Chapter 5
Groundwater Potential Evaluation

CHAPTER 5 GROUNDWATER POTENTIAL EVALUATION

5.1 Introduction

Hydrogeological maps are specialised maps on which groundwater resources and, as far as necessary, surface-water features are depicted on a base of topography and geology. Apart from their importance to hydrogeologists and groundwater specialists, hydrogeological maps are required also for use by non-specialists, such as administrators and economists, engineers in charge of town and country planning, technicians in agricultural, industrial and domestic water supplies, as well as by farmers, industrialists and private individuals. (International Legend for Hydrogeological Maps; UNESCO (1970))

However, it is actually unfamiliar and difficult for general stakeholders to use hydrogeological map for their purposes. Therefore, groundwater resources potential evaluation maps were made using the same data for mapping of the hydrogeological map of IDB and results of water balance analysis to be easy understanding and practical use.

5.2 Schematic Water Balance and Groundwater Recharge

Schematic water balance and groundwater recharge in each sub-basin were analyzed by using meteorological and hydrological data and remote sensing techniques. The purpose of the analysis is to delineate areas with high groundwater recharge potential: namely, high infiltration potential in IDB. Three kinds of water balance analyses were implemented. The first analysis: monthly macro water balance was aimed at grasping the monthly and annual amount of groundwater recharge potential among sub-basins in IDB. The second analysis was concentrated on grasping the distribution of the infiltration potential in each sub-basin in the rainy season. The third analysis was applied to the sub-basin "G" (see Figure 5-1) to know more detail distribution of the infiltration potential under consideration of surface water runoff.

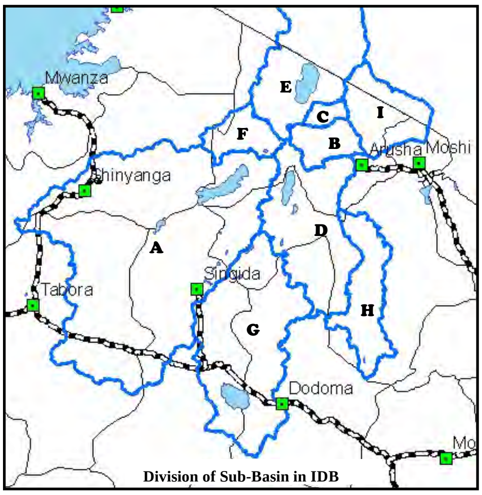


Figure 5-1 Sub-basins in IDB

5.2.1 Schematic Analysis of Monthly Water Balance in Each Sub-basin

Schematic analysis of monthly water balance was applied to all sub-basins of IDB. The water balance is expressed by following equation.

$$P = E + R \pm I \quad \cdots\cdots (1)$$

Where, P is rainfall, E is evapotranspiration, R is runoff and I is infiltration. Each sub-basin in IDB has no outlet of surface water so that the runoff term is neglected in this analysis.

(1) Estimation of Rainfall in Each Sub-basin

Rainfall data in every month derived from "Summary of Rainfall in Tanzania" (1975: East Africa Community, Nairobi) was used for the estimation of the long-term averaged monthly rainfall in each sub-basin. Because the present number of the observation points operated by Tanzanian Meteorological Agency was very few for this purpose.

First, the distribution of rainfall was estimated spatially, then the average monthly rainfall of each sub-basin was estimated.

(2) Estimation of Evapotranspiration

Makkink equation (Makkink, 1957) was applied to estimate potential evapotranspiration ET (mm/day). The equation is defined as follows,

$$ET_{mak} = \frac{\Delta}{\Delta + \gamma} \frac{Rs}{\lambda} \quad \cdots\cdots (2)$$

In addition, the following equation (3) (ERSDAC, 2005, Nagai, 1993) were adopted for estimation of actual evapotranspiration because of various ground conditions of each sub-basin.

$$ET = \alpha[\, (a - A) \frac{\Delta}{\Delta + \gamma} \frac{Rs}{\lambda} + b] \quad \cdots\cdots (3)$$

Where, Rs (cal/cm2/day) is the total solar radiation, Δ (mbar /°C) is the slope of the saturation vapour pressure curve, γ (in mbar/ °C) is the psychrometric constant, λ (cal/g) is the latent heat, a and b are local constant values. A is Albedo and α is conversion value to actual evapotranspiration (0< α =<1.0). Rs: the total solar radiation is calculated by using following equation.

$$Rs = Ra\ (0.18 + 0.55n/N)$$

Where, Ra is the outer space solar radiation, n is the observed sunshine hours and N is the possible sunshine duration.

{Δ / (Δ ＋ γ) } is dimensionless parameter and approximated by using the following equation.

$$\frac{\Delta}{\Delta + \gamma} = 1 / [1.05 + 1.4 \exp(-0.0604T)]$$

Where, T is the observed temperature. λ (latent heat) is calculated by using following equation.

$$\lambda = 2.5 - 0.0025T$$

The necessary data for the estimation of each term in "Modified Makkink Equation" is summarized as follows.

Terms of Makkink equation	Necessary basic data
Albedo	1) Processed satellite images into classified land covers. 2) Correlation of land covers and Albedo values.
Total solar radiation	Sunshine hours
Slope of the saturation vapour pressure curve	Temperature
Psychrometric constant	Temperature
Latent heat	Temperature
Local constant values (a, b)	Comparison between observed Pan evaporation data and estimated ET_{mak}.

Observed meteorological data used in this calculation are as follows, Temperature, sunshine hours and pan evaporation data from 1974 to 2004, derived from "Tanzania Meteorological Agency". As a result, the actual evapotranspiration in IDB is estimated by using following equation.

$$ET = \alpha \left[(1.28 + 0.05 - A) \frac{\Delta}{\Delta + \gamma} \frac{Rs}{\lambda} - 1.452 \right] \qquad \cdots\cdots (4)$$

Although evapotranspiration needs water on ground and soil moisture, actual evapotranspiration estimated by above equation is not necessarily real evapotranspiration. Therefore, it should be properly called "possible evapotranspiration".

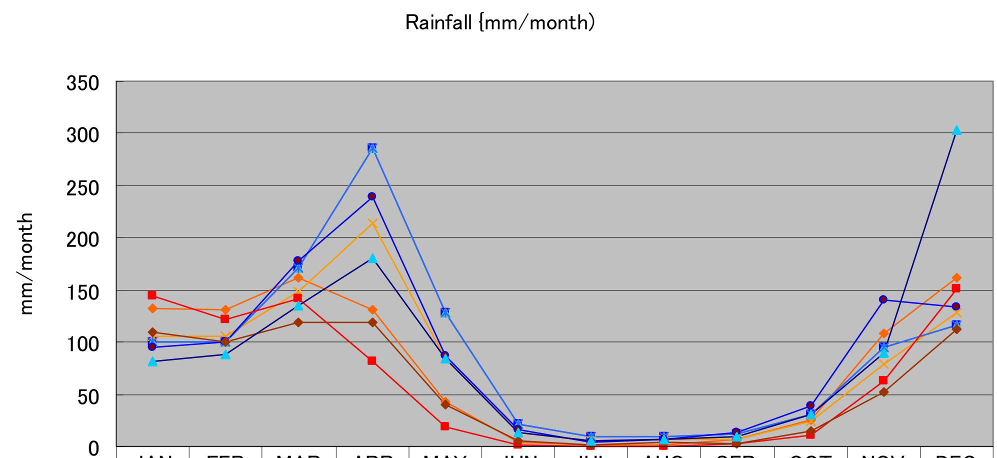
(3) Results

Rainfall, possible evapotranspiration, and infiltration were estimated with above methods.

1) Rainfall

The estimated rainfalls in each sub-basin are shown in Figure 5-2.

In the northern sub-basins, monthly rainfall has its maximum value in April; on the other hand, in the southern sub-basins monthly rainfall has no major peak and has rather stable values during the rainy season.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
A	132	131	161	131	42	4	1	1	7	26	108	162
B	100	100	171	286	128	22	9	9	12	30	95	116
C	100	100	171	286	128	22	9	9	12	30	95	116
D	106	105	149	214	84	14	6	6	7	25	79	128
E	100	100	171	286	128	22	9	9	12	30	95	116
F	95	101	178	239	88	17	4	7	13	39	141	134
G	145	122	141	81	18	2	0	0	3	11	63	151
H	109	100	119	120	40	6	1	4	3	15	52	112
I	82	89	135	181	84	14	6	7	10	31	90	304

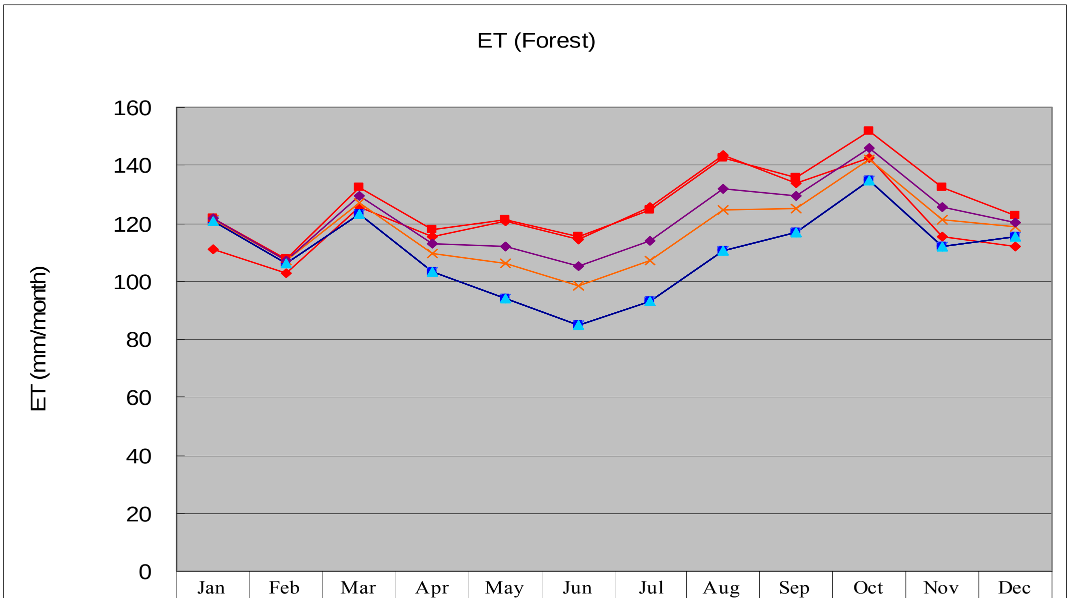
month

Figure 5-2 Monthly Rainfall by Sub-basin

2) Possible Evapotranspiration

The estimated possible evapotranspirations in each sub-basin are shown in Figure 5-3.

Monthly actual possible evapotranspiration in southern sub-basins has higher value than that in northern sub-basins. Each sub-basin has its highest evapotranspiration in October.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A sub	111	103	125	115	121	114	125	144	134	143	116	112
B sub	121	106	123	103	94	85	93	110	117	135	112	115
C sub	121	106	123	103	94	85	93	110	117	135	112	115
D sub	121	107	127	110	106	98	107	125	125	142	121	119
E sub	121	106	123	103	94	85	93	110	117	135	112	115
F sub	121	106	123	103	94	85	93	110	117	135	112	115
G sub	122	108	132	118	121	115	124	143	136	152	132	123
H sub	121	107	129	113	112	105	114	132	129	146	125	120
I sub	121	106	123	103	94	85	93	110	117	135	112	115

Figure 5-3 Monthly Possible Evapotranspiration by Sub-basin

3) Possible Infiltration (Groundwater Recharge)

The estimated possible infiltrations in each sub-basin are shown in Figure 5-4 to 5-7.

Monthly possible infiltration in IDB, it practically contains runoff component, occurs only in the rainy season. Annual possible infiltration is 155 mm/year on the average in the whole IDB. The sub-basin F (Olduvai sub-basin) has the highest annual possible infiltration, and the sub-basin H (Masai Steppe sub-basin) has the lowest value in IDB. These values highly depend on the quantities of rainfall in each sub-basin.

It is necessary to take notice that even if "annual summation of monthly rainfall" minus "annual summation of calculated monthly evapotranspiration" is less than zero, there are still infiltrations during rainy season. Shortly, there is no water for evapotranspiration in dry season so that calculated actual evapotranspiration can not occur. So it is natural to presume that there are no evapotranspiration and no infiltration during dry season, and when rainfall excess evapotranspiration precipitates, the balance will be possible infiltration. Therefore it is clear that even the case before mentioned happens, there are still possible infiltration during rainy season when the water balance is analyzed by month or shorter period.

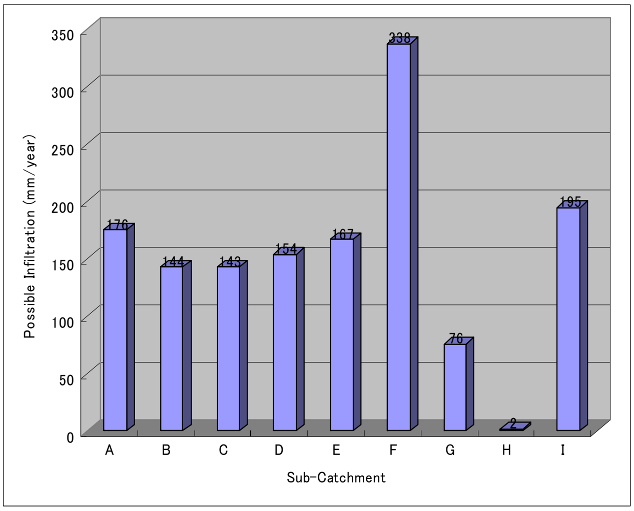


Figure 5-4 Annual Possible Infiltration Height in mm

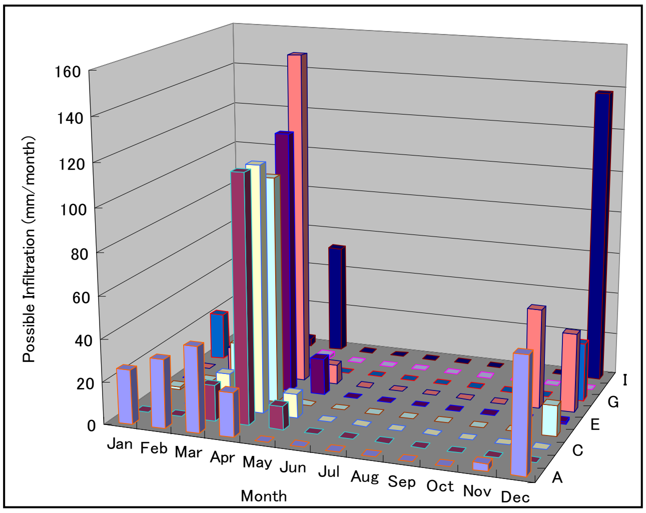


Figure 5-5 Monthly Possible Infiltration Height in mm

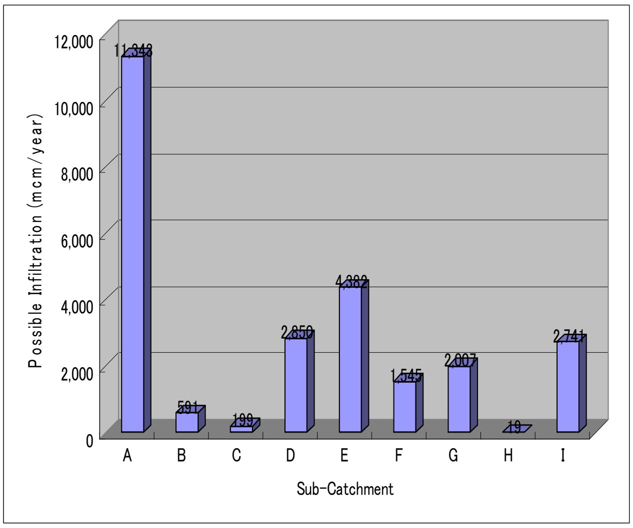


Figure 5-6 Annual Possible Infiltration Volume in mcm (million cubic meter)

