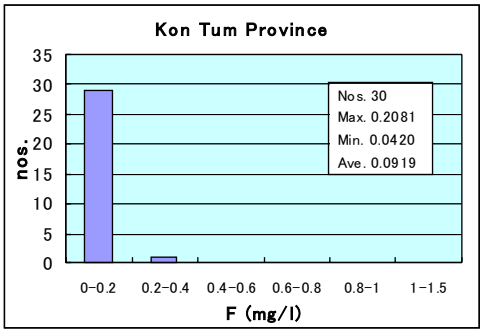
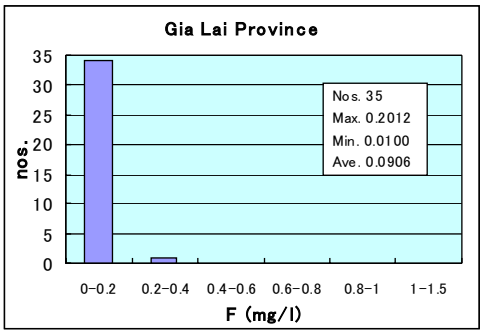
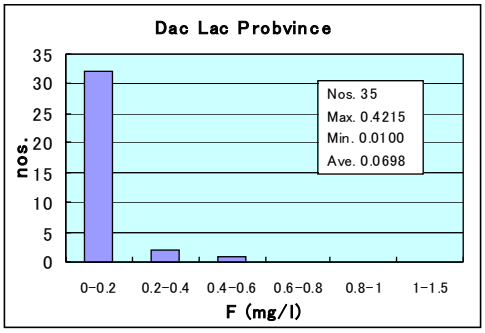


Figure 6.14 Measured As Concentration - Each Water Source







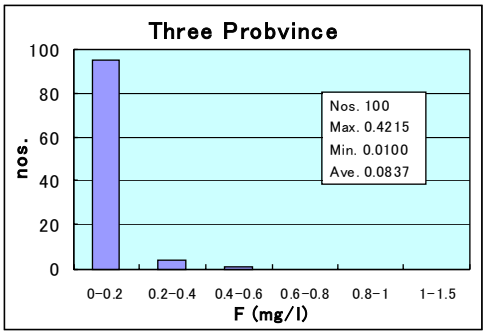
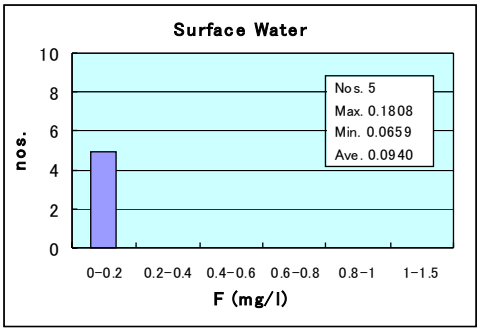
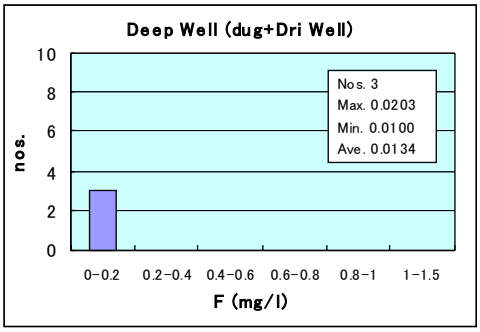
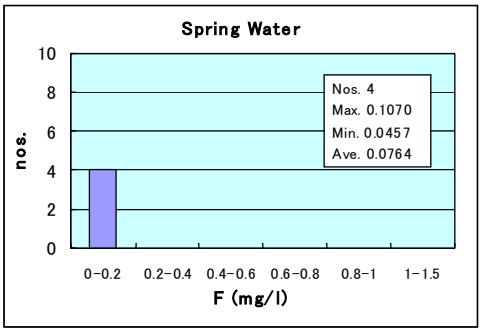
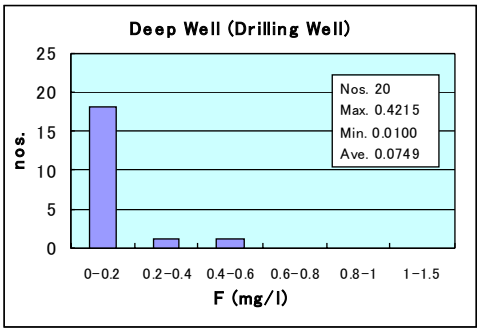


