The Study on Groundwater Development in Central Cambodia
Final Report

Main Report

LOCATION MAP
EXCHANGE RATE AND LIST OF ABBREVIATION
EXECUTIVE SUMMARY

CONTENTS

4.5 Groundwater Resource Evaluation

4.5.1 Hydrogeological Unit

The hydrogeologic settings of the study area, which is mentioned in the previous section, shows that the areas of Kg. Cham consists of the basalt which was originated from Pliocene and Pleistocene volcanic activities and thick Plio-Pleistocene sediments such as clay, silt, sand, and gravel layers. The area can be divided into several aquifer zones or groundwater basins according to the topography and geology.

On the other hand, the basement rocks are distributed in the shallow place in Kg. Chhnang. Thin Quaternary sediments such as clay and sand cover the basement rocks. These soft sediment forms an aquifer, however, its yield is generally poor as well as its water quality. The aquifers are weathered zone and/or fractured zone of the basement rocks, and some areas individually form small groundwater basins bounded by geological structure such as the fault.

The hydrogeological unit of the Study area can be summarized as Table 4.5.1.1.

Table 4.5.1.1 Hydrogeological Unit of the Study Area

<table>
<tr><th rowspan="2">Geologic Age</th><th rowspan="2">Lithology</th><th rowspan="2">Hydrogeologic Unit</th><th colspan="2">Area of Distribution</th></tr>
<tr><th>Kg.Chhnang</th><th>Kg.Cham</th></tr>
<tr><td rowspan="3">Holocene</td><td>Alluvial sand</td><td>Unconfined or Confined Aquifer</td><td rowspan="2">Along the Tonlesap river and its tributaries</td><td rowspan="2">Along the Mekong river and its tributaries</td></tr>
<tr><td>Alluvial clay</td><td>Aquitard</td></tr>
<tr><td>Laterite</td><td>Aquitard</td><td colspan="2">Plateau</td></tr>
<tr><td rowspan="3">Pleistocene
Pliocene</td><td>Basalt</td><td>Confined Aquifer</td><td colspan="2">Plateau</td></tr>
<tr><td>Sand,gravel</td><td>Confined Aquifer</td><td colspan="2" rowspan="2">Widely distributed</td></tr>
<tr><td>Clay, Silt</td><td>Aquitard</td></tr>
<tr><td>Pre Tertiary</td><td>Basement Rocks (mainly sand stone)</td><td>Aquifer or Impermeable basement</td><td>Exposed at mountain and isolated hill</td><td>Underlain by Plio-Pleistocene Sediments</td></tr>
</table>

4.5.2 Aquifer Productivity

As far as the groundwater quantity is concerned, the study area is divided into a high groundwater potential zone in the eastern part of Kg. Cham which is located along the left bank of the Mekong River and a low potential zone located in the western part, Kg. Chhnang. In the eastern parts, the basalt forms several groundwater basins according to the topographical and geology. The Plio-Plestocene sediments also forms a groundwater basin, which is contiguous to the "Mekong Groundwater Basin" in the downstream of the Mekong River. The western part, Kg. Chhnang, is located in the right bank of the Tonle Sap River. In this area, thin Quaternary sediments forms poor shallow aquifer while the fracture zone and the weathered zone forms individual small groundwater basins. The aquifer productivity is closely related to the hydrogeological conditions. Groundwater potential in the areas of Memot, Tboung Khmum, Ou Reang Ov, Cham Kar Leu in Kg. Cham is higher because the exploitable aquifers are sand and gravel layers of Plio-Pleistocene formations and fracture of the basalt. On the other hand, the productivity of basement rock aquifers is generally small and aquifer zones are limited to the weathered portions and/or fractured zones.

Figure 4.5.2.1 presents a correlation between the drawdown and the pumping rate. The upper figure indicates Pumping Rate (*Q*) and Drawdown (*s*) relation by province. As clearly shown, the test wells in Kg. Chhnang indicate greater drawdown and smaller pumping rate while that of Kg. Cham indicates smaller drawdown and greater pumping rate. That means smaller Specific Capacity (*Sc*) in Kg. Chhnang and greater in Kg. Cham.

The lower figure indicates the productivity of aquifer. As seen in this figure, *Q* of the basement rocks ranges from 10 m^3/day to 200m^3/day at the wider drawdown range. . *Q* of the basalt shows intermediate value of 15 m^2/day to 100 m^2/day. The drawdown ranges from 2m to 15m. Plio-Pleistocene sediments show highest values of Q. It ranges from 60 m^3/day to 230m^3/day.