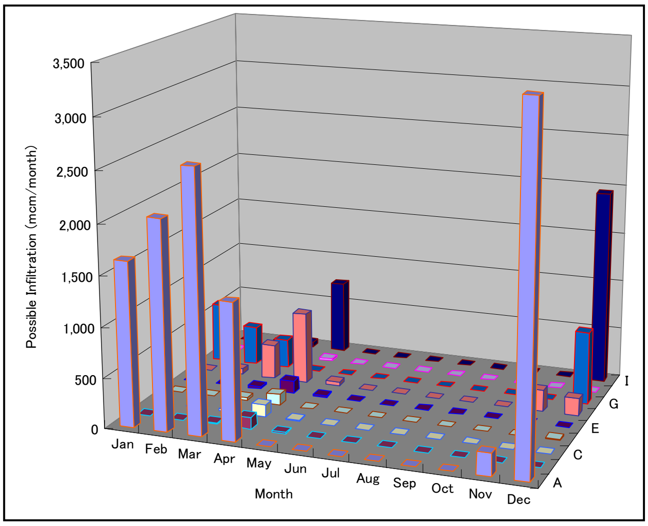


Figure 5-7 Monthly Possible Infiltration Volume in mcm (million cubic meter)

5.2.2 Possible Groundwater Recharge in Each Sub-basin during Rainy Season

Simplified water balance analysis was applied to each sub-basins of IDB to grasp the areas with high groundwater recharge potential in each sub-basin during rainy season. This analysis was implemented by using the LANDSAT/ETM satellite image in February 2000 as a representative of rainy season. The minimum unit of spatial resolution of the remote sensing image is set to 75m x 75m by using nearest neighbour interpolation method. The original resolution of the LANDSAT/ETM is 30m/pixel.

(1) Estimation Method

The equation of the simplified water balance is the same as those used in the analysis of the macro water balance (refer to 5.2.1). The simplified water balance analysis is different from the previous analysis at the following points.

● Rainfall

Rainfall was calculated at each pixel of the LANDSAT images from a distribution map of monthly average rainfall in February, which is derived from "Summary of Rainfall in Tanzania" (1975: East Africa Community, Nairobi)

● Possible Evapotranspiration

Possible evapotranspiration was also calculated from Makkink equation (3) at each pixel of the LANDSAT images by using distribution maps of sunshine hours, temperatures and land covers. The sunshine hour and temperature distribution maps were derived from observation data provided by Tanzania Meteorological Agency. The observation period is 1975 to 2004.

The spatially processed values of temperature were rectified by an altitude effect through SRTM DEM data. The altitude effect of temperature is estimated at 0.7°C/100m using regression analysis between observed temperature data and elevation of each meteorological station. Land covers at each pixel, which affects albedo value, was estimated by the results of principal component analysis using LANDSAT ETM+ band1 to band5 data.

(2) Results

The rainfall map, possible evapotranspiration map and possible infiltration map for rainy season (February) are shown in Figure 5-8, Figure 5-9, and Figure 5-10 respectively.

1) Rainfall Map

The rainfall map shows that the southern area of Ngorongoro Crater (north sides of Lake Eyasi and Lake Manyara) and the area near Tabora region have much rainfall than the others. On the other hand, the Masai Steppe (the sub-basin I) has little rainfall.

2) Possible Evapotranspiration Map

The possible evapotranspiration distribution in the whole IDB is strongly affected by the sunshine hours. In addition, the possible evapotranspiration in areas where have especially higher elevation such as Mt. Kilimanjaro and Mt. Hanang is affected by the temperature. The possible evapotranspiration in southern sub-basins has higher value than that in northern sub-basins.

3) Possible Infiltration (Groundwater Recharge) Map

The possible infiltrations of each sub-basin in February as a representative of rainy season were summarized in below Table 5-1. The possible infiltration quantity (mm/month) and infiltration rate (%) has the highest value in the sub-basin A. The second highest group consists of sub-basin

D (Lake Manyara sub-basin), E (Lake Natron sub-basin), F (Olduvai sub-basin) and G (Bahi sub-basin). The lowest possible infiltration group consists of sub-basin B {Monduli (1) sub-basin}, C {Monduli (2) sub-basin}, H (Masai Steppe sub-basin) and I (Namanga sub-basin).

Table 5-1 Summary of Water Balance Analysis for IDB in February

Sub-basin		Area (Km^2)	Rainfall (million m^3/month)	Evapo-transpiration (million m^3/month)	Possible Infiltration		
					(million m^3/month)	(%)	(mm/month)
A	Lake Eyasi	64,545	8,068	3,550	4,518	56	70
B	Monduli (1)	4,115	296	214	82	28	20
C	Monduli (2)	1,385	100	72	28	28	20
D	Lake Manyara	18,491	1,886	1,072	814	43	44
E	Lake Natron	26,224	2,229	1,180	1,049	47	40
F	Olduvai	4,577	476	220	256	54	56
G	Bahi (Manyoni)	26,445	2,962	1,613	1,349	46	51
H	Masai Steppe	9,313	764	596	168	22	18
I	Namanga	14,080	986	704	282	29	20

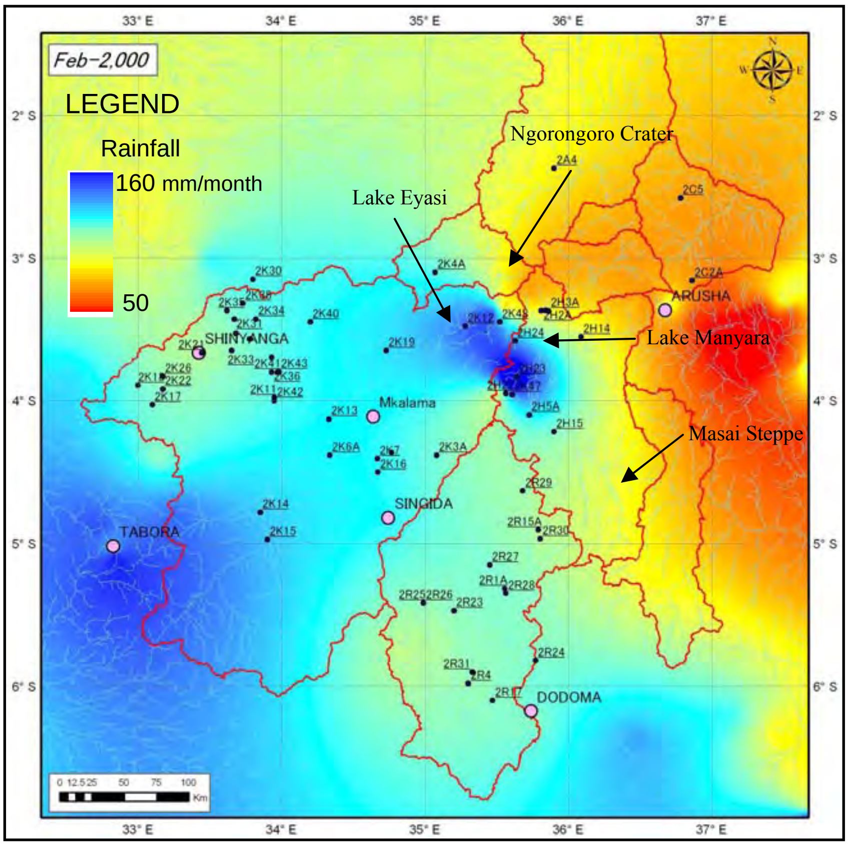


Figure 5-8 Rainfall Map in February

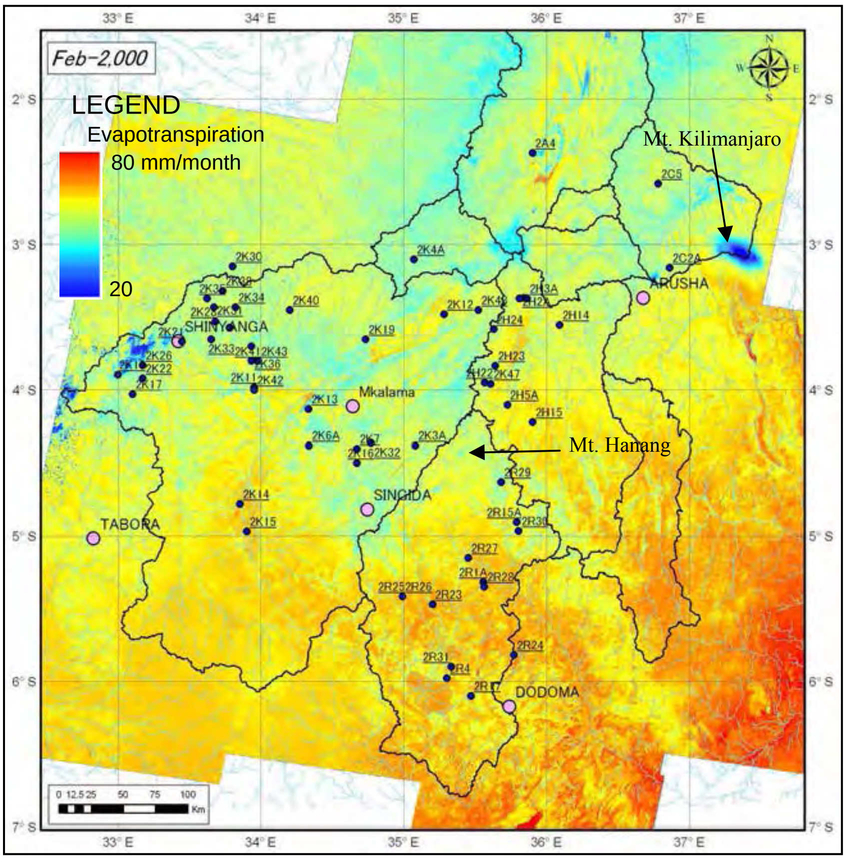


Figure 5-9 Possible Evapotranpiration Map in February

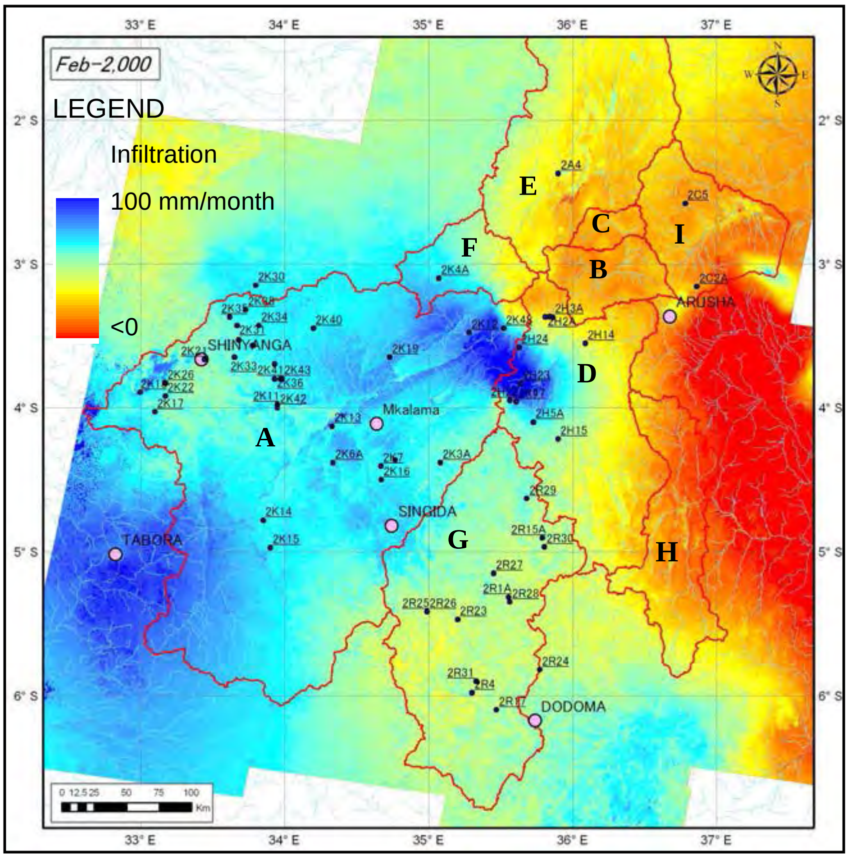


Figure 5-10 Possible Infiltration Map (P-ET) in February

5.2.3 Detailed Analysis of Possible Groundwater Recharge in Sub-basin G by Using Remote Sensing Technique

Taking the Phase I study results into consideration, including fluoride contamination, ground water potential and population regards, the sub-basin G area was selected as a detailed water balance analysis area of interest. The purpose of the detailed analysis is to grasp the areas with high infiltration (groundwater recharge) potential in the sub-basin G during rainy and dry season. The sub-basin G is located in the southern central part of the Internal Drainage Basin (IDB). The topographic features characterizing the basin are divided into two regions by ENE-WSW trending fault. Mountainous and high altitude areas, approximately 1,000-1,800m in elevation, are distributed in the northern area, and low plain, Bahi swamp and gentle hills, approximately 800-1,000m in elevation, are widely spread in the southern area. Drainages developed in this area converge to the Bahi swamp, and main drainage is Bubu River, which flows north to the Bahi swamp.

(1) Method

The equation of the detailed water balance is the same as those used in macro water balance (refer to 5.2.1, 5.2.2). The detailed water balance analysis is different from the previous analyses at the following points;

● Dry and Rainy Seasons

The applied seasons of the detailed analysis are rainy (February 2000) and dry seasons (September 2000) by using the corresponding satellite images

● Runoff

The runoffs at the following hydrometric gauging stations were included to the detailed water balance

Table 5-2 Used Hydrometric Gauging Station Data of River Water Level

hydrometric Gauging Station		Calculated monthly discharge (million m^3/month)		Observation Period
		February	September	
2R1A	Bubu at Farkwa	51.7	0	1957 - 1989
2R23	Mponde	5.6	0	1969 – 1985
2R25	Msemembo	6.3	0	1970 - 1991
2R26	Madumu at Makuru	4.7	0	1970 - 1990
2R29	Bubu at Thawi	14.2	0	1972 - 1985

The locations of these hydrometric gauging stations are shown in Figure 5-14 with its water catchments. For estimating runoff coefficient (Ra), following equation (5) was used.

$$Ra = \frac{R}{P} \quad \cdots\cdots (5)$$

where, R is total monthly runoff (m^3) and P is total monthly rainfall (m^3).