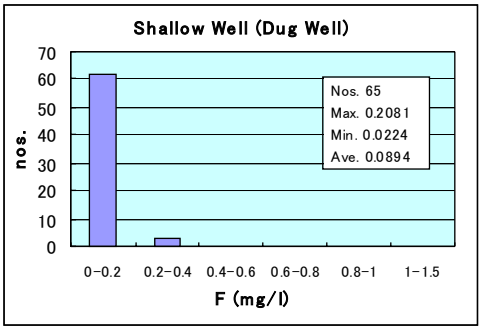
Figure 6.15 Measured F – Province

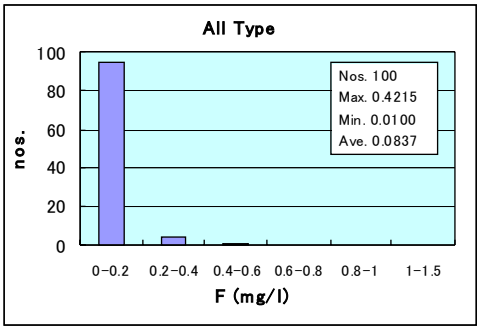












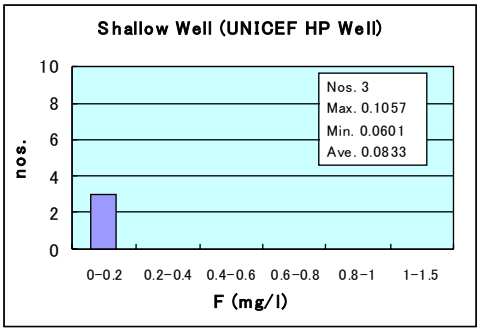