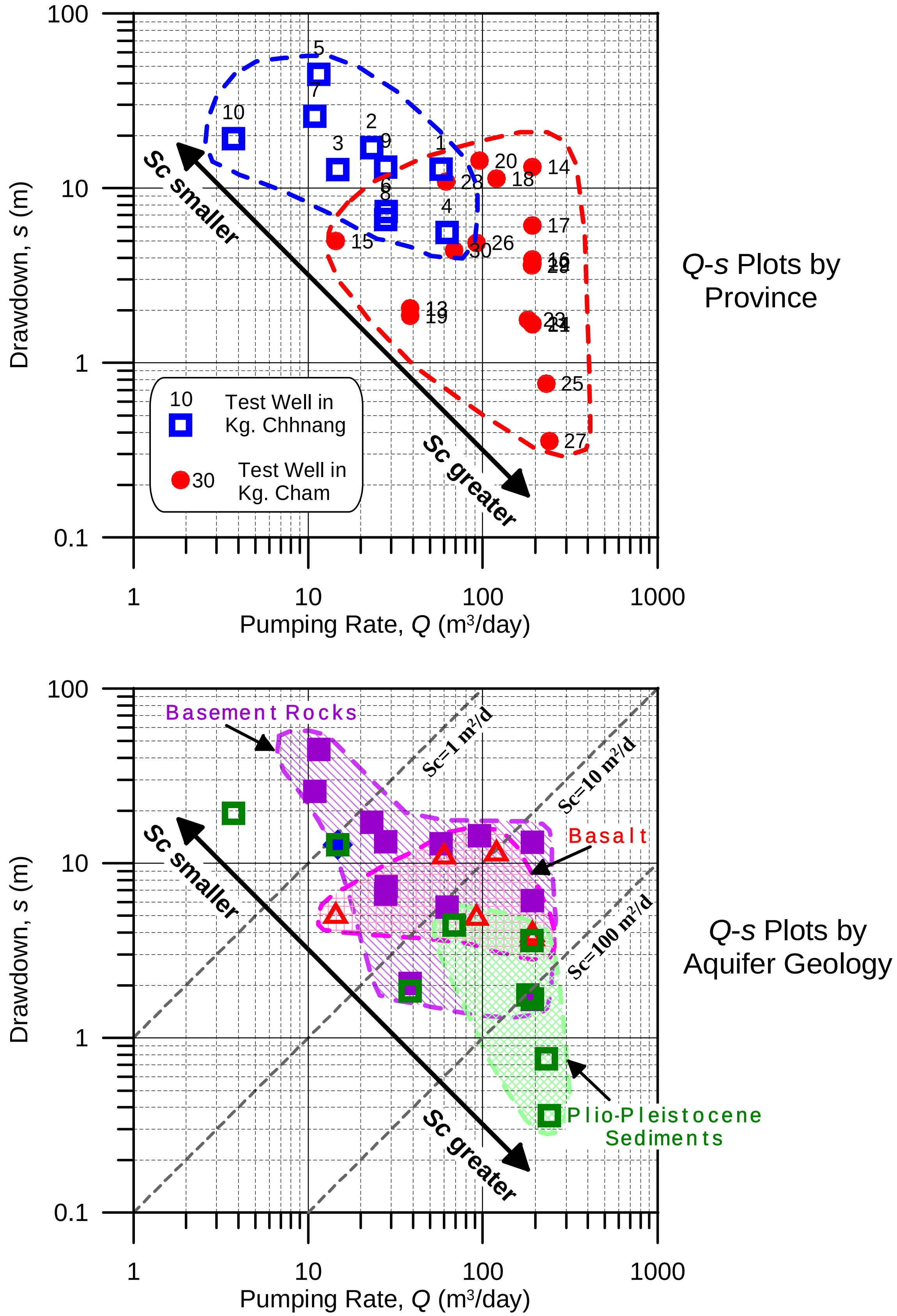

Figure 4.5.2.1	***Q-s*** **Plots of Test Wells by Province and Aquifer Geology**
THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

Sc : Specific Capacity
(= *Q* / *s*)

4.5.3 Groundwater Potential

Considering the hydrogeological settings presented in the hydrogeological map, the pumping test and water quality test conducted on the sites, the groundwater potential of the study area is evaluated and summarized by province/district and aquifer as shown in Table 4.5.3. Hydrogeological map of the Study area at a scale of 1/200,000 is attached in this report as well as Figure 4.5.3.