(2) Results

1) Rainfall

The rainfall maps in the sub-basin G for rainy season (February) and dry season (September) are shown in Figure 5-11.

The rainfall in February (rainy season) is about 110mm/month, in September (dry season) it is just a few mm/month over sub-basin G. The rainfall is high at northwestern area in the sub-basin G..

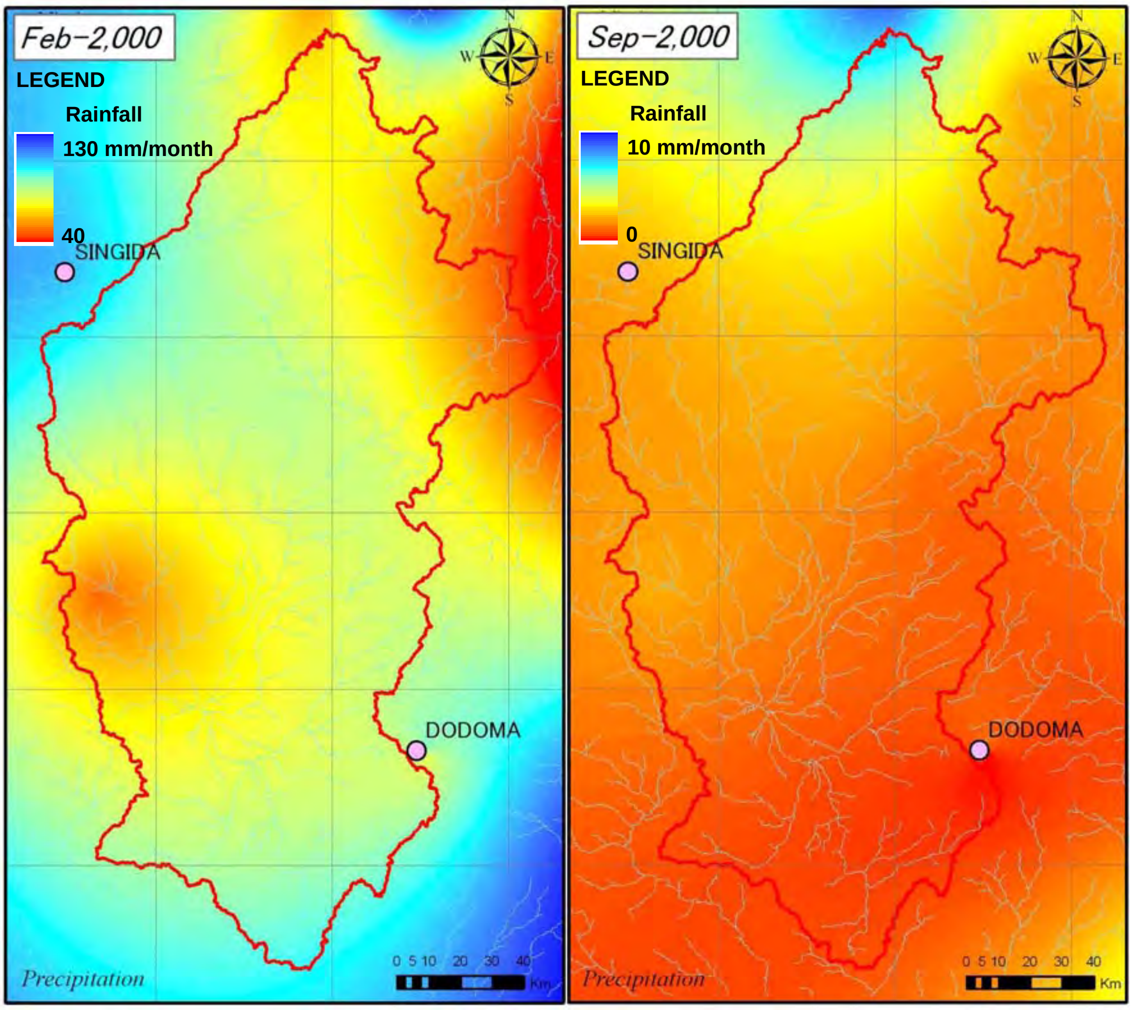


Figure 5-11 Rainfall Maps of Sub-basin G

2) Evapotranspiration

The evapotranspiration maps in the sub-basin G for rainy season (February) and Dry season (September) are shown in Figure 5-12.

The calculated evapotranspiration in February was 40 to 80 mm/month, and in September was 60 to 105 mm/month. The evapotranspiration in southern part has higher value than that in northern part in the sub-basin G.

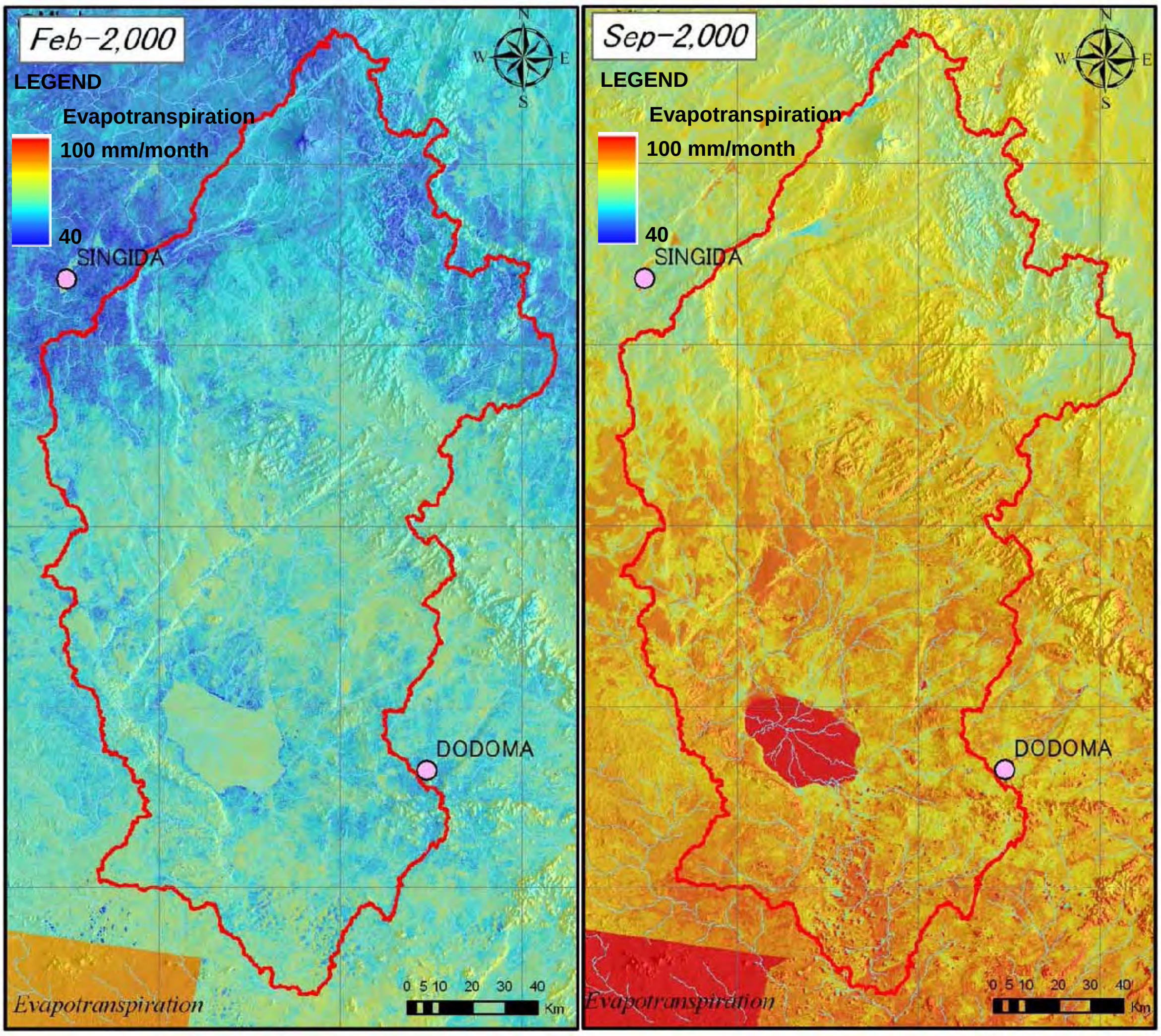


Figure 5-12 Evapotranspiration Maps of Sub-basin G

3) Infiltration

The infiltration values in February and September are shown in the Table 5-3 and 5-4 respectively. The infiltration values for the whole sub-basin G in the Tables 5-3 and 5-4 (the last rows) mean the possible infiltrations because there are no outlets of runoffs. The minus values of the infiltrations in the Table 5-4 mean no practical infiltration.

Table 5-3 Results of Detailed Water Balance Analysis for Sub-basin G in February

Hydrometric gauging station	Area (Km^2)	Rainfall (million m^3/month)	Evapotranspiration (million m^3/month)	Runoff (million m^3/month)	Infiltration (million m^3/month)	Infiltration Rate (%)
2R1A	7,121	783.3	420.1	51.7	311.5	40
2R23	3,374	384.7	192.3	5.6	186.7	49
2R25	811	94.0	45.4	6,292.9	42.3	45
2R26	811	94.0	45.4	4,684.2	43.1	46
2R29	1,220	133.0	64.7	14,215.7	54.1	41
Whole G	26,445	2,961.8	1,613.1	0	1,348.7	46

Table 5-4 Results of Detailed Water Balance Analysis for Sub-basin G in September

Hydrometric Gauging Station	Area (Km^2)	Rainfall (million m^3/month)	Evapotranspiration (million m^3/month)	Runoff (million m^3/month)	Infiltration (million m^3/month)	Infiltration Rate (%)
2R1A	7,121	16.4	555.4	0	(-539.0)	0
2R23	3,374	10.5	263.2	0	(-252.7)	0
2R25	811	1.54	62.4	0	(-60,883.3)	0
2R26	811	1.54	63.2	0	(-61.7)	0
2R29	1,220	4.9	89.0	0	(-84.2)	0
Whole G	26,445	45.0	2,194.9	0	(-2,150.0)	0

The infiltration distribution maps in February and September are shown in Figure 5-13. It is necessary to pay attention that colour scale in the right figure is different from the left. The infiltration in September takes minus value. It means there is no possible infiltration.

The infiltration in February is higher at northern part such as Katesh and Mgori.

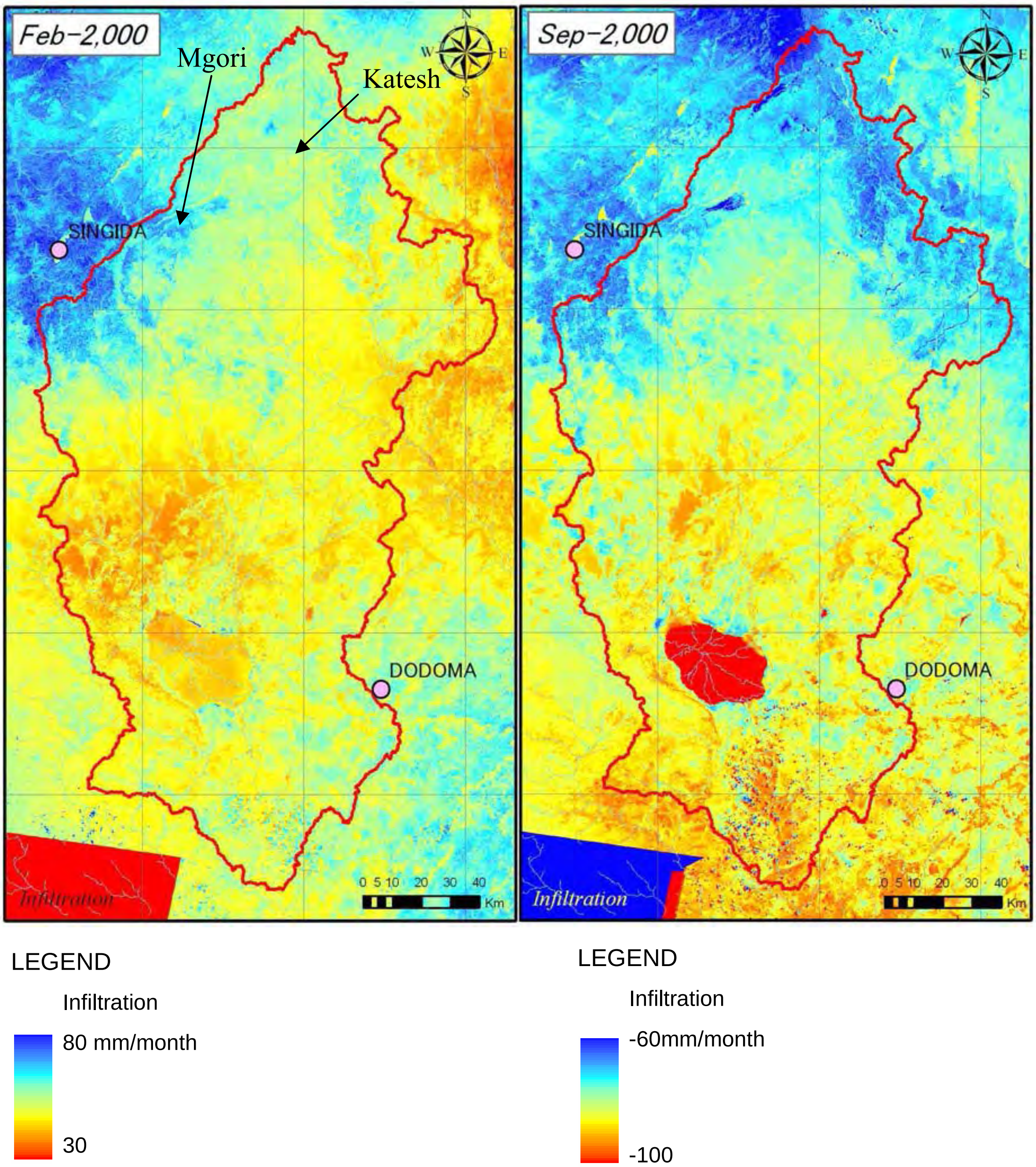


Figure 5-13 Possible Infiltration Maps (I=P-ET) of Sub-basin G

4) Runoff

The runoffs at each hydrometric gauging station are shown in Table 5-5. The runoff coefficient in February varies from 1.5 % to 10.7 %. The average runoff coefficient is about 6 %. It depends on the hydrological and meteorological conditions of the locations of each hydrometric gauging station and their catchments. During dry season, there are almost no runoffs in the sub-basin.

Figure 5-14 shows the infiltration map. It is estimated by equation (1) with runoff term. Since the runoff values are adopted in the small catchments corresponding to each gauging station, the distribution of infiltration is drawn only for the catchments.

Runoff values in September are almost zero because of dry season. The Infiltration map in September should be the same as the possible infiltration map (Figure 5-13).