Figure 6.16 Measured Fluoride Concentration - Each Water Source

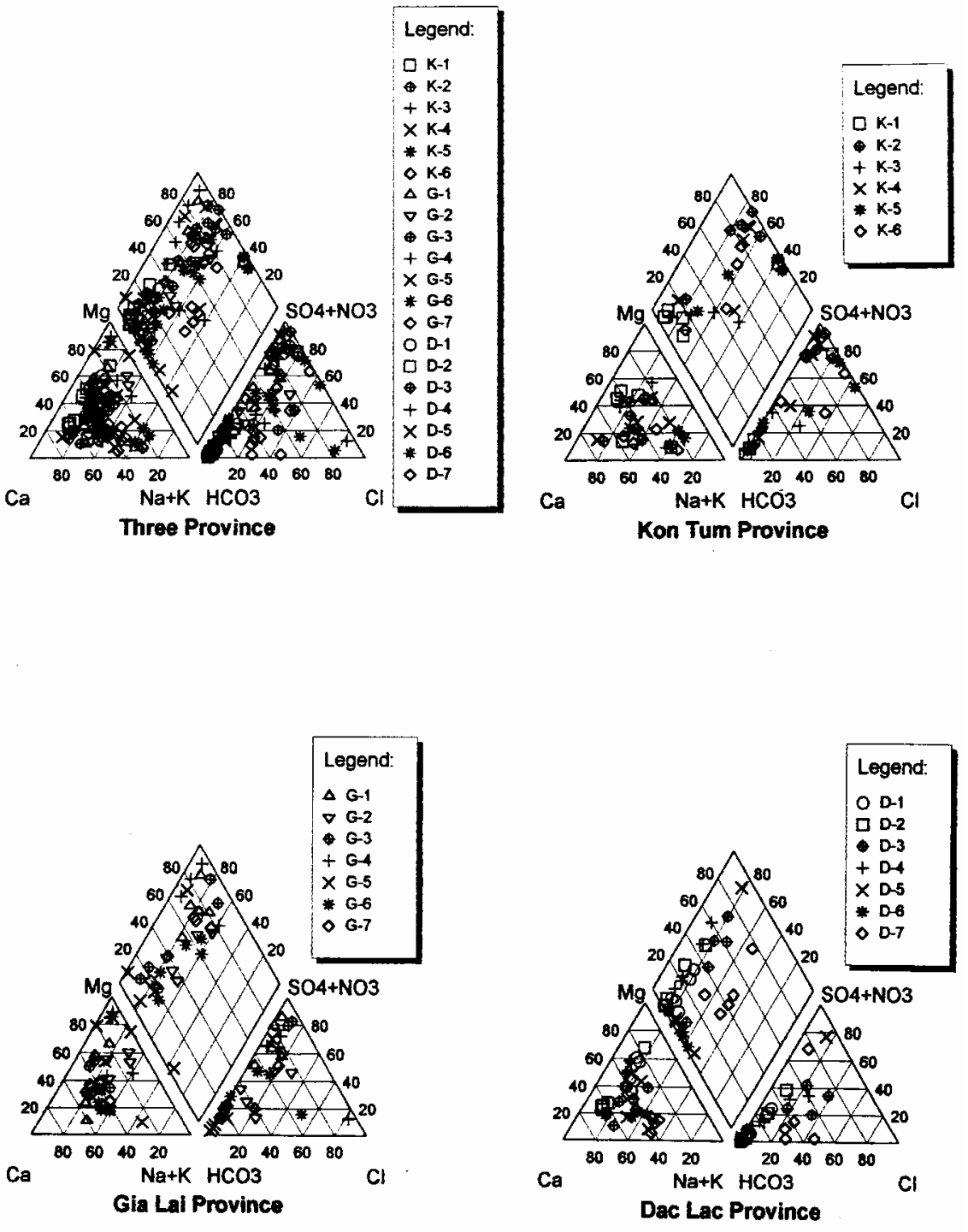


Figure 6.17 Trilinear Diagram of Water Samples from Each Province

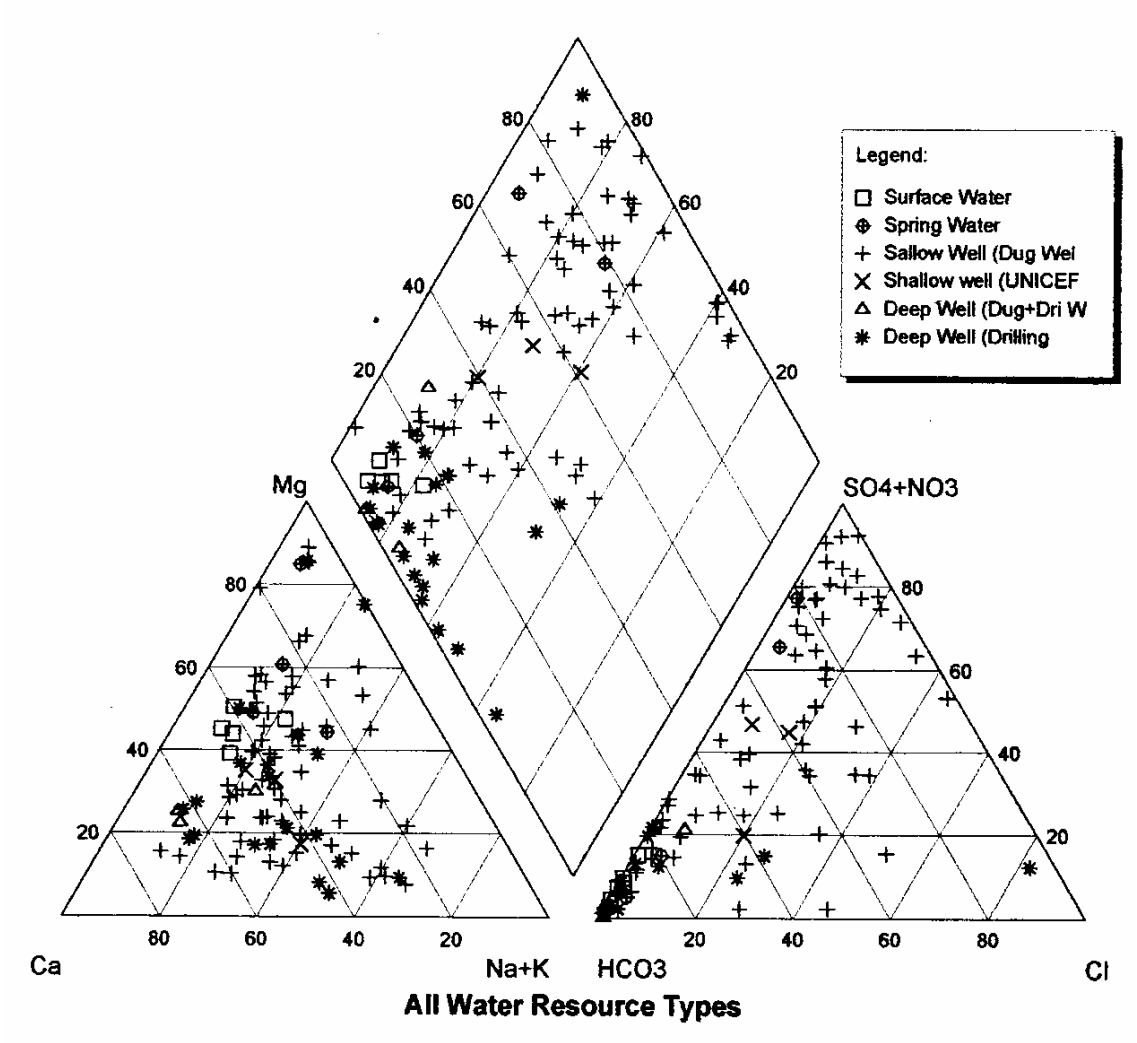