Table 4.5.3 Evaluation of Groundwater Potential

Province	District	Hydrogeologic Feature	Main Aquifer	Specific Capacity	Water Quality	Groundwater Potential
Kampong Chhnang	Kampong Leng Chul Kiri Baribo Kg.Chhnang (PT) Rolea Phier Kampong Tralach	Located along the Tonle Sap river. Covered by thin alluvial sediments forming a shallow aquifer of poor quantity and quality. Fissure and weathered basement rocks become an aquifer.	Fissure and wethered basement rocks (sandstone, rhyolite)	Specific capacity of the basement rocks ranges from less than 0.2 to 200m²/day depending on the fracture zone.	Shallow alluvial aquifer locally contains iron and arsenic higher than WHO guideline. Basement rocks aquifer locally contains high fluoride.	(1)Alluvial shallow aquifer (depth:10-20m) is poor in quantity and locally high iron with arsenic. Low potential. (2) Basement rock is generally impermeable (depth: more than 10m). Fissured and weathered parts of the rocks become excellent aquifer of high potential. Pumping rate: 3.7 to 63.4m³/day
	Tuk Phos Samaki Meanchey	Covered by thin Pleistocene sandy and clayey sediments. Basement rocks is located at shallow depth.				
Kampong Cham	Bateay Cheng Prey Kang Meas Kroch Chma Srei Santhor Kok Sotin	Located along the Tonle Sap river and Mekong river. Alluvial and Plio-Pleistocene formation consist of thick clayey sediments. Shallow thin sandy layer forms aquifer of saline or iron rich groundwater.	Alluvial and Plio-Pleistocene sediments.	Specific capacity of alluvial aquifer is 15.6m²/day at the test well in Cheng Prey	Generally high iron. Locally accompanied by high arsenic. High chloride (386mg/l) and TDS(1507mg/l) at the test well.	Groundwater potential is low in terms of quality. High iron and arsenic contents in shallow aquifer (Depth:20m). Locally groundwater is salinized. Pumping rate 68.9m³/day at the test well.
	Stung Trang Chamkar Leu Prey Chhor Kampong Siem Kampong Cham (PT)	Plio-Pleistocene sandy layer and basalt forms good aquifers. In Stung Trang, Pleistocene sandy aquifer is locally in artesian condition.	Plio-Pleistocene basalt and sediments	Specific capacity of basalt is 49.9 m²/day in Chamkar Leu.	Generally good quality of water. Basalt aquifer is less iron. Plio-Pleistonce aquifer has slightly high iron groundwater.	Groundwater potential is high. Well depth: 50-80m. Flowing well :30-40l/min. Pumping rate in the test well: 180m³/day.
	Tbong Khmum O Reang Ov Dambe Ponhea Krek	Plio-Pleistocene sand or gravel layer and basalt form good aquifers. In Ponhea Krek , Plio-Pleistocene aquifer is locally in artesian condition.	Quaternary basalt and Plio-Pleistocene sediments	Plio-Pleistocene aquifer: 115-670 m²/day Basalt: 5.5-27.9m²/day	same as the above	Groundwater potential is excellent and productive(Depth 40-100m) Pumping rate of basalt: 60-90m³/day, Plio-Pleistocene: 185-230m³/day Flowing well: 60 l/min
	Memot	Located on the gently undulated hill composed of basalt and Plio-Pleistocene sediments forming good aquifers. Basement rock locally found at depth of 15m	Basalt, Plio-Pleistocene sediments, Basement rocks (sandstone)	Sandstone:6.7-114.6m²/day Basalt: 2.9-52m²/day Plio-Pleistocene:20.7m²/day	Good quality. Iron and arsenic free. No fluoride in basement rock aquifer.	Groundwater potential is high. Well depth: 25-50m. Pumping rate:14.4-192 m³/day.

4.6 Water Balance Analysis

4.6.1 Methodology

Based on the collected climatic data, the water balance in the study area can be computed with reasonable accounting from the following water balance equation:

$$P = Int + Rof + AP + ATP + SM + RE \qquad (4.6.1)$$

where

P :	rainfall
Int :	interception loss
Rof:	surface runoff
AP:	actual evaporation from soil surface
ATP:	actual evapotranspiration
SM:	soil moisture recharge
RE:	groundwater recharge

In equation (4.6.1), the rainfall could be measured directly, but the rest of the components are difficult to be measured in the field satisfactorily. In the study area, all these parameters are not measured or available daily. Therefore, it becomes imperative to estimate these parameters in some scientific manner before proceeding to the water balance computation.

4.6.2 Measured Parameters

(1) Rainfall

Generally the rainfall is measured by a rain gauge. In the study area, monthly rainfall data measured at Kg. Chhnang and Kg. Cham are available, however, daily rainfall data are not available. Therefore, the daily rainfall data at Phnom Penh for a period from 1985 until 1995 measured by the Department of Meteorology were used for the water balance computation assuming that the similar daily rainfall occurs in the study area.

(2) Pan-Evaporation

The most common method of measuring evaporation is by means of evaporation pans. There are various types of evaporation pans but the U.S. Class A pans are most widely used. There are three (3) stations measuring pan-evaporation in and around the Study Area, viz. Kg. Cham, Phnom Penh, and Svay Rieng. However, only the data of Phnom Penh can be used because of the reliability and less of lacking data.