Table 5-5 Runoff Coefficient of the Drainages in the Sub-basin G in February

Hydrometric Gauging Station		Monthly discharge (R) in February (million m^3)	Monthly Rainfall (P) in February (million m^3)	Runoff coefficient (Ra=R/P)
2R1A	Bubu at Farkwa	51.7	731.4	0.071
2R23	Mponde	5.6	384.	0.015
2R25	Msemembo	6.3	94.0	0.067
2R26	Madumu at Makuru	4.7	94.0	0.050
2R29	Bubu at Thawi	14.2	133.0	0.107
			Average	0.062

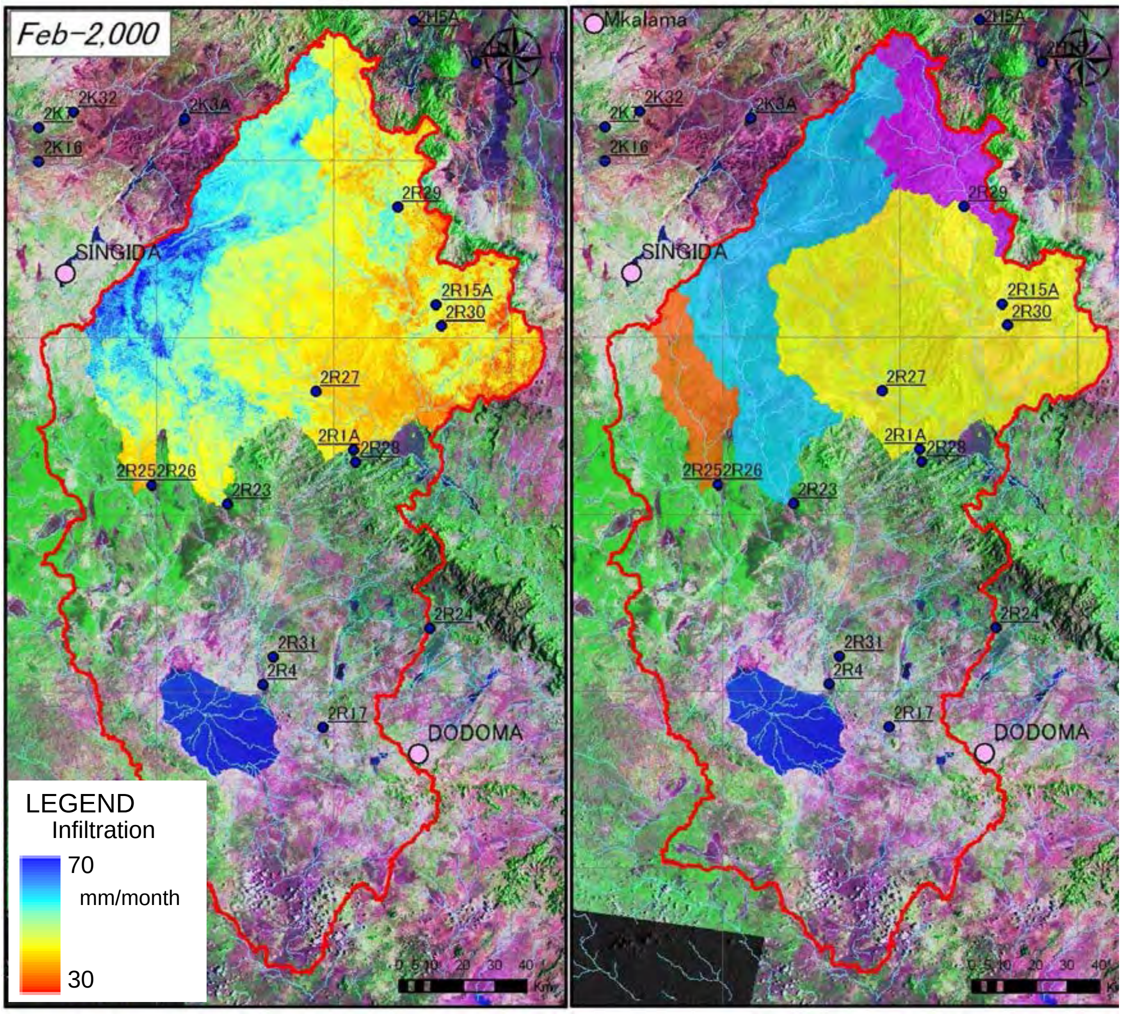


Figure 5-14 Infiltration Map (I = P-ET-Ra×P) of 2R1A, 2R23, 2R25, 2R26 and 2R29
Right figure shows the catchment areas corresponding to each gauging station because of no runnof during dray season.

5.3 Groundwater Potential Evaluation

Groundwater potential for development was evaluated on the basis of the results of the hydrogeological analysis mentioned in Chapter 4 and water balance analysis above mentioned. Five indices: namely, yield, static water level, drilling depth, electric conductivity and fluoride concentration of groundwater, were selected in order to evaluate basic potentiality of groundwater from hydrogeological point view. Infiltration, which was estimated by water balance analysis, was regarded as potentiality of groundwater recharge, was selected from hydrological point of view. Apart from importance of these six indices of natural conditions, social conditions are required also for actual groundwater development for rural water supply, which seems to be most probable needs for stakeholders in IDB. Therefore, two typical social indices: population density and rural water supply ratio by district in IDB were selected.

5.3.1 Indices for Groundwater Potential Evaluation

(1) Well Yield

Well yield is fundamental data for designing water supply facility. To evaluate the well yield, relationship between well yield and scale of rural water supply facility was checked as Table 5-6. This provisional calculation was based on the following assumptions.

- Average Scale of Household = 6 people/household (Refer to "Household Survey" in Chapter 10 of Supporting Report)
- Target Unit Water Consumption: 25L/day/person (Water Policy)
- Operation Hour : 12 hours
- Operation Rate: 0.75

In IDB, the maximum and minimum yield is recorded as 48.0 m^3/ h and 0.05 m^3/ h respectively. The average well yield is 6.31m^3/h with 3.24 m^3/h of standard deviation.

Table 5-6 Evaluation of Well Yield

Village Scale No. of Household	Population	Demand (m^3/day)	Necessary Yield (m^3/h)	Target Yied (m^3/h)	Evaluation
0	0	0	0	0	
50	300	7.5	0.8	1	Poor
100	600	15	1.7	2	Fair
500	3,000	75	8.3	10	Good
1,000	6,000	150	16.7	20	Very Good
5,000	30,000	750	83.3	100	Excellent
>	>	>	>	>	

(2) Static Water Level

The required capacity of the pump for withdrawal depends on the depth of the groundwater table from the ground surface in case of the same withdrawal volume. The depth of groundwater is also closely related to withdrawal cost: namely, operation cost of production wells. Data of static water level in IDB is 148.1m for the maximum depth, -0.06m for the minimum depth and 13.9m for the average depth with 13.8m of standard deviation.

(3) Drilling Depth

Drilling depth is a main factor of drilling cost as an initial cost of production well. Therefore, this value was selected as one of the indices for the evaluation of groundwater potential. Data of drilling depth in IDB is 268.2m for the maximum depth, 2.6m for the minimum depth and 79.5m for the average value with 36.9m of standard deviation. In case of deep borehole (deeper than 20m), the drilling cost is directly proportional in general to its depth based on the cost estimation materials of Tanzanian drilling companies. Therefore, allocation of evaluation score was decided as shown in Table 5-8 considering data distribution.

(4) Water Quality (EC)

Electric conductivity (EC) is strongly related to total dissolved solid (TDS) as a representative index of salinity of groundwater. TDS is also important item on water quality standards and related to treatment cost for drinking water, productivity of live stocks and agricultural crops. Table 5-7 shows affection of TDS to animals and agricultural crops. Evaluation score regarding TDS was allocated as shown in Table 5-8 based on affection to human using exchange ratio between EC and TDS (Refer to Figure 5-15. The maximum value is 1,173.3 mS/m which is equivalent to TDS 8,232mg/L) and the minimum value is 4.39 mS/m: TDS 30.8 mg/L. The average value is 126.0 mS/m (TDS 884mg/L) with 74.89 mS/m of the standard deviation. Allocation of evaluation score was decided with as

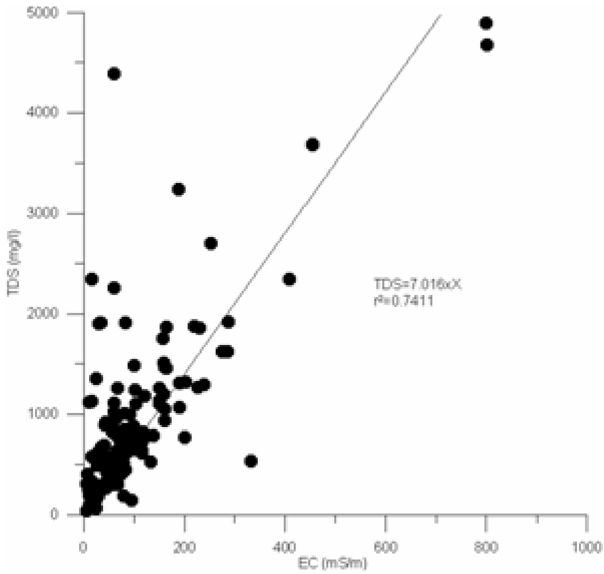
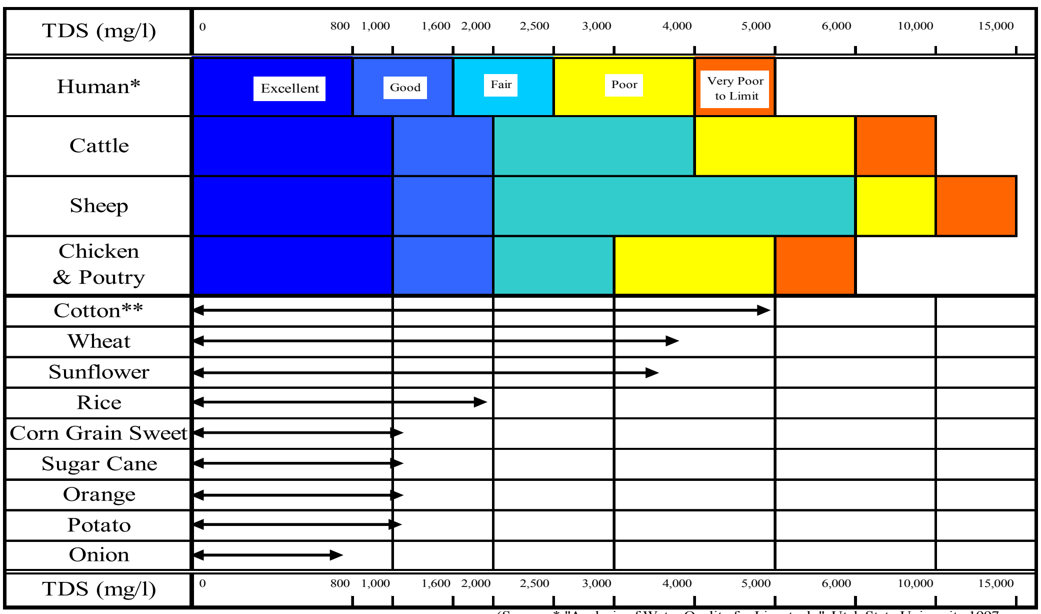


Figure 5-15 Correlation between EC and TDS

Table 5-7 Affection of TDS to Animals and Agricultural Crops



(Source: * "Analysis of Water Quality for Livestock ", Utah State University,1997
** Lenntech Water Treatment & Air Purification Holding B.V. Home Page)

shown in Table 5-8 in considering of affection and data distribution.

(5) Water Quality (Fluoride)

Fluoride is one of the most important indices for groundwater development in IDB. Allocation of evaluation score for fluoride was set as shown in Table 5-8 considering WHO Guidelines (1.5 mg/L), Tanzanian Standard "TZS 789:2003 Drinking (potable) Water Specification (4.0 mg/L)", and "The Tanzanian Temporary Standards of Quality of Domestic Water (upper limit 8 mg/L)". Data of fluoride in IDB is 34.9 mg/L for the maximum value, 0.05 mg/L for the minimum value and 2.48 mg/L for the average fluoride with 3.02 mg/L of standard deviation.

(6) Average Monthly Infiltration (recharge)

Average monthly infiltration in IDB was estimated by water balance analysis (Refer to 5.2.2).
The maximum and minimum value is 201.4 mm/month and -36.5mm/month respectively. The average value is 57.0 mm/month with 33.0 mm/month of the standard deviation. Allocation of evaluation score was decided with as shown in Table 5-8 in considering of data distribution.

(7) Rural Water Supply Ratio

Rural water supply ratio by district in IDB was quoted from "Water and Sanitation in Tanzania" (Water Aid (2005)). (Refer to 4.1.2) Its definition of the ratio is "households with access to improved water sources" which are piped water source and protected water source. The maximum value is 81.8 % (Armeru District) and the minimum value is 4 % (Sikonge District). The average value is 23.6 % with 20.1 % of the standard deviation. Allocation of evaluation score was decided with as shown in Table 5-8 in considering of data distribution.

(8) Population Density

In the case of groundwater resources development, particularly rural water supply, population density is one of the most important factors in terms of investment efficiency. Allocation of evaluation score was set with the data distribution in consideration as shown in Table 5-8.

Table 5-8 Allocation of Evaluation Scores by Each Index

Score		Natural Condition												Social Condition	
		Basic Condition										Recharge			
		(1)Yield (m^3/h)		(2)Static Water Level (m)		(3)Drilling Depth (m)		(4)Water Quality [EC] (mS/m)		(5)Water Quality [Fluoride] (mg/L)		(6)Infiltration (mm)		(7)Water Supply Ratio (%)	(8) Population Density (person/km^2)
10	Better	60 <	Exl	< 5	Exl	< 10	Exl	-		-		100 <	Exl	< 5	150 <
9	↑	20 - 60		5 - 10		10 - 20		< 25	Exl	< 0.5	Exl	80 - 100		5 - 10	100 - 150
8		15 - 20	Very good	10 - 15	Very good	20 - 30	Very good	25 - 50		0.5 - 1.0		60 - 80	Very good	10 - 15	80 - 100
7		10 - 15		15 - 20		30 - 40		50 - 75	Very good	1.0 - 1.5	Very good	50 - 60		15 - 20	65 - 80
6		6 - 10	Good	20 - 30	Good	40 - 50	Good	75 - 100		1.5 - 2.0		40 - 50	Good	20 - 25	55 - 65
5		2 - 6		30 - 40		50 - 70		100 - 125	Good	2.0 - 2.5	Good	30 - 40		25 - 30	40 - 55
4		1.5 - 2	Fair	40 - 50	Fair	70 - 100	Fair	125 - 150		2.5 - 3.0		20 - 30	Fair	30 - 40	30 - 40
3		1 - 1.5		50 - 70		100 - 150		150 - 200	Fair	3.0 - 3.5	Fair	10 - 20		40 - 50	20 - 30
2	↓	0.5 - 1	Poor	70 - 100	Poor	150 - 200	Poor	200 - 250		3.5 - 4.0		0 - 10	Poor	50 - 70	10 - 20
1	Worse	< 0.5		100 <		200 <		250 - 300	Poor	4.0 - 8.0	Poor	< 0		70 <	< 10
0		-		-		-		300 <		8.0 <		-		-	-

5.3.2 Groundwater Potential Evaluation

Regarding the following five cases, groundwater potential in IDB was evaluated.