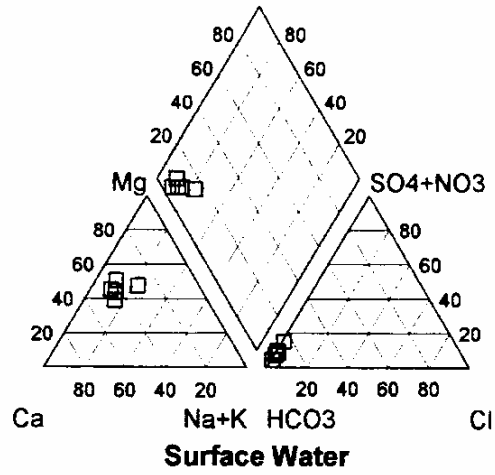
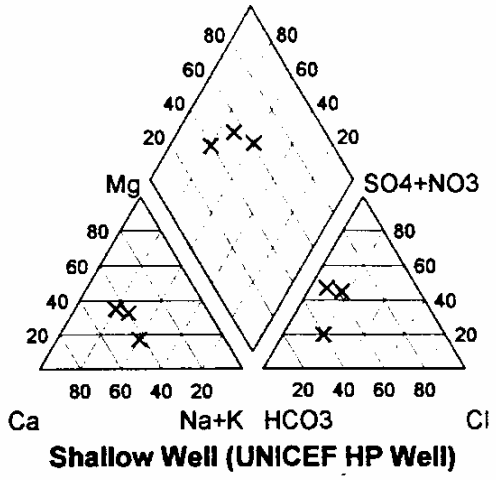
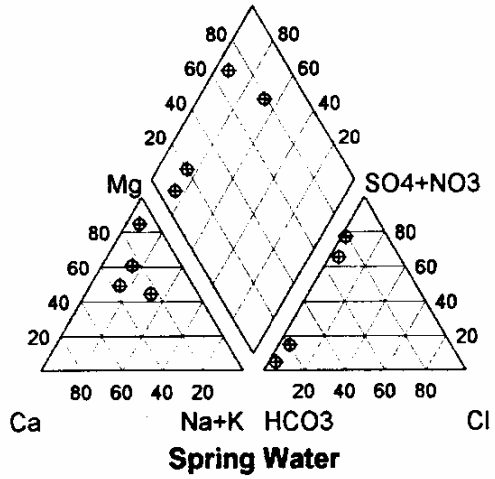
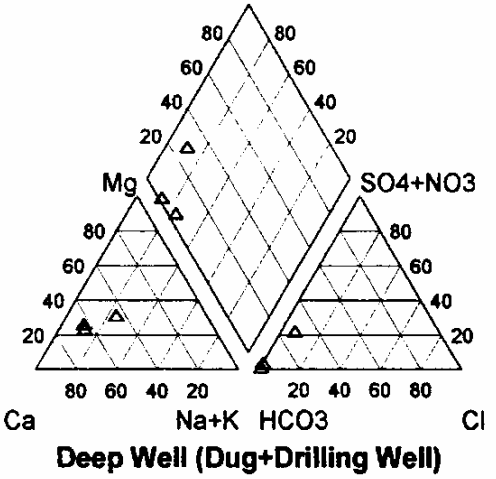