In the study, the measured pan-evaporation data at Phnom Penh were used to estimate actual soil evaporation and actual evapotranspiration components.

4.6.3 Estimated Parameters

(1) Interception loss

Some amount of rainfall captured by vegetation and trees does not reach the ground surface and evaporates from the leaf surface. This interception loss can be determined by comparing the precipitation in gauges beneath the vegetation with that recorded nearby under the open sky. But generally interception loss is not measured. Therefore 0.5 mm per rainfall event is estimated as the interception loss. It is important not to ignore this small loss, because when all the small quantities are totaled they may well amount to a significant component of the water balance.

(2) Surface runoff

Surface runoff occurs when the soil is fully saturated and the rainfall intensity exceeds the infiltration rate of the soil. The surface runoff can be measured by stream gauges, but it is not available in the Study Area. Therefore the estimation of surface runoff is required. There are some methods for estimating surface runoff. In the Study the SCS curve number model (Soil Conservation Service, 1972) was employed.
The SCS (1972) developed a method for computing abstraction from storm rainfall. For the storm as a whole, the depth of excess precipitation or direct runoff P_e is always less than or equal to the depth of precipitation, P; likewise, after runoff begins, the additional depth of water retained in the watershed, F_a, is less than or equal to some potential maximum retention S. There is some amount of rainfall I_a (initial abstraction before ponding) for which no runoff will occur. So the potential runoff is $P - I_a$. The hypothesis of the SCS method is that the ratios of the two actual to the two potential equations are equal, that is:

$$\frac{F_a}{S} = \frac{P_e}{P - I_a}$$

(4.6.2)
From the continuity principle,

$$P = P_e + I_a + F_a \qquad (4.6.3)$$

Combining (4.6.2) and (4.6.3) to solve for P_e gives:

$$P_e = \frac{(P - I_a)^2}{P - I_a + S} \qquad (4.6.4)$$

which is the basic equation for computing the depth of direct runoff from a storm by the SCS method. By study of results from many small experimental watersheds, an empirical relation was developed:

$$I_a = 0.2\, S \qquad (4.6.5)$$

On this basis,

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (4.6.6)$$

Plotting the data for P and P_e from many watersheds, the SCS found curves of the type. To standardize these curves, a dimensionless curve number CN is defined such that $0 \leq \mathrm{CN} \leq 100$. The curve number and S are related by:

$$S = \frac{1000}{\mathrm{CN}} - 10 \qquad (4.6.7)$$

where S is in inches The curve numbers presented in the SCS runoff type curves apply for normal antecedent moisture conditions (AMC II). For dry conditions, (AMC I) or wet conditions (AMC III), equivalent curve numbers can be computed by:

$$\mathrm{CN(I)} = \frac{4.2\mathrm{CN(II)}}{10 - 0.058\mathrm{CN(II)}} \qquad (4.6.8)$$

and

$$\mathrm{CN(III)} = \frac{23\mathrm{CN(II)}}{10 + 0.13\mathrm{CN(II)}}$$

(4.6.9)

The range of antecedent moisture conditions for each class is described by Chow (1988).

The curve numbers have been tabulated by SCS on the basis of soil type and land use. Four (4) soil groups are defined as follows:

Group A:	Deep sand, deep loess, aggregated silts
Group B:	Shallow loess, sandy loam
Group C:	Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay
Group D:	Soils that swell significantly when wet, heavy plastic clays, and certain saline soils

The values of CN for various land uses on these soil types were given by SCS. For a watershed made up of several soil types and land uses, a composite CN can be calculated. In the Study, Group B was selected for the Study Area, and CN(II)=71, which is a runoff curve number for cultivated land with conservation treatment, was chosen to estimate average water balance of the Study Area. From equations (4.6.8) and (4.6.9), CN(I) and CN(III) are calculated as 51 and 85, respectively.

(3) Actual evaporation from soil surface

The loss of water by evaporation from the soil surface is a major component of the annual water balance under the tropical monsoon conditions. The actual evaporation from soil surface is nearly equal to the potential evaporation when the soil surface is saturated with water. As the soil surface dries up, soil evaporation gradually diminishes, until eventually it ceases altogether when the water vapor pressure in the soil interstices equals that in the atmosphere. The maximum depth of the soil where soil evaporation will occur depends upon the texture of the soil. The soil evaporation from a greater depth is possible in clayey soils with a high capillary rise. But it is very difficult to measure the actual soil evaporation in the field.

The daily actual soil evaporation AE can be estimated as a function of the daily pan-evaporation value E_p, the number of days t, following a rain of sufficient amount to recharge the surface 10 cm of soil and fraction *B* of incoming solar radiation reaching the soil surface (Russel, 1978). The following equation is used to compute the daily actual soil evaporation from the daily rainfall data and pan-evaporation data:

$$AE = B\frac{E_p}{t} \qquad (4.6.10)$$

Under uncropped conditions or barren land *B*=1.0, but under cropped conditions it is a time-dependent function of crop growth that can be measured directly or estimated from the leaf area index (LAI).