(1) Case-1: Basic Indices for Natural Conditions

Five indices: well yield, static water level, drilling depth, EC, and fluoride were selected for evaluation of groundwater development potential in terms of basic natural conditions. These indices were summed up at every one square kilometre calculation grid in IDB for the synthetic evaluation. The result illustrated in Figure 5-16.

(2) Case-2: Basic Indices and Infiltration

Above mentioned five basic indices and infiltration was calculated for the total natural conditioned. The results are shown in Figure 5-17.

(3) Case-3: Two Times Weighted of Fluoride in Case-1

Weighting factor of fluoride was applied two times in Case-1. Figure 5-18 shows Shinyanga area, western of Singida and Hanang area become lower potentiality of groundwater development.

(4) Case-4: Case-2+Population Density

Figure 5-19 shows groundwater potential evaluation based on Case-2 and population density in addition. Figure 5-19 shows Shinyanga area, western of Singida and Hanang area become lower potentiality of groundwater development.

(5) Case-5: Case-4 and Water Supply Ratio

The final case: Figure 5-20, shows groundwater potential evaluation based on Case-4 and rural water supply ratio; namely, all layers were calculated. Since Tabora Region has many districts whose ratio is low, potentiality in the western part of IDB is increased.

5.3.3 Conclusion of Groundwater Potential Evaluation

Since one of the main purposes of this study is to evaluate groundwater potential in IDB from hydrogeological and hydrological points of view, high potential areas in IDB can be easily distinguished. Although the resolution of analysis using water supply ratio in district level is not enough, the case study for rural water supply, which is most probable development plan in IDB, was carried out as shown in Figure 5-20. Synthetic analysis with groundwater potential evaluation and social conditions with population density and rural water supply ratio indicate that i) Kondoa/Babati area, ii) Karatu/Mbulu area, iii) South Singida town area, iv) Igunga area and v) West Shinyanga area, have relatively high potentiality for rural water supply development.

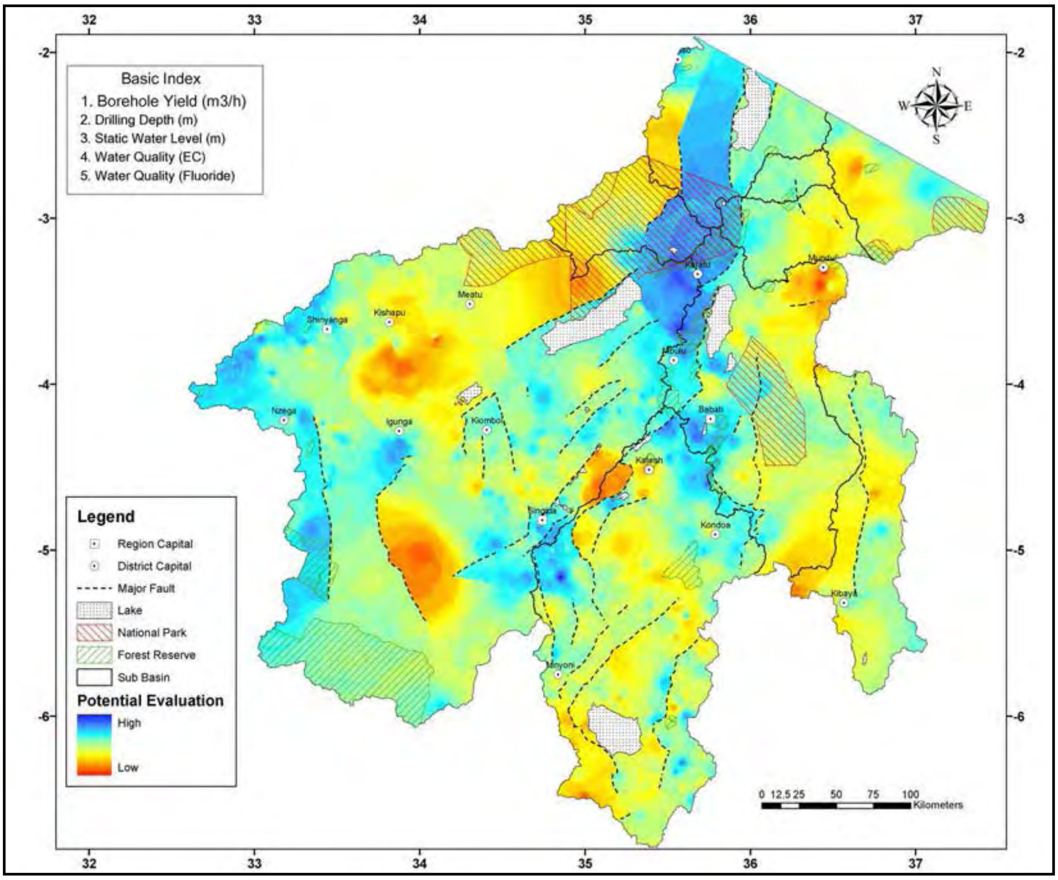


Figure 5-16 Case-1: Groundwater Potential Evaluation (Basic)

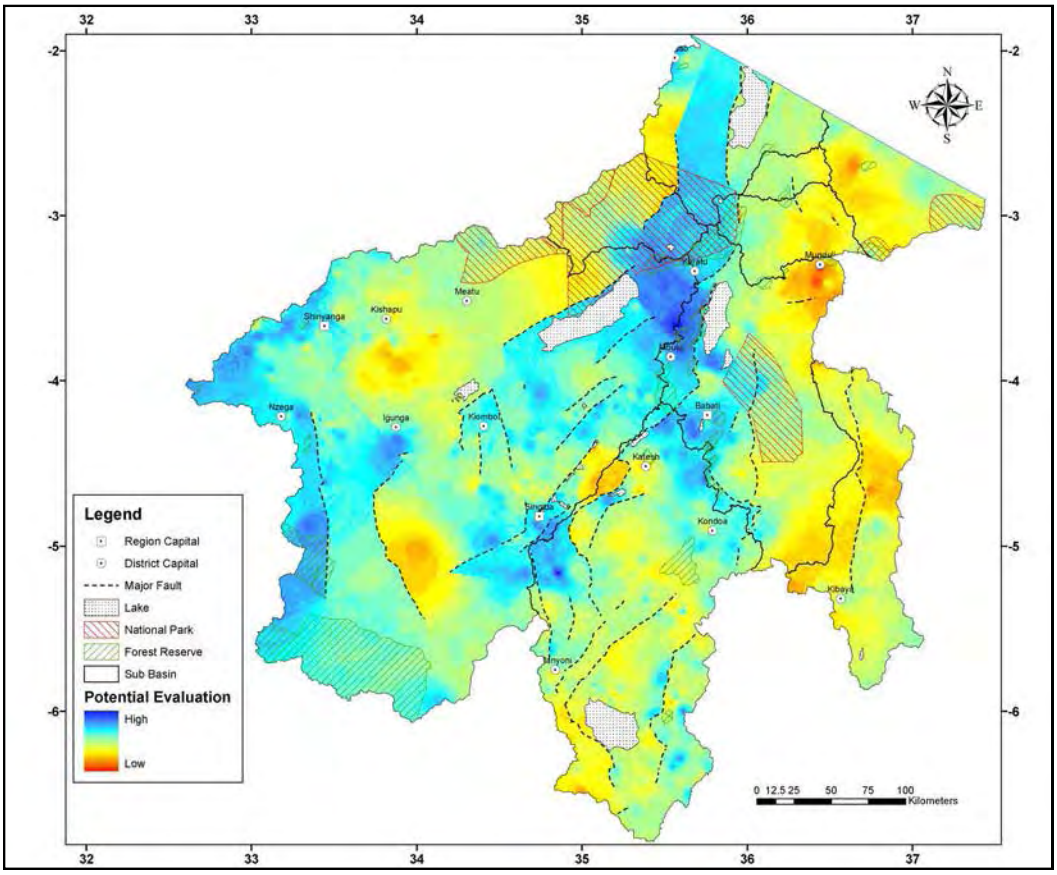


Figure 5-17 Case-2: Groundwater Potential Evaluation (Basic + Infiltration)

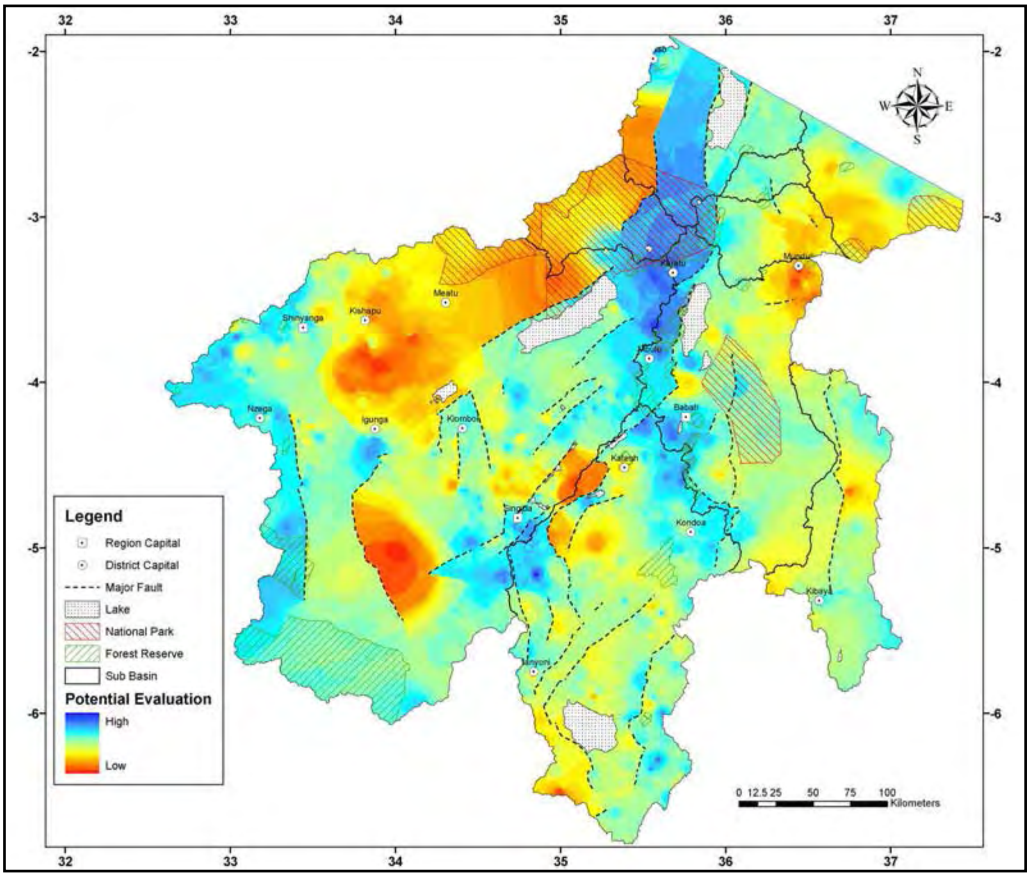


Figure 5-18 Case-3: Groundwater Potential Evaluation (Basic, 2 X Fluorides)

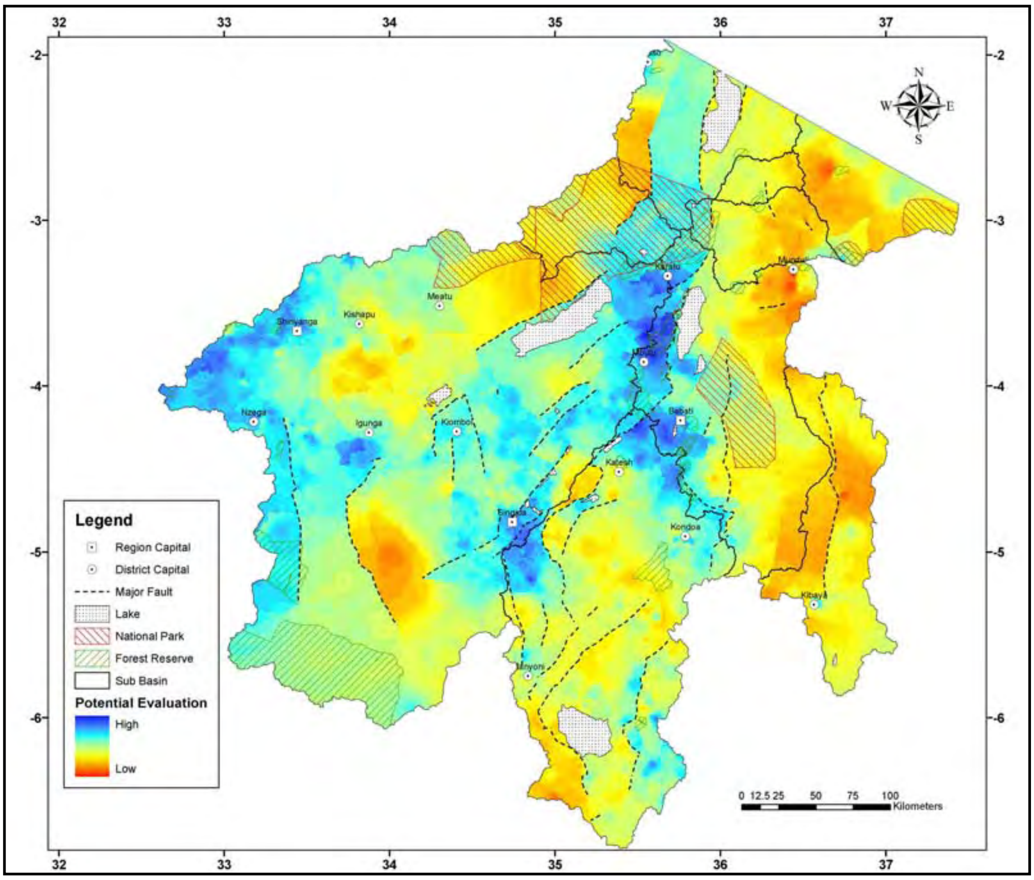


Figure 5-19 Case-4: Groundwater Potential Evaluation (Case-2 + Population Density)