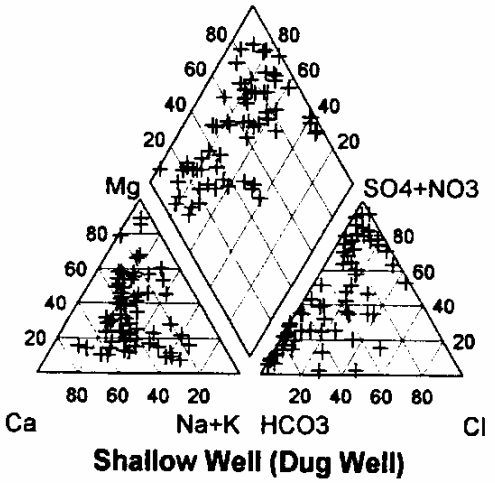
Figure 6.18 Trilinear Diagram of Water Samples from All Water Sources











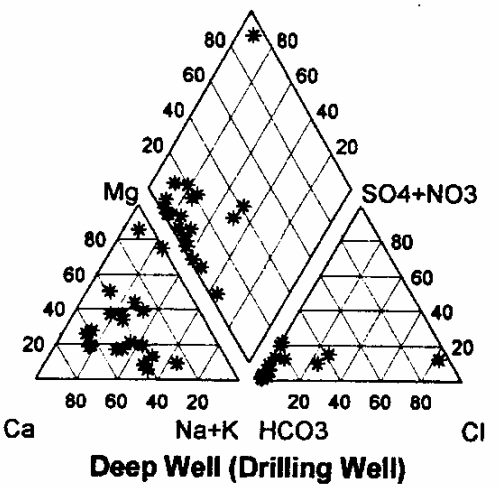


Figure 6.19 Trilinear Diagram of Water Samples from Each Water Source

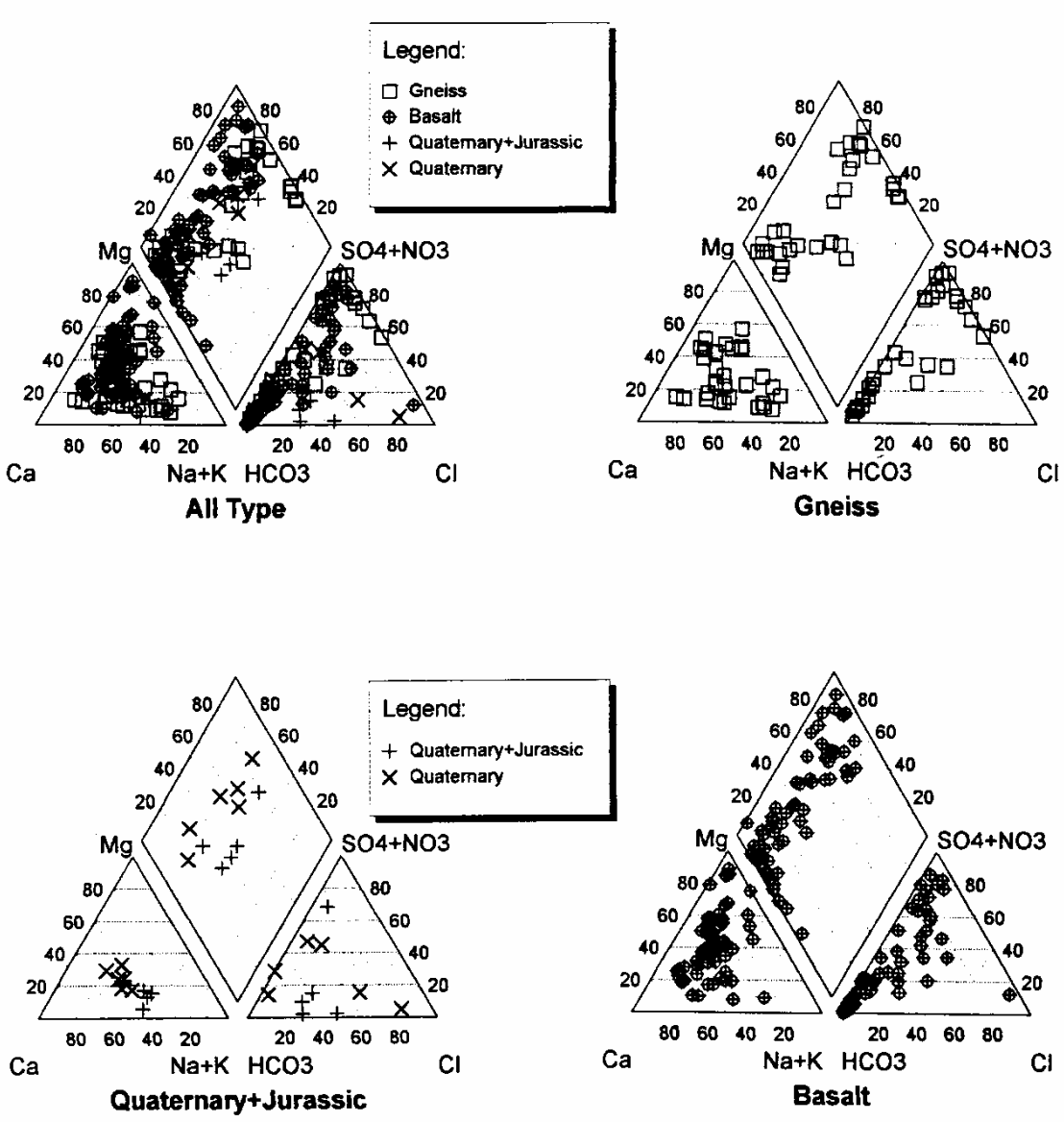
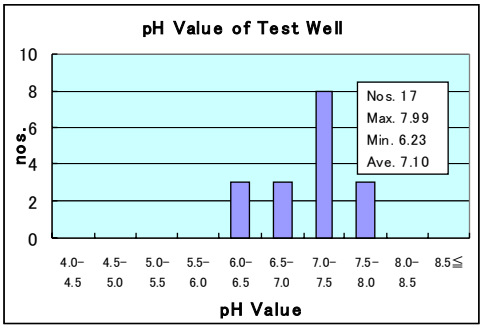
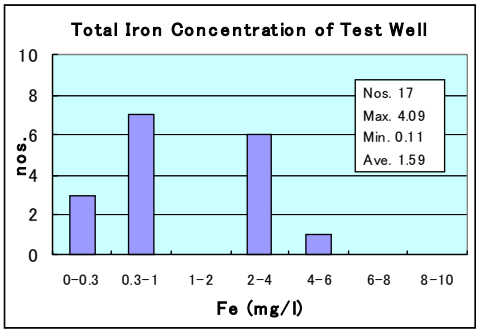
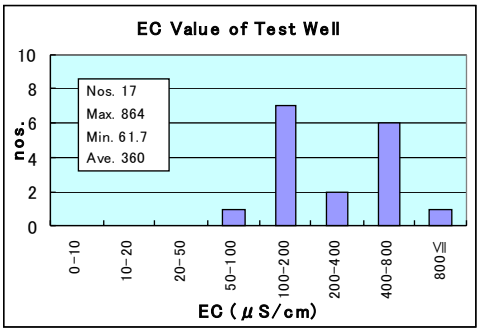
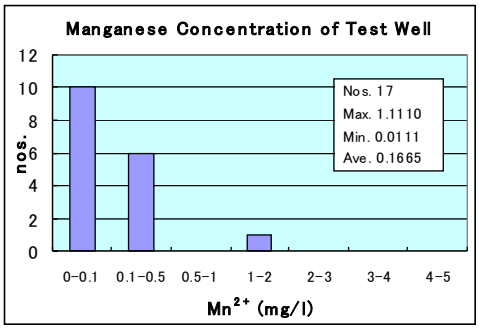