(4) Actual evapotranspiration

It is difficult to separately measure the actual water losses by soil evaporation and transpiration. From the definition, obviously if there is no vegetation in the area, the transpiration is zero. Also in case of that the moisture content of the root zone is less than the wilting point, the transpiration does not occur. The actual transpiration depends manly upon the species of plant, density of vegetation, stages of crop growth, climatic conditions and moisture holding capacity of the soil.

The ratio of evapotranspiration (moisture not limiting) of a particular crop to pan-evaporation CTR throughout the growing season has been reported. So if the CTR of the vegetation is known and assuming moisture is not limiting, the evapotranspiration can be computed using daily pan-evaporation data.

In the actual field conditions, the area is not fully covered by vegetation and the soil moisture is also limited so that the actual evapotranspiration is smaller than the potential evapotranspiration. For calculation of the actual evapotranspiration in a particular area, the ratio of vegetation-covered area to no vegetation area has to be taken into account as well as the available water in the root zone. In the study, it was assumed that 70% of the study area is covered with vegetation. The CTR values by cropping stage were estimated from the values of paddy and maize.

(5) Soil moisture

The maximum amount of water that the soil can hold against the force of gravity is termed the field capacity, which is measured as the ratio of weight of water retained by soil to the weight of the soil when dry. The lowest amount of moisture that is held by the soil, not available for transpiration by vegetation, is the wilting point. The difference between the field capacity and the wilting point constitutes the available soil moisture. The field capacity varies with types of soils and the thickness of the soil zone.

When sufficient rainfall occurs and the soil zone is assumed to fill up to the field capacity, the surplus water leaves the soil zone. The water, which has remained in the soil zone as the available soil moisture, will be extracted as the soil evaporation and the transpiration by plants. After the available soil moisture becomes zero, neither actual soil evaporation nor actual evapotranspiration will occur until next rainfall event, which supplies soil moisture.

The depth of the soil to which the soil evaporation occurs may vary with the physical properties of soil. In sandy soils, this should probably be less than 10 cm, and in clay soils it should be more. The transpiration from plants occurs from the root zone that varies with vegetation and root growth.

In the study, two (2) layer model of the soil zone was developed for the soil moisture calculation. In the upper layer up to 20 cm depth from the surface, it is assumed that the soil evaporation and transpiration will occur, whereas in the second layer below 20 cm depth, the available soil moisture will be extracted as transpiration from plants.

(6) Groundwater recharge

The component of the groundwater recharge, which is *RE* in equation (4.6.1), can ultimately be obtained from the water balance computation in the soil moisture zone.

4.6.4 Result of Computation

Although available data for the water balance computation are limited, each water balance component in equation (4.6.1) was computed using actual daily rainfall data from 1986 to 1995 and average monthly evaporation data for a period from 1929 to 1960 in Phnom Penh. The computation was carried out for a period from January 1, 1986 until December 31, 1995 on daily basis. A daily evaporation value was uniformly given throughout a month from the monthly evaporation value.

Although the water balance computation was carried out by daily basis, the results of the computation are summarized in monthly basis as shown in Table 4.6.4.1. The monthly average of the water balance components are tabulated in Table 4.6.4.2. The results of the water balance computation are also summarized yearly as shown in Table 4.6.4.3.

(1) Groundwater Recharge

The annual groundwater recharge is estimated from 315.4 mm in 1992 to 649.3 mm in 1987. The ratio of groundwater recharge to rainfall ranges from 28.2 to 41.8%. An average groundwater recharge from 1986 to 1995 is estimated as 448.1 mm/year, that is 34.0% of the rainfall.

In a monthly basis, the groundwater recharge in September is the largest. The average monthly recharge in September is 137.0 mm. The second largest monthly recharge occurs in October at an average recharge of 104.6 mm. The average monthly recharge in May, July and August ranges from 43.8 to 49.9 mm. The month of June has smaller recharge at 24.2 mm. On the other hand, the average monthly recharge values in January, February and December is 0 mm. The average recharge in March and April is also small, showing 3.3 and 5.6 mm, respectively.

From the SCS model, it is understood that the occurrence of groundwater recharge is influenced by daily pattern of rainfall as well as the intensity of daily rainfall. Therefore, the percentages of monthly recharge to monthly rainfall vary from 9.76% in April and 47.11% in October.