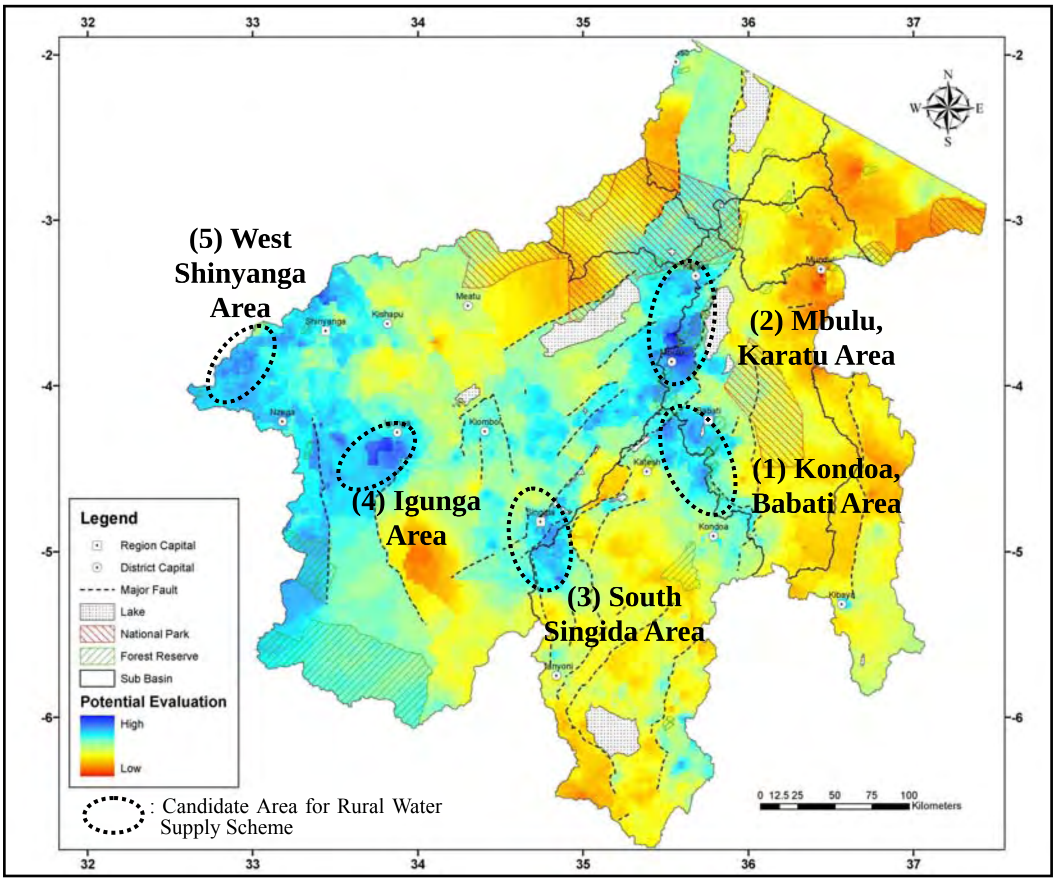


Figure 5-20 Case-5: Groundwater Potential Evaluation (Case-4 + Water Supply Ratio) and Candidate Areas for Rural Water Supply Scheme

Chapter 6
Organizational System for Water Sector

CHAPTER 6 ORGANIZATIONAL SYSTEM FOR WATER SECTOR

6.1 Organizational System for Water Resources Development and Management

6.1.1 National Development Plan for Water Sector

Water resources development and management is carried out based on the National Water Policy 2002 (NAWAPO) in Tanzania. This policy was formulated based on the National Development Vision 2025 (Vision 2025) and the Poverty Reduction Strategy Paper (PRSP), which is currently revised and called as the National Strategy for Growth and Reduction of Poverty (NSGRP), and also by revising the 1991 National Water Policy.

The target of Vision 2025 to water and sanitation sector is to access safe water by 2025 through involving private sector, strengthening local government and communities, and promoting broad-based grass root participation through mobilizing their knowledge and experience. In the NSGRP, it is aimed to increase proportion of rural population with access to clean and safe water from 53% in 2003 to 65% by 2009/2010 within 30 minutes of time spent on collection water, and to increase urban proportion with access to clean and safe water from 73% in 2003 to 90% by 2009/2010.

The main aim of NAWAPO is to provide a comprehensive framework for sustainable development and management of the national water resources for economy-wide benefits and an increase availability of water supply and sanitation services. NAWAPO also incorporates the decentralization policy in the public service sector into the Local Government Reform Policy. The main objectives of the NAWAPO are as follows;

- To address cross-sectoral interests in watershed management and participatory integrated approaches in water resources planning, development and management.
- To lay a foundation for sustainable development and management of water resources in the changing roles of the Government from service provider to that of coordination, policy and guidelines formulation, and regulation.
- To ensure full cost recovery in urban areas with considerations for provision of water supply services to vulnerable group through various instruments including lifeline tariffs.
- To ensure full participation of beneficiaries in planning, construction, operation and maintenance, and management of community based domestic water supply schemes in rural areas.

Following NAWAPO, Ministry of Water (MoW) prepared the National Water Sector Development Strategy (NWSDS) as a single strategy document for Water Sector Development in June 2004 and was revised in 2006. NWSDS suggests immediate priorities and methodologies to solve the constraints in the water sector. NWSDS adopted a new framework for water resources management to harmonize "development" with "environment". For this challenge, NWSDS shows role or responsibility of each related organizations and express that the role of the government will change from public service provider to coordinator of policy, formulation of guidelines and regulations, and that the related various organizations and staff will participate in water resources management and promote basin water offices to function on a financial autonomy basis.

6.1.2 Organizational System for Water Sector

(1) Organization Structure of MoW

Ministry of Water and Livestock Development (MoWLD) was subdivided into Ministry of Water (MoW) and Ministry of Livestock Development (MoLD) in January 2006 under the present Tanzanian Government established in December 2005. The organization structure of MoW is shown in Figure 6-1. The Water Resources Division is the executive and responsible agency for the study.

The Regional Water Engineer (RWE), staff of Regional Consultancy Unit (RCU), and District/Municipal Water Engineer (DWE/MWE) were engaged in management of water resources and water supply under MoWLD. RCU had mainly two types of staff: for water resources management and water supply development. The former was composed of the staff who worked for the survey and management of water resources such as hydrology and hydrogeology under the Water Resources Division. The latter was composed of the staff who worked for water supply development such as designing, construction, and repairing of water supply facility or training for O&M under the Rural Water Supply Division. Water Quality Laboratory also was set up as an annex to the RCU.

(2) Basin Water Offices

"River Basin Management Approach" was applied for water resources management since 1980s in Tanzania and nine basins were set up by Act No. 42 of 1974 (amendment Act No. 10 of 1981). Basin Water Offices (BWOs) were established in Pangani Basin in 1991, Rufiji Basin in 1993 and Lake Victoria Basin in 2000. Moreover, the concept of IWRM (Integrated Water Resources Management) was introduced in National Water Policy 2002, and Basin Water Boards (BWBs) and BWOs were established in all basins.

In addition, under the decentralization policy, RWE becomes one of the technical advisors of water sector, and referred as to Technical Water Advisor (TWA) in social sector support services of Regional Administrative Secretariat (RAS) under the Prime Minister's Office - Regional Administration and Local Government (PMO-RALG). TWA currently gives approval of implementing water supply plans, support to procure fund for it, evaluate/monitor of it by

District/Municipal Council as technical advisor. TWA also support government staff of District/Municipal Councils. Therefore, the budget for the development plan of Local Government Authorities such as District Council (DC) or Municipality Council (MC) is requested to each Ministry through RAS and PMO-RALG. Then each Ministry requests to Ministry of Finance (MoF) and the budget from MoF is allocated directly to DC or MC.

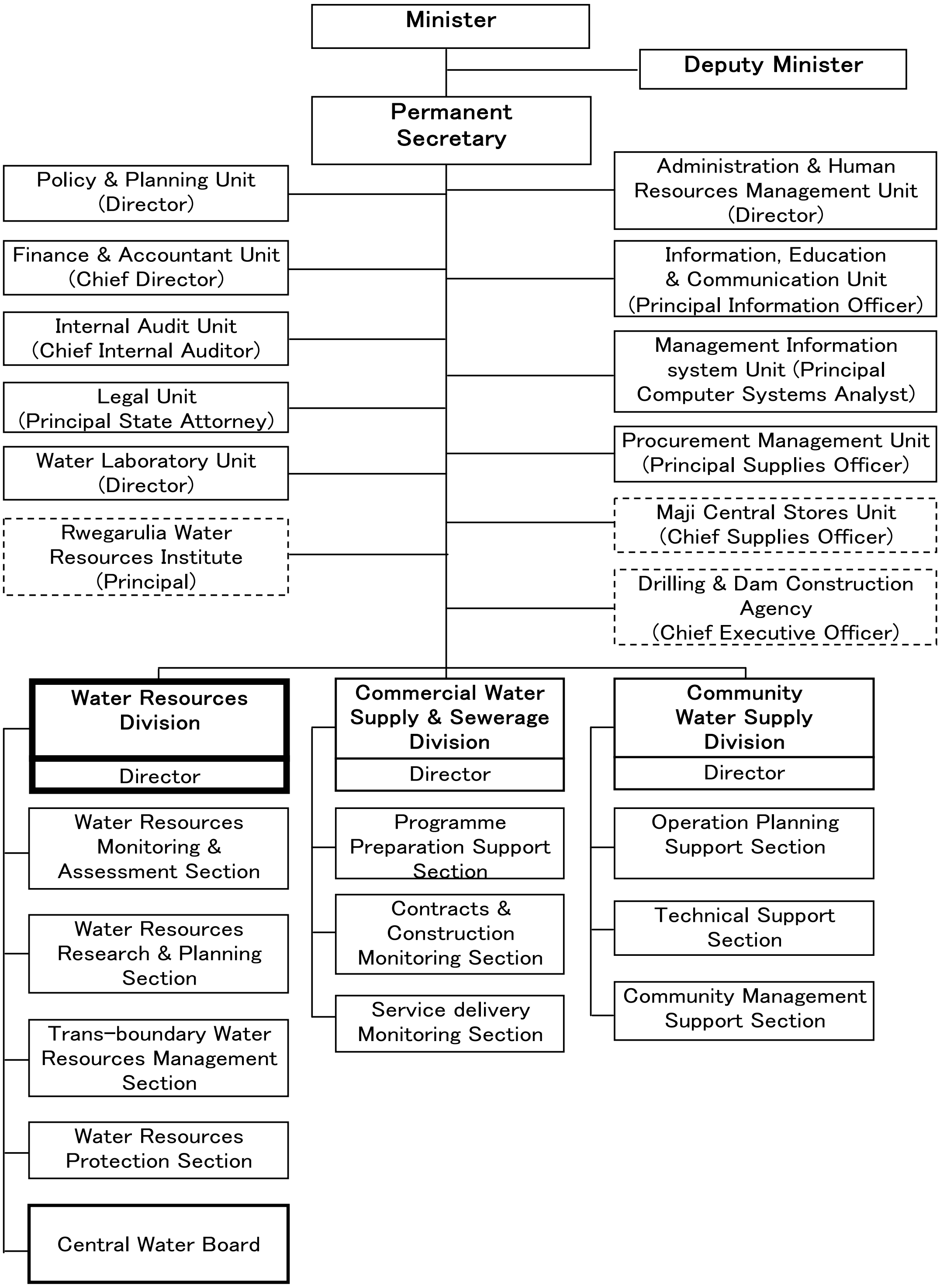


Figure 6-1 New Organization Structure of MoW

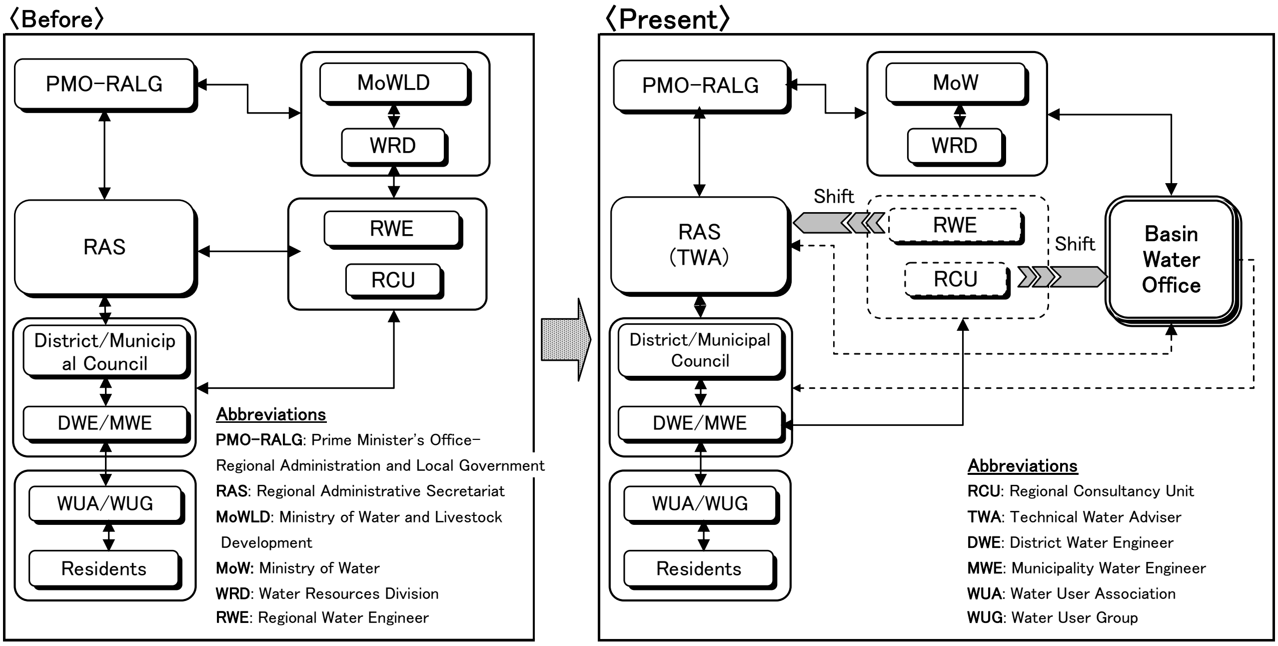


Figure 6-2 Present Institutional Framework of Water Resources Management

The water resources staff from the former RCU or government has been transferred to form the new staff of BWOs. Their technical or engineering works have been transferred gradually to the BWOs. The reformed present institutional framework of water resources management is shown in Figure 6-2.

6.2 Internal Drainage Basin Water Office (IDBWO)

This Study started just one year after establishment of the Internal Drainage Basin Water Office (IDBWO), which was established in Singida on 29th October 2004. During the first phase of the study (Oct. 2005 – Mar. 2006), the JICA Study Team found the organization and operations of IDBWO still under development. The team noticed the following issues on the function of IDBWO.

- Staff of IDBWO

  Regardless 27 technicians were required when the office was established; there were only 13 employees (four engineers, five civil staff and four administrative officers). Two thirds of the nominees belonged still to the previous offices in Arusha, Shinyanga and Dodoma as staff of sub-offices without clear reasons.

- Inner Meeting of IDBWO

  Inner meeting of IDBWO had been scarcely held since its establishment. Therefore, there was not enough communication and consensus building for the functions of the new office among the staff of the head office, much less the staff of the sub-basin offices.

- Incomplete Operation Transfer under Reorganization of Water Sector

  Based on NWSDS, the main activities of water resources management and development transfer from RCUs to BWOs, and District/Municipality take charge of water supply scheme and O/M of water supply facility. However, their transfer was incomplete in IDBWO because of unclear tasks, role-sharing, responsibilities, and cooperation system among the related organizations. For example, the staff in charge of water supply development (designing, construction and O&M) was bewildered by transfer from RCU to IDBWO. Therefore, they sometimes worked for technical issue requested by DC/MC because of lacking of their technical staff.

- Difficulty of Performing Tasks in the Vast area of IDB

  IDBWO did not have a well-established management system to carry out their primary works such as collecting data on water resources, providing water resources information, collecting water user fees, improving pollution of water resources, surveying water quality, and so on due to the vastness of the basin area as one of the main reasons.

- Work-sharing and Communication System among Offices

  Since IDBWO did not have an established communication system or a clear work-sharing agreement among the head office and the sub-basin offices, it was difficult for IDBWO to complete their tasks smoothly. IDBWO planned to increase the number of staffs in the head office in Singida and to set up a new sub-basin office in Babati in order to improve such a situation. However, unfortunately it did not come true.