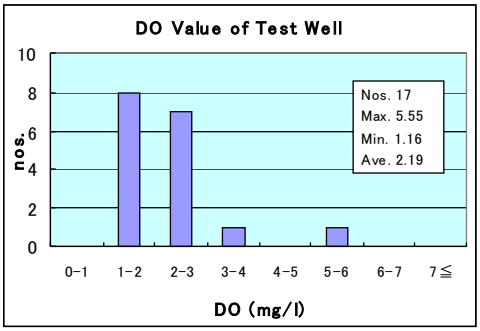
Figure 6.20 Trilinear Diagram of Water Samples from Each Geology Area

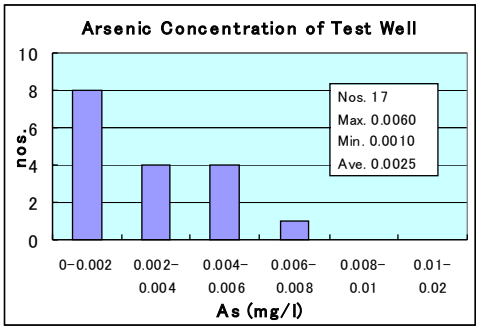


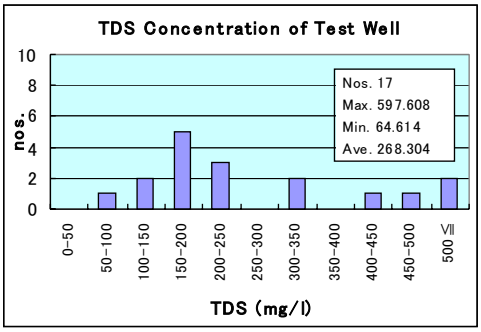












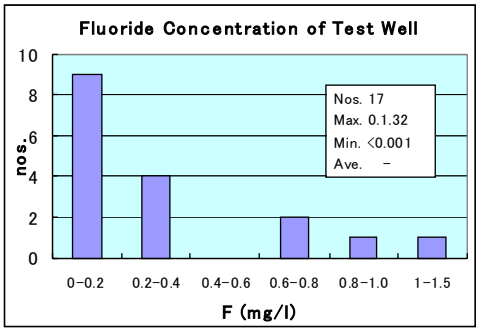


Figure 6.21 Measured Values and Concentrations of Test Well