(2) Water Balance

In the water balance estimation, the biggest component is actual transpiration ATP, it’s average value is 511.3 mm/year (=38.8 % of rainfall). The average actual evaporation is computed as 231.1 mm/year (= 17.6% of rainfall). The average surface runoff is estimated as 101.9 mm/year (7.7%), however, it ranges widely from 34.3 to 183.2 mm/year in the period from 1986 to 1995.

It is noted that the accuracy of the water balance estimation has limitations because there are several assumptions and estimations in the input parameters. More accurate water balance estimation could be done if it is available to obtain more data qualitatively and quantitatively, such as daily evaporation data, transpiration data, soil data, etc by area. Water balance analysis by Tank Model method could be done if daily unconfined groundwater levels were monitored. It is also noted that quantitative relation between groundwater and surface water, such as river water and lake water, should be studied for detailed water balance analysis.

Table 4.6.4.1 Monthly Results of Water Balance Computation (1/2)

Year	Mon	Precipitation (mm)	Pan-Evaporation (mm)	Interception Loss (mm)	Surface Runoff (mm)	Actual Evaporation (mm)	Actual Transpiration (mm)	Groundwater Recharge (mm)
1986	1	0.0	130.2	0.0	0.0	0.0	0.0	0.0
1986	2	4.5	131.6	0.5	0.0	4.0	0.0	0.0
1986	3	4.5	170.5	0.5	0.0	4.0	0.0	0.0
1986	4	48.7	150.0	1.2	0.0	21.1	24.0	0.0
1986	5	149.8	105.4	2.5	5.2	31.8	36.5	35.0
1986	6	90.9	105.0	3.6	0.0	38.9	72.4	0.0
1986	7	181.3	99.2	1.8	3.6	29.9	78.9	44.5
1986	8	224.5	96.1	2.6	5.7	34.9	105.4	96.1
1986	9	301.3	69.0	2.0	20.1	25.0	81.8	147.0
1986	10	235.1	77.5	2.5	38.5	33.1	71.0	92.9
1986	11	86.9	96.0	1.8	2.5	18.9	55.1	33.1
1986	12	23.8	117.8	2.0	0.0	17.4	13.0	0.0
1987	1	0.0	130.2	0.0	0.0	0.0	3.1	0.0
1987	2	0.0	131.6	0.0	0.0	0.0	2.8	0.0
1987	3	0.0	170.5	0.0	0.0	0.0	1.1	0.0
1987	4	0.0	150.0	0.0	0.0	0.0	0.0	0.0
1987	5	24.6	105.4	2.1	0.0	15.9	7.0	0.0
1987	6	150.2	105.0	3.0	0.0	37.6	68.5	10.0
1987	7	138.2	99.2	2.9	0.0	31.7	84.9	17.7
1987	7	183.6	96.1	2.5	7.0	32.5	101.6	40.3
1987	9	474.3	69.0	1.6	65.6	29.8	90.0	285.6
1987	10	257.1	77.5	2.9	4.1	28.0	80.6	127.5
1987	11	323.8	96.0	2.1	70.3	34.4	56.6	168.2
1987	12	0.0	117.8	0.0	0.0	6.7	23.8	0.0
1988	1	0.0	130.2	0.0	0.0	0.0	3.1	0.0
1988	2	22.9	136.3	1.0	0.0	11.3	12.7	0.0
1988	3	22.2	170.5	0.5	0.0	2.9	2.4	0.0
1988	4	96.3	150.0	2.6	0.4	37.5	39.9	0.0
1988	5	70.2	105.4	4.4	0.2	21.0	47.6	12.3
1988	6	172.9	105.0	2.5	1.0	37.4	73.4	38.0
1988	7	152.9	99.2	3.0	1.4	31.1	90.4	39.7
1988	7	177.8	96.1	3.8	0.0	32.1	105.0	37.9
1988	9	445.0	69.0	4.0	114.9	25.8	89.6	190.6
1988	10	137.4	77.5	2.6	0.9	28.0	79.9	41.5
1988	11	71.4	96.0	1.7	0.0	15.3	44.7	26.0
1988	12	0.0	117.8	0.0	0.0	0.0	6.0	0.0
1989	1	15.0	130.2	0.5	0.0	8.0	6.7	0.0
1989	2	0.0	131.6	0.0	0.0	1.7	4.1	0.0
1989	3	54.0	170.5	2.2	0.0	23.8	13.0	0.0
1989	4	63.2	150.0	1.4	0.3	19.2	26.0	0.0
1989	5	183.5	105.4	3.3	26.3	30.2	43.2	69.5
1989	6	38.4	105.0	3.1	0.0	21.8	42.4	0.5
1989	7	86.6	99.2	2.2	0.0	27.3	69.8	0.0
1989	7	162.4	96.1	2.0	9.1	27.0	50.4	51.0
1989	9	398.7	69.0	2.6	107.0	27.9	83.9	155.9
1989	10	328.6	77.5	2.5	27.4	25.5	80.6	196.9
1989	11	107.3	96.0	1.7	13.1	15.9	45.5	57.7
1989	12	0.0	117.8	0.0	0.0	0.0	6.2	0.0
1990	1	0.0	130.2	0.0	0.0	0.0	3.1	0.0
1990	2	0.0	131.6	0.0	0.0	0.0	2.5	0.0
1990	3	0.0	170.5	0.0	0.0	0.0	0.0	0.0
1990	4	26.2	150.0	2.0	0.0	16.4	4.5	0.0
1990	5	227.1	105.4	2.0	13.7	31.9	42.4	109.4
1990	6	63.8	105.0	2.2	0.0	22.0	53.1	0.0
1990	7	166.8	99.2	2.5	1.2	36.5	84.3	20.3
1990	7	174.6	96.1	3.0	1.2	31.1	96.5	70.5
1990	9	246.6	69.0	3.4	8.5	27.9	90.0	84.1
1990	10	98.3	77.5	3.6	0.0	26.8	80.5	8.1
1990	11	138.7	96.0	1.1	9.7	23.4	52.2	62.2
1990	12	0.0	117.8	0.0	0.0	0.0	6.3	0.0