Based on the above-mentioned situation of IDBWO, the Study Team listed immediate issues to be resolved as follows.

- Awareness of Basin Management and IDBWO

  This is important since the concept of basin water management and the role of IDBWO was not well recognized by the other related organizations or the staff who carried out the actual activities of water resources development and water supply in IDB.

- Cooperation with Related Organization and Demarcation of Roles

  Since IDB covers a large area, it is difficult for IDBWO and other related organizations to communicate with each other. However, cooperation with them (especially that involving RAS and District/Municipal Councils) and demarcation of the roles among them are important in order to conduct the water basin management.

- Capacity Building of Staff in IDBWO

  Capacity building for the staff in IDBWO is needed including re-education of the new framework of the basin water management and its concrete activities.

6.3 Capacity Development (CD) for IDBWO

6.3.1 Current Conditions of IDBWO

(1) Office Arrangement and Assignment Situation of IDBWO Staff

IDBWO consists of Singida Head Office and three sub-offices: Shinyanga Sub-office, Arusha (Babati), and Dodoma. Table-6-1 shows the existing staff of IDBWO. Total staff numbers is 48. When Gauge readers and Meteorological observers are added in this, the grand total becomes 70 staff members in IDBWO.

Table 6-1 Staff Distribution of IDBWO

Section \ Office	Singida Head Office	Shinyanga Sub-office	Arusha (Babati) Sub-Office	Dodoma Sub-Office	IDBWO
Hydrology	2 (4)	3 (7)	0 (6)	0 (5)	5 (22)
Hydrogeology	3	4	3	1	11
O&M	9	7	0	0	16
Supporting Staff	8	3	0	0	11
Water Laboratory	2	3	0	0	5
Total	24 (4)	20 (7)	3 (6)	1 (5)	48 (22)

Note: ( ) shows Number of Gauge reader and Meteorological Observer.
Sources: IDBWO Staff Equipments, Tools and Activities Guidelines Manual (Draft2)

The staff transferred from RCU are classified into three sections: water quality section, water resources management section, and water supply section. The staff of the water quality section work as regional laboratory staff in and out of IDB after establishment of BWOs.

According to MoW, professional staff and technicians who were received the official notification of appointment, as the staff of IDBWO from Basin Water Coordinator in MoW is 18 staff. They had belonged to the section of water resource management. On the other hand, there were the staff in water supply section were fallen in IDBWO (Singida or Shinyanga) as per official instructions from the Ministry of Water regarding dissolution of the RCUs.

(2) Office Building and Equipment

IDBWO occupies parts of RCU's buildings. Several staffs use a small room in the Arusha Water Office's building as the temporary Arusha Sub-office. Dodoma Sub-office also use one room for one member temporary in Dodoma Urban Water Supply Office.

Table 6-2 shows the equipment list in each office. Singida Head Office has office facilities such as computer, photocopy machine, telephone, and fax, but there is no facility in sub-offices. There is some survey equipment in Singida Head Office and Shinyanga Sub-office, but the number of items is insufficient for the IDBWO activities. In the case of Arusha and Dodoma Sub-offices, they lack not only office facilities but also survey equipment.

Under such circumstances, it is difficult for IDBWO offices to communicate with each other, so they have difficulties in conducting their activities for basin water management. As for the internet connection, a few staffs of IDBWO sometimes use it in the JICA Study Team Office. IDBWO has no Internet connection.

Table-6-2 Equipment and Tool List of IDBWO

Items \ Office	Singida Head Office	Shinyanga Sub-office	Arusha (Babati) Sub-Office	Dodoma Sub-Office	IDBWO Total
Computer	3	0	0	0	3
Photocopy Machine	1	0	0	0	1
Fax	1	0	0	0	1
Telephone	1	0	0	0	1
Vehicle (Double Cabin)	2	0	0	0	2
Vehicle (Lorry)	1	0	0	0	1
Current Meter Large	1	1	0	0	2
Leveling Instrument	1	1	0	0	2
Tripod	1	1	0	0	2
Leveling Staff	1	1	0	0	2
Analytical Equipment	1	1	0	0	2
Glassware	1	1	0	0	2
Field Test Kit	1	1	0	0	2
Microbiological Equipment	1	1	0	0	2
Internet Network *1	1	0	0	0	1

Note: *1 Internet Connection share with SUWASA's Office in Singida and JICA Study Team's Office.
Sources: IDBWO Staff Equipments, Tools and Activities Guidelines Manual (Draft2)

(3) Actual Condition of IDBWO and Arrangement of Job Description for Basin Water Management

In the course of OSP, the organization chart and sectional job description prepared previously were reviewed by the staff of IDBWO. First, the organization chart was revised in consideration of real situation of the staffs and their specialties. Then, the sectional job description was also reviewed. Especially, the activities of the unreal sections were categorized by necessity or non-necessity, and the activity of necessity was confirmed the operability by other existing sections or new additional sections. In addition, the job-description of water supply section shifted from RCU made clear, and staff of IDBWO decided to become a contact organization for their activity until the MoW would decide their new position in water sector. Revised organization chart and job-description of IDBWO are shown as Figure 6-3 and Table 6-3. Based on the revised job description, the staffs of IDBWO agreed to request setting up new sections such as “Socio-economic Section” and “Legal and Conflicts Resolution Section” for water right, resolution of conflict, and sensitization for user of community.

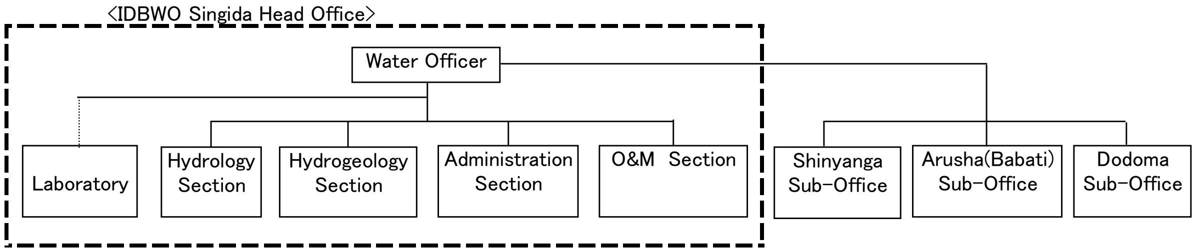


Figure-6-3 Organizational Chart of IDBWO by Organization Strengthening Team

Table 6-3 JOB Description of IDBWO by Organization Strengthening Team

Section	JOB Description
Administration Section	*Establish/update personnel database. *Capacity building for the Basin staff. *Dealing with employment issues. *Communication with other Institutions. *Keeping reports and office documents. *Preparing meetings/workshops/seminars etc. *Training. *Information dissemination. *Prepare Basin Annual Work Plans. *Coordinate and utilize different research activities and results. *Prepare project write-ups.
Hydrology Section (Surface Water Resources Section)	*Operation and maintenance of data collection network. *Data collection (Hydro meteorological/Hydrometric.) *Data processing and analysis (Hydro meteorological/Hydrometric.). *To liaise with other institution collecting data. *Routine inspection of data collecting stations. *Establishing/updating hydrological database. *Involving communities in O&M of the network. *Assessing adequacy of data collecting stations in the network. *Preparing water balance for different streams/rivers. *Demarcation of water sources. *Receive water permit applications. *Submission of processed water permits application to Basin Water Board (BWB).
Hydrogeology Section (Ground Water Resources)	*Operating and maintaining ground water monitoring stations. *Collecting data on groundwater. *Groundwater data processing and analysis. *Establish/update groundwater database. *Ground water exploration. *Identifying and listing potential aquifers. *Identifying and demarcating potential groundwater areas that can be affected by human activities. *Monitoring of drilling activities. *Preparation of Hydro-geological maps. *Preparation of borehole location maps. *Demarcation of water sources. *Water use inspection for complications. *Receive discharge permit applications. *Supervision of borehole drilling and pumping test. *Investigation and construction of shallow wells.
Laboratory Section	*Water sources protection in collaboration with other stakeholders. *Awareness creation to protect environmental degradation. *Water quality monitoring and pollution control. *To prosecute defaulters.
Operation and Maintenance Section	*Designing water facilities. *Construction of water facilities (dam, wind mill etc…) *Rehabilitation of water facilities. *Water facilities data collection.

(4) Problem Analysis of IDBWO

Issues on management of IDBWO were discussed by all staff in IDBWO. This discussion was carried out by three teams using the problem analysis of the PCM methodology. As the outcome of the discussion, the following three items were added to the issues listed previously in 6.2.

1) Difficulty of Leadership

Organizations in Tanzania generally apply Top-down Management System that the leader of an organization has authority, discretion, and responsibility in the course of the activities and other staff performs them under the leader. The leader of IDBWO who is Water Officer is very busy on a daily basis and in difficult situation because of vast jurisdiction, insufficient work force and equipment, and poor infrastructure especially transportation. Therefore, IDBWO could not hold regular meetings, and the leadership such as preparing the annual action plan for basin water management, giving appropriate instruction to staff, checking the progress of the office performance, discussing solutions for challenges, and so on, has not been exhibited properly. Furthermore, the health condition of the IDB Water Officer recently makes it more difficult.

2) Deputy System of Leadership

There should be a deputy system of leadership in IDBWO: namely, a deputy of Water Officer is selected from the staff members during Water Officer's absence. However, it seems that its system does not function well because of the adverse effect of the top-down management system. (Deputy Water Officer is not an official or legal post.)

3) Water User Fees and Shortage of Revenue

An operation budget of IDBWO consists of the budget from MoW and water user fees collected from users in IDB. IDBWO will not be able to receive the budget from MoW and they have to run by only water user fees on a fanatically autonomous basis in the near future.

Water user fees had been collected by the Central Water Board of MoW through District/Municipal councils. After establishment of BWOs, they have to collect the water user fees. However, the information regarding water user fees was not fully explained to District/Municipal Councils and most of users. IDBWO has not yet collected exact information about water users. IDBWO collects the fee only from few users who were registered by water right list long before. Since the collection of the fee is carried out by IDBWO personnel directly by visiting users in turn, it is very inefficient because of high cost in accommodation, transportation, field allowance and so on. Therefore, it is one of the main reasons why IDBWO is always budget-stricken. It is also reason why IDBWO staff cannot receive funds for their activities when the basin accountant goes to do it for long period.

6.3.2 Purpose of Capacity Development

Operation and management performance of IDBWO was particularly discussed at the Steering Committee in March 2006. It has been concerned about whether IDBWO could take over the results of the Study and furthermore perform their tasks independently or not. It was concluded that an extension of the study period and execution of Capacity Development Program (CDP) should be conducted additionally in order to raise the IDBWO performance level based on the agreement between JICA and the Ministry of Water. CDP consisted of upskilling technology program and organization strengthening program. CDP was additionally planned and conducted as the possible assistance by JICA Study Team to improve such issues of IDBWO, which were made clear in the Phase-1 of the Study mentioned above. This program was designed to upgrade staff's capacity and strengthen the organization of IDBWO.

6.3.3 Contents of Capacity Development Program

CDP was carried out from October 2006 to October 2007 as shown Table 6-4 and 5. (Refer to Chapter 12 of Supporting Report in the details).

Table 6-4 Contents of Upskilling Technology Program

Theme	Overall goal	Target	Method	Schedule
Hydrology/ Meteorology	Acquire technology on investigation and data analysis	IDBWO staff	Lecture & Practice	October 2006
GIS/Database	Acquire Basic Knowledge of GIS/DB and Understand Outline of Application in Groundwater Development /Management	IDBWO staff / Other Basin Water Office staff	Lecture & Practice	March 2007
Remote Sensing	Acquire Basic Knowledge and Techniques of Remote Sensing	IDBWO staff / Other Basin Water Office staff	Lecture & Practice	August 2007
Geophysical Survey/Drilling supervision	Acquire technique and knowledge for implementation and data analysis	IDBWO staff	Lecture & Practice	August and September 2007
Hydrogeology	Acquire technique and knowledge for utilization of Hydrogeological map	IDBWO staff	Lecture & Practice	October and November 2007

6.3.4 Organization Strengthening Program

"Organization Strengthening Team" (OST) was organized for Organization Strengthening Program (OSP) in IDBWO whose members were selected from the IDBWO. Main activities were; understanding actual situation of IDBWO, arrangement of job description for basin water management, analysis of management issues in IDBWO, consideration for demarcation or relationship between IDBWO and related organization, and so on. Finally, they prepared the management manual and the action plan for future activity. The staff of IDBWO could understand regarding basic information and challenges that IDBWO was facing or the contents of basin water management by themselves through this program.

Table 6-5 Contents of Organization Strengthening Program

Theme	Main Item	Person in Charge	Method	Schedule
Fixing organization structure in IDBWO	Checking present conditions of IDBWO	All Staff of IDBWO	PCM Workshop	October, 2006
	Checking activities for watershed management by IDBWO			
	Formulation of Operation & Management Manual for IDBWO	Organization Strengthening Team	Discussion	
Clarification of role demarcation among IDBWO and other related organizations and formulation of cooperation system	Confirmation of cooperative tasks among IDBWO and major related organizations	Organization Strengthening Team	Discussion	November, 2006
	Meetings with DWE and TWA in related six regions			
	Confirmation of practical methods to cooperate with related organizations			
Formulation of Operation and Management Plan	Explanation of IDBWO's tasks for basin water resources development & management to IDBWO's staffs	All Staff of IDBWO	Workshop	March, 2007
	Formulation of improvement plan for IDBWO's organization system	Organization Strengthening Team	Discussion	
	Formulation of action plan for IDBWO's staff	Section Leaders of IDBWO		

6.3.5 Evaluation of Capacity Development

Capacity development program was conducted to improve the performance of IDBWO in order to turn over, utilize and expand the Study results. Although the program succeeded in bottom-up of IDBWO considerably, continuous assistances from MoW or other donor organizations are expected to let IDBWO perform their tasks properly and independently.

6.4 Recommendation for IDBWO after OSP

The reorganization of MoW was conducted in 2007 as shown in Figure 6-1 and the arrangement of job description of each section is on going. The organization structures of all BWOs were integrated along this reorganization. Figure 6-4 shows the organizational framework of IDBWO revised by OST through OSP based on new ideas from MoW. The task of BWOs is not changed but job description of each section is also undergoing development in BWOs.