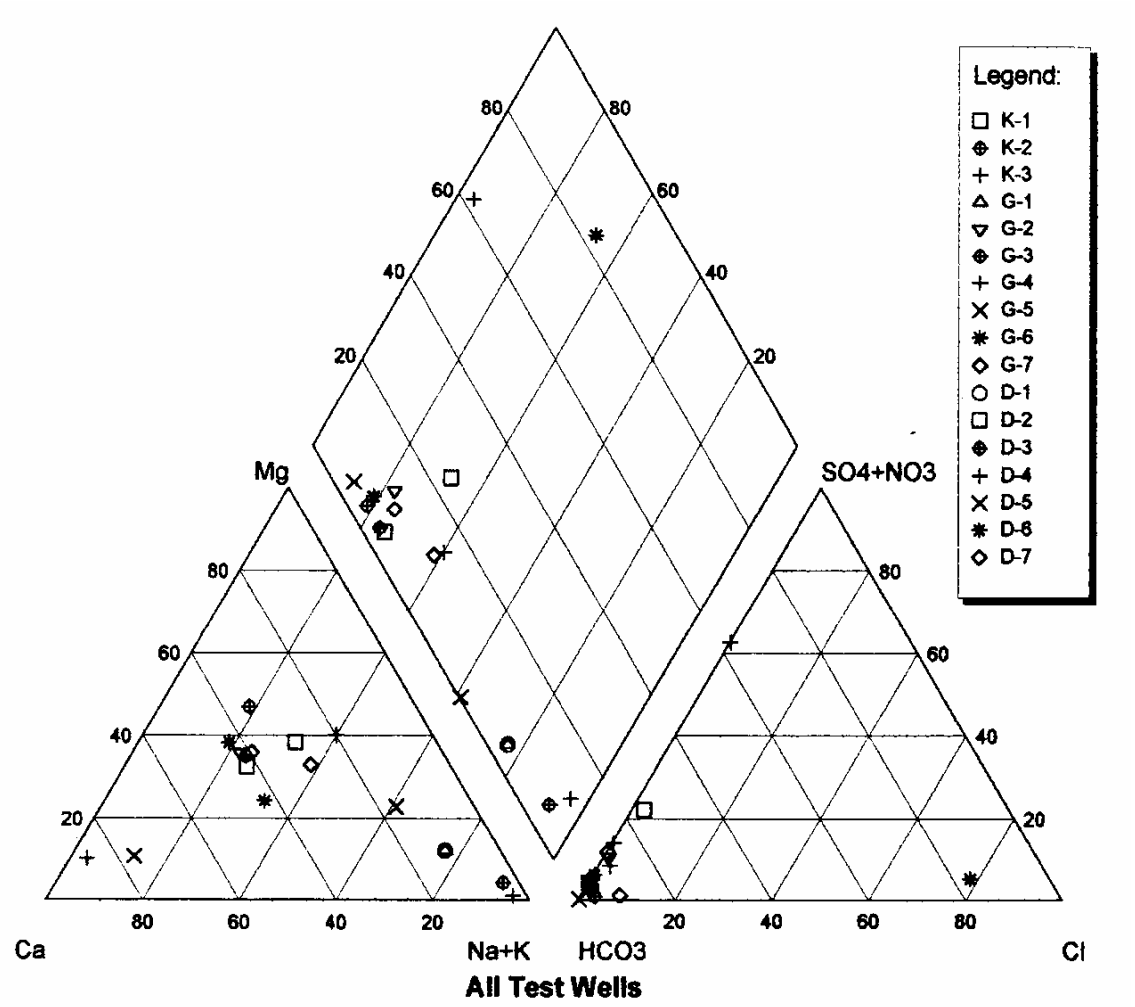
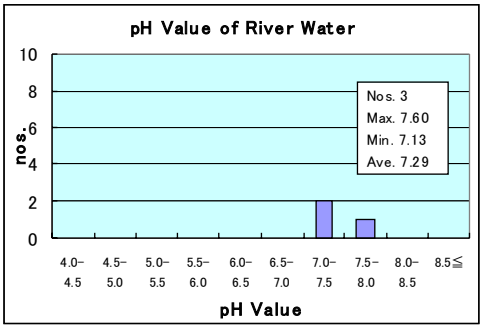
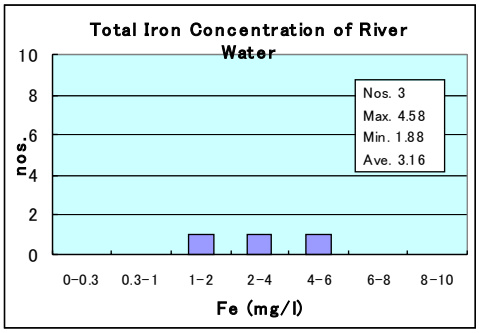
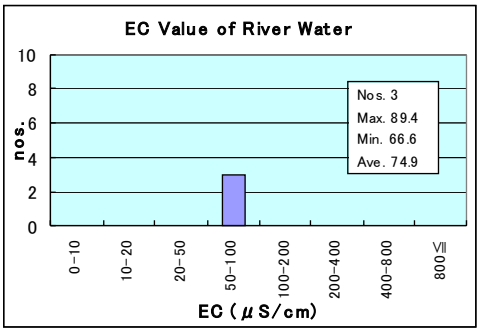
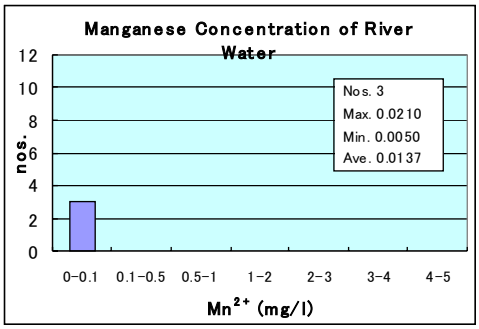


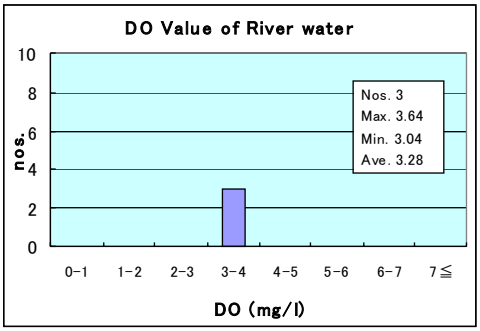
Figure 6.22 Trilinear Diagram of Water Samples from Test Well