Table 4.6.4.1 Monthly Results of Water Balance Computation (2/2)

Year	Mon	Precipitation (mm)	Pan-Evaporation (mm)	Interception Loss (mm)	Surface Runoff (mm)	Actual Evaporation (mm)	Actual Transpiration (mm)	Groundwater Recharge (mm)
1991	1	0.0	130.2	0.0	0.0	0.0	3.1	0.0
1991	2	0.0	131.6	0.0	0.0	0.0	2.8	0.0
1991	3	0.0	170.5	0.0	0.0	0.0	0.4	0.0
1991	4	83.4	150.0	1.5	5.0	18.2	15.0	11.0
1991	5	53.4	105.4	3.0	0.0	20.5	33.4	0.0
1991	6	304.5	105.0	4.0	56.3	36.3	70.9	128.0
1991	7	284.3	99.2	3.0	34.4	36.8	105.4	117.6
1991	7	193.7	96.1	2.5	1.6	30.1	96.0	71.4
1991	9	120.2	69.0	2.6	0.0	23.3	58.9	21.0
1991	10	210.2	77.5	2.1	1.3	28.8	80.6	104.0
1991	11	2.2	96.0	0.5	0.0	2.8	14.5	0.0
1991	12	1.7	117.8	1.0	0.0	0.7	6.2	0.0
1992	1	3.1	130.2	0.5	0.0	2.6	2.4	0.0
1992	2	2.5	136.3	0.5	0.0	2.0	0.0	0.0
1992	3	0.6	170.5	0.5	0.0	0.1	0.0	0.0
1992	4	35.0	150.0	1.2	0.0	27.5	6.5	0.0
1992	5	93.4	105.4	3.0	2.1	16.4	20.6	21.2
1992	6	113.9	105.0	3.5	0.0	41.7	76.9	0.0
1992	7	219.5	99.2	3.0	11.3	34.9	105.3	52.5
1992	7	198.4	96.1	3.2	19.0	33.4	98.0	41.4
1992	9	216.5	69.0	3.6	6.3	22.9	71.5	104.8
1992	10	197.2	77.5	4.0	14.3	24.8	75.7	95.5
1992	11	10.9	96.0	1.5	0.0	11.2	19.1	0.0
1992	12	3.8	117.8	0.5	0.0	3.3	6.0	0.0
1993	1	21.1	130.2	0.5	0.0	9.6	4.2	0.0
1993	2	0.0	131.6	0.0	0.0	4.1	3.4	0.0
1993	3	61.4	170.5	1.4	2.7	19.2	14.3	0.0
1993	4	63.7	150.0	1.0	0.5	13.6	35.6	21.7
1993	5	73.2	105.4	1.5	1.6	16.2	26.7	12.9
1993	6	83.0	105.0	2.5	0.0	18.3	44.1	12.6
1993	7	245.1	99.2	3.5	7.4	42.3	105.4	96.7
1993	7	81.0	96.1	4.2	0.0	26.0	62.8	4.0
1993	9	241.2	69.0	2.5	19.5	28.1	80.7	87.9
1993	10	385.8	77.5	2.0	46.0	32.2	80.6	218.5
1993	11	59.4	96.0	1.5	0.0	15.6	29.3	3.5
1993	12	12.4	117.8	2.0	0.0	16.2	28.9	0.0
1994	1	0.4	130.2	0.4	0.0	0.0	3.1	0.0
1994	2	0.0	131.6	0.0	0.0	0.0	2.8	0.0
1994	3	164.2	170.5	2.0	40.7	37.6	17.8	33.1
1994	4	61.1	150.0	1.3	0.4	14.1	37.3	23.1
1994	5	157.7	105.4	4.0	21.1	31.3	44.4	53.7
1994	6	106.1	105.0	3.4	0.0	30.9	42.1	8.8
1994	7	96.5	99.2	3.7	3.3	36.5	72.3	16.5
1994	7	154.3	96.1	3.3	0.0	31.4	69.6	34.2
1994	9	332.9	69.0	1.5	27.9	29.4	90.0	163.9
1994	10	126.9	77.5	1.9	13.3	20.6	78.3	42.2
1994	11	5.6	96.0	0.5	0.0	1.6	7.4	0.0
1994	12	17.9	117.8	1.0	0.0	16.4	9.2	0.0
1995	1	0.0	130.2	0.0	0.0	0.0	1.5	0.0
1995	2	0.0	131.6	0.0	0.0	0.0	0.0	0.0
1995	3	18.0	170.5	1.0	0.0	10.5	2.4	0.0
1995	4	94.3	150.0	2.0	22.0	18.2	11.6	0.0
1995	5	234.6	105.4	3.5	27.2	31.9	46.5	124.4
1995	6	146.8	105.0	4.0	0.0	35.4	67.5	43.7
1995	7	156.4	99.2	3.6	0.0	34.5	94.4	42.0
1995	7	208.9	96.1	3.7	5.7	33.1	97.4	52.0
1995	9	277.1	69.0	2.0	31.7	29.3	84.7	128.7
1995	10	243.6	77.5	3.1	37.5	27.8	79.1	118.8
1995	11	22.4	96.0	0.5	0.0	10.4	20.7	0.0
1995	12	11.2	117.8	1.1	0.0	8.2	7.8	0.0