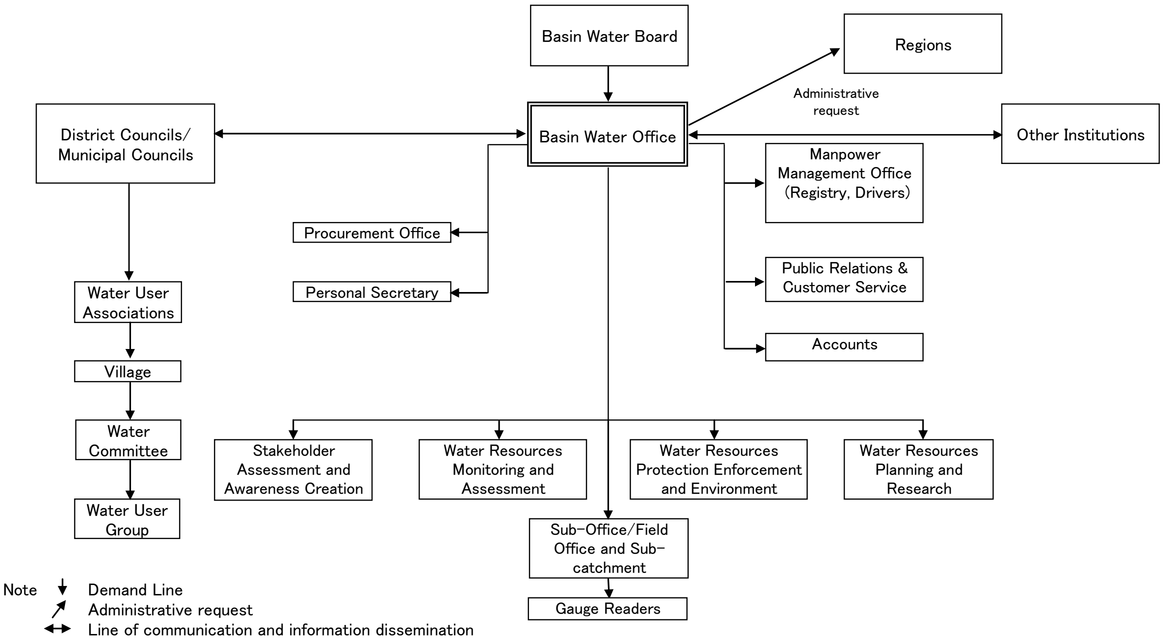


Figure 6-4 Organizational Framework for IDBWO by OST

(1) To Hold Management Meeting

IDBWO needs to hold the regular management meeting for the purposes as follows.

- Planning and implementation of basin water management work
- Monitoring and management of IDBWO’s daily business
- Improvement of organization system
- Back-up system in absence of Water Officer.

According to the plan which was made in OSP, OST proposes to hold three kinds of meetings: i) weekly meeting to discuss the daily business in each office, ii) monthly meeting with all staff, and iii) quarterly meeting to discuss among the delegates from each offices.

(2) To Discuss Water User Fees

Water user fees are important part of the revenue of IDBWO and it will become more important for self-support accounting system. IDB is vast and has few big water users because of disadvantaged surface water and dependence of groundwater. Therefore, IDBWO has to collect water user fees effectively from many small water users. Discussion items are listed below.

- To promote awareness of stakeholders that IDBWO is responsible office to collect water user fees.
- To coordinate with District/Municipality to make people understand about water user fees.
- To establish database of Water user feess in cooperation with District/Municipality.
- To set up effective collection system of water user fees. For example, it may be possible to apply the same collecting system as for O/M cost by WUG/WUA , and to link bank transfer system and the collecting system as shown Figure 6-5.

(3) To Establish Data Collecting and Monitoring System

The data collection and analysis on water resources in IDB have been conducted by JICA Study Team during the Study. The outcome and activity will be taken over to IDBWO and MoW, and the result will be provided to the related stakeholders. At the same time, IDBWO has to continue

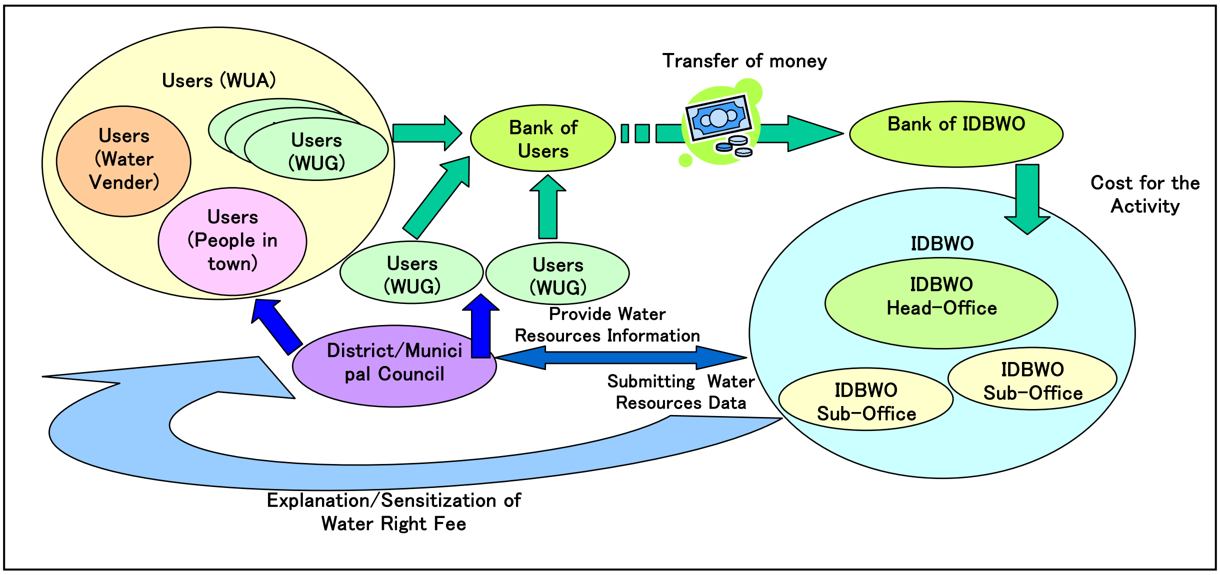


Figure 6-5 Water User Fees Collection System with Bank Transfer System

collecting the data and update their database. There are two kinds of data that should be collected by IDBWO: i) existing/new water supply facility data belong to District/Municipal Council or MoW and ii) data from river gauging stations, meteorological stations, and monitoring boreholes constructed by JICA. IDBWO made their plans for them during OSP as shown in Figure 6-6 and 7. These systems should be made to function actually as soon as possible.

(4) Necessity of Assistance from MoW

IDBWO has not yet functioned properly. Although the staff of IDBWO have to do their best in cooperation with other related organizations, continuous assistances from MoW is also indispensable.

For example, a meeting on operational cooperation between Mow and PMO-RAGO is needed for smooth implementation of IDBWO tasks because RAS and District/Municipal Council as the most related organization to IDBWO are under PMO-RALG. In addition, MoW should assist IDBWO's requirement of staff, facility, and equipment. MoW also should visit IDBWO periodically, check the office performance, and provide proper advice and support.

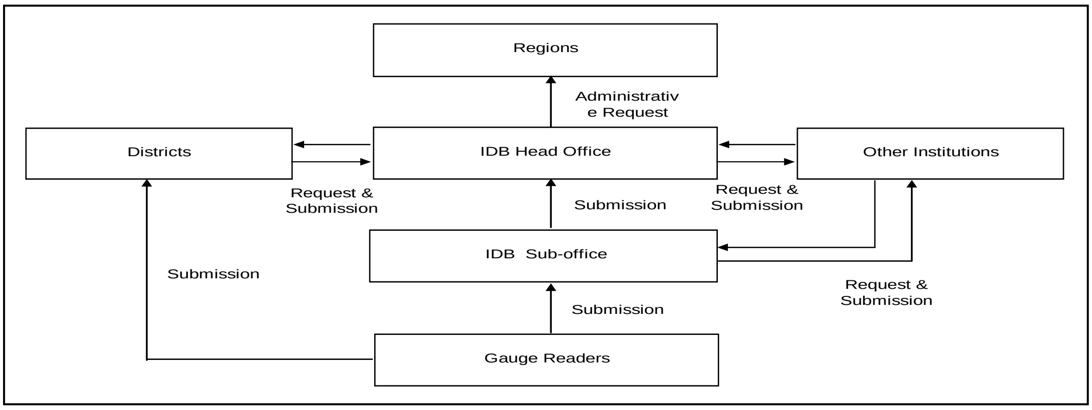


Figure 6-6 Tentative Flow Chart of Data Collection from Related Other Organizations

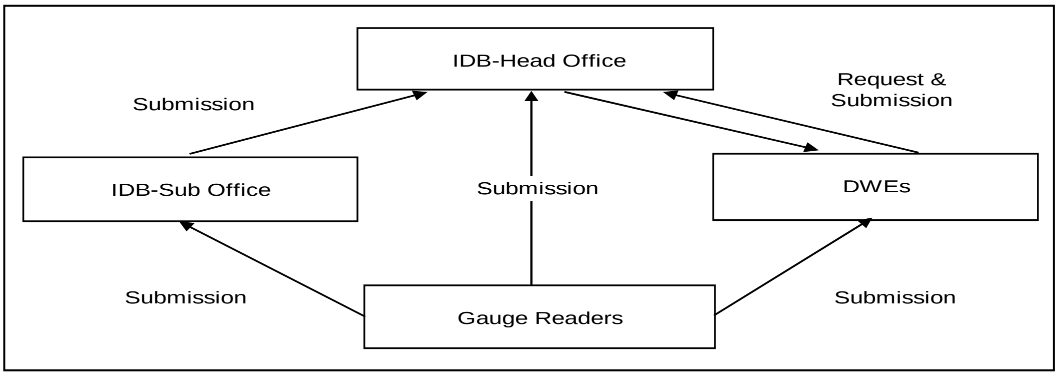


Figure 6-7 Tentative Flow Chart of Data Collection from Monitoring Borehole

Chapter 7
Conclusion and Recommendations

CHAPTER 7 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

This Study has been carried out for approximately two year and half since September 2005. Wide-ranged data for water resources management and the survey results conducted during the Study were accumulated into the water resources management database of IDB.

Various types of figures for synthetic analysis to understand the natural and socio-economic conditions of IDB were drawn by GIS and they were compiled as GIS Figure Book. Hydrogeological map and the groundwater potential evaluation map were finally established based on such figures as the final output. The former is the first version of full-scale hydrogeological map covering 143,000 km^2 of IDB. It is expected to play important role as a provider of the fundamental information for water resources development and management in water-scarce IDB. However, it is not always user-friendly for not only general stakeholders but also engineers in other field. Therefore, the latter was drawn to supplement it.

The groundwater potential evaluation map assesses potentiality of groundwater resources in IDB with six indices of hydrogeological conditions to a resolution accuracy of one km^2 grid by the spatial analysis function in GIS for easily understanding and practical use. In conclusion, the five candidate areas for rural water supply scheme, which is the most feasible use of groundwater resources in IDB, could be nominated by the above-mentioned method considering with two social conditions in addition to their natural conditions. They are（i) Kondoa/Babati area, ii) Karatu/Mbulu area, iii) South Singida town area, iv) Igunga area and v) West Shinyanga area.

There have been fluoride problems caused by drinking water contaminated with high fluoride in IDB. According to the dental fluorosis survey in the Study, almost of all children living in the villages where water sources were contaminated with more than 1.5mg/l fluoride in the northern part of IDB, had moderate level of its symptom. The survey results implied that the major cause of the dental fluorosis was not only contaminated water but high fluoride contained in Magadi. As for removal technology of fluoride from water, several methods are confirmed their capability technically but its applicability was concluded to be very difficult to IDB, particularly into the rural areas, from the socio-economic point of view. Awareness campaigns of fluoride contamination, guidance of better water sources and restriction of Magadi are needed to be as an interim measure.

On the other hand, technology transfer and capacity development programs were conducted in the Study. They consisted of on-the-job training, technical training courses in Japan for three C/P personnel, and capacity development program including the five items of the upskilling technology programs and the organization strengthening program. The capacity development program was conducted to improve the performance of IDBWO in order to take over, utilize and expand the Study results. Although the program succeeded in bottom-up of IDBWO considerably, continuous assistances from MoW are needed to have IDBWO perform their tasks properly and independently.

This Study was started from the redefinition of accurate basin boundary and conducted full-scale groundwater resources assessment for the first time within nine basins in Tanzania, and regarded as the important first step to the goal of "Integrated Water Resources Management" (IWRM). It is also strongly expected that the results and experiences throughout the Study which was conducted in the second largest basin in Tanzania: IDB, would be referred to as a typical model of groundwater resources assessment for the other basins.

7.2 Recommendations

7.2.1 Water Resources Development and Water Quality

(1) Water Resources Development

Since surface water resources in IDB are not suitable for drinking water supply due to unstable quantity resulting from hydrological characteristics of IDB and treatment cost, it is inevitable to depend on groundwater resources especially in the case of rural water supply scheme. Rural water supply master plans and feasibility studies targeting for the five areas: i) Kondoa/Babati area, ii) Karatu/Mbulu area, iii) South Singida town area, iv) Igunga area and v) West Shinyanga area, should be carried out immediately.

(2) Groundwater Quality Problem

Main groundwater problems in IDB are fluoride and salinity. Since high cost purification methods such as ion exchange or reverse osmosis are only applicable against saline water, groundwater development should be planned in the low risk area using the distribution map of EC (TSD) drawn in the Study.

(3) Necessity of Detailed Epidemiological Investigation for Fluorosis

Fluorosis in IDB was confirmed by the dental fluorosis survey of the Study. However, how much of an impact is contributed by the fluoride in drinking water and the high-level fluoride content in Magadi, which people are accustomed to use for daily cooking, is not clear. Therefore, detailed epidemiological investigation should be conducted immediately not only for risk management to fluorosis but awareness campaign of fluoride contamination, guidance to better water sources with less fluoride concentration, and discouraging consumption of Magadi as temporary measures.

7.2.2 Monitoring System and Update of the Study

(1) Groundwater Monitoring

Long-term monitoring is fundamental for groundwater resources management. It is necessary to set up a monitoring system and start monitoring immediately at least for the monitoring wells that were newly constructed during the Study.

(2) Restructuring Monitoring and Collection System of Basic Data for Water Resources Management

Water resources management needs a wide range of data not only natural conditions but social conditions. Even basic data: namely, precipitation, river flow discharge, groundwater level, and water quality data, are lacking and in poor quality. Furthermore, village or ward-wise economic data is also important. It is still the case that IDBWO cannot figure out water resources volume and allocate them for water resources management. Although the Study Team used satellite data to supplement lacking data, it is not almighty. Therefore, a long-term effort to accumulate basic data is necessary by any means. Simultaneously, awareness campaign for necessity of water resources assessment to the related organizations is also important.

(3) Continuation and Update of the Study

Database for IDBWO was constructed by accumulating a wide range of data for water resources management as much as possible during the Study. The results of the Study were based on the many kinds of analysis using the database. IDBWO should enhance quality of the database by accumulating more existing data and monitoring hydrological and hydrogeological conditions in IDB; and update the Study results.

(4) Use of GIS

Many maps in "GIS Figure Book" are only an output for the purpose of the Study based on the database covering wide-range fields. Since GIS is not only a mapping tool but can be used for various purposes of users with the same GIS database, the availability of GIS established in the Study should not be limited so other relevant organizations as well as IDBWO can share the usefulness. Therefore, GIS resources, such as software, hardware and human resources, of those organizations should be further developed as necessary.[k1]

7.2.3 Organization Strengthening of IDBWO

Organization strengthening of IDBWO should be continued to accomplish the above-mentioned recommendations based on the issues to be solved, which are recognized by IDBWO staff themselves through the organization strengthening program in the Study. Since the organization strengthening only by IDBWO's self-supporting effort has limitations, it is strongly desired that Ministry of Water should support its effort without interruption.