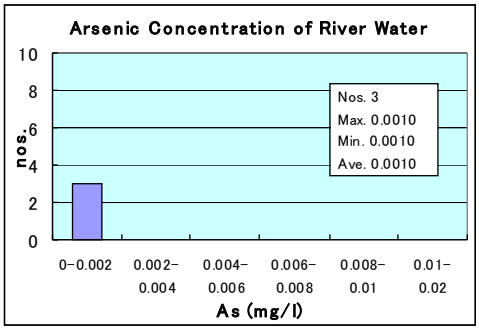


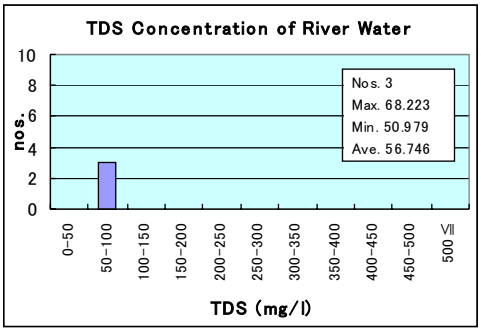












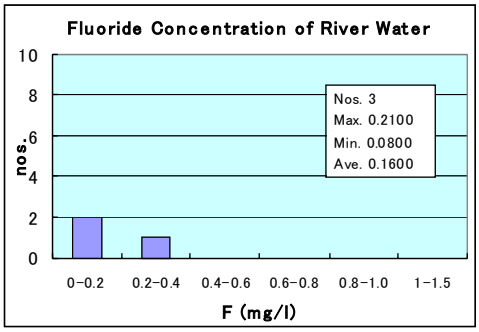


Figure 6.23 Measured Values and Concentrations of Alternative Water Sources

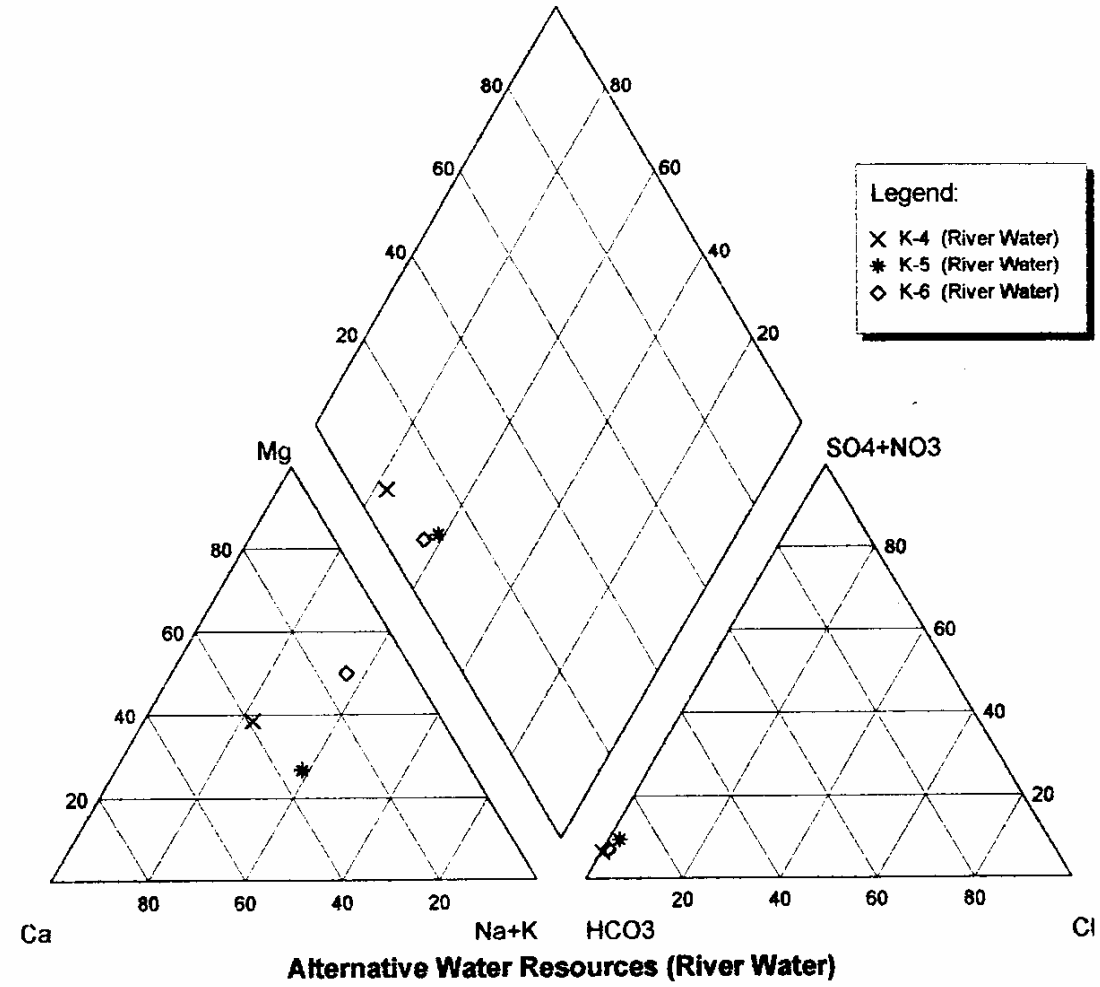


Figure 6.24 Trilinear Diagram of Water Samples from Alternative Water Sources