Table 4.6.4.2 Monthly Average of Water Balance Components

Month	Precipitation [P] (mm)	Pan-Evaporation (mm)	Interception Loss (mm)	Surface Runoff (mm)	Actual Evaporation (mm)	Actual Transpiration (mm)	Groundwater Recharge [RE] (mm)	RE/P
1	4.0	130.2	0.2	0.0	2.0	3.0	0.0	0.00%
2	3.0	132.5	0.2	0.0	2.3	3.1	0.0	0.00%
3	32.5	170.5	0.8	4.3	9.8	5.1	3.3	10.19%
4	57.2	150.0	1.4	2.9	18.6	20.0	5.6	9.76%
5	126.8	105.4	2.9	9.7	24.7	34.8	43.8	34.59%
6	127.1	105.0	3.2	5.7	32.0	61.1	24.2	19.02%
7	172.8	99.2	2.9	6.3	34.2	89.1	44.8	25.90%
8	175.9	96.1	3.1	4.9	31.2	88.3	49.9	28.35%
9	305.4	69.0	2.6	40.2	26.9	82.1	137.0	44.85%
10	222.0	77.5	2.7	18.3	27.6	78.7	104.6	47.11%
11	82.9	96.0	1.3	9.6	15.0	34.5	35.1	42.32%
12	7.1	117.8	0.8	0.0	6.9	11.3	0.0	0.00%
Total	1316.5	1349.2	22.1	101.9	231.1	511.3	448.1	34.04%
Total in %	100.00%		1.68%	7.74%	17.56%	38.84%	34.04%	

Table 4.6.4.3 Yearly Water Balance Components

Year	Precipitation [P] (mm)	Pan-Evaporation (mm)	Interception Loss (mm)	Surface Runoff (mm)	Actual Evaporation (mm)	Actual Transpiration (mm)	Groundwater Recharge [RE] (mm)	RE/P
1986	1351.3	1348.3	21.0	75.6	259.0	538.1	448.6	33.20%
1987	1551.8	1348.3	17.1	147.0	216.6	520.0	649.3	41.84%
1988	1369.0	1353.0	26.1	118.8	242.4	594.7	386.0	28.20%
1989	1437.7	1348.3	21.5	183.2	228.3	471.8	531.5	36.97%
1990	1142.1	1348.3	19.8	34.3	216.0	515.4	354.6	31.05%
1991	1253.6	1348.3	20.2	98.6	197.5	487.2	453.0	36.14%
1992	1094.8	1353.0	25.0	53.0	220.8	482.0	315.4	28.81%
1993	1327.3	1348.3	22.6	77.7	241.4	516.0	457.8	34.49%
1994	1223.6	1348.3	23.0	106.7	249.8	474.3	375.5	30.69%
1995	1413.3	1348.3	24.5	124.1	239.3	513.6	509.6	36.06%
Average	1316.5	1349.2	22.1	101.9	231.1	511.3	448.1	34.04%
Average %	100.00%		1.68%	7.74%	17.56%	38.84%	34.04%	