CHAPTER 6

EVALUATION OF GROUNDWATER RESOURCES

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6.1 Water Balance Analysis

The climate in the Study Area is subtropical, dominated by seasonal winds or monsoons. The rainy season in the northern part of Vietnam starts from May and lasts in September. The distribution of rainfall pattern will greatly affect the groundwater environment, because the most of groundwater recharge is presumed to be originated from rain water.

It is necessary to understand the water balance in the Study Area, because both the surface water and groundwater is limited resources. Particularly for evaluating groundwater resource, estimation of groundwater recharge is very important. In this Study, data of some basic components of the water balance equation have been collected and evaluated. A groundwater development plan in the target communes should be designed considering the local and regional water balance conditions.

6.1.1 Rainfall

The Study Team has collected monthly rainfall data at Thai Nguyen, Hanoi, Ninh Binh, Thanh Hoa, and Ha Tinh. The duration of collected rainfall data is more than 30 years. The monthly average rainfall at the five (5) locations are tabulated in Table 6.1.1.

Figure 6.1.1 shows the average monthly rainfall pattern in the Study Area with average annual rainfall. The average annual rainfall is less than 2,000 mm in Hanoi, Thanh Hoa, and Ninh Binh. Among the five (5) meteorological stations, Hanoi has the smallest annual rainfall of 1,683.9 mm. Average values of annual rainfall in Thanh Hoa and Ninh Binh are 1,728.7 and 1,860.7 mm, respectively. Thai Nguyen has an average annual rainfall of 2,049.7 mm. In the Study Area, Ha Tinh has the greatest average annual rainfall of 2,719.9 mm.

The average monthly rainfall pattern of the Study Area differs from north to south. In Thai Nguyen, the maximum monthly rainfall (402.2 mm) occurs in July. Hanoi has the maximum rainfall (293.7 mm) in August. The rainfall in September is the highest in Ninh Binh (381.8 mm) and Thanh Hoa (387.1 mm). In Ha Tinh, the maximum monthly rainfall (736.9 mm) occurs in October, and rainfall from September to November is dominant compared with other months.

Figures 6.1.2 to 6.1.4 show the results of probability analysis of annual rainfall. The probability and return periods of flood and drought years were obtained from the Hazen Plot. According to the probability analysis, the predicted annual rainfall in the year of once in 10 years drought probability is 1,180 mm in Thanh Hoa, showing the smallest among the five locations. The same annual rainfalls in Hanoi, Ninh Binh, and Thai Nguyen are 1,280 mm, 1,330 mm, and 1,660 mm, respectively. Ha Tinh has the greatest annual rainfall of the 10-years drought probability year, that is 1,905 mm. The predicted annual rainfall in the year of once in 50 years drought probability is 1,040 mm in Thanh Hoa, showing the smallest. The same annual rainfalls in Ninh Binh, Hanoi, and Thai Nguyen are 1,100 mm, 1,230 mm, and 1,450 mm, respectively. Ha Tinh has the greatest annual rainfall of the 50-years drought probability year, that is 1,700 mm. The analysis shows that the annual rainfall in Thanh Hoa and Ninh Binh is smaller than Hanoi in drought years. Subsequently, annual groundwater recharge in drought years is presumed to be less in Thanh Hoa and Ninh Binh than in Hanoi.

In addition, about 60 % of annual rainfall in Ha Tinh occurs in a period from September to November in Ha Tinh. However, the monthly rainfall at Ha Tinh in the former part of the rainy season is less than those in other four locations. The rainfall in the three month period is strongly influenced by typhoons coming from the East Sea (South China Sea).

As a result, it is presumed that the occurrence of groundwater recharge from rain water differs from place to place, and changes in groundwater level are also influenced by the rainfall patterns.

6.1.2 Evaporation

More than 30 year's evaporation data at five (5) meteorological stations in the Study Area have been collected. The data were measured by evaporation pan so that the data can be called as pan-evaporation data. The occurrence of pan-evaporation is influenced by several factors, such as humidity of air, air temperature, solar radiation, sun shine duration, wind velocity, etc. Table 6.1.2 shows the average monthly and annual pan-evaporation at the five (5) locations. Hanoi has the highest average annual pan-evaporation of 976.5 mm. On the other hand, Ha Tinh has the lowest value of 800.9 mm. A decreasing trend of pan-evaporation from north to south can be found in the Study Area.

Figures 6.1.5 to 6.1.7 show the average monthly rainfall and pan-evaporation by province. In Thai Nguyen, the highest evaporation occurs in May (94.2 mm/month) and the lowest occurs in February (61.1 mm/month). There are two (2) peaks of average monthly pan-evaporation; the second peak is in October (90.9 mm/month). The monthly evaporation is higher than the rainfall from January to March and November to December.

The distribution of average monthly pan-evaporation in Hanoi is similar to that in Thai Nguyen. The maximum evaporation occurs in July (96.9 mm/month), and evaporation more than 90 mm/month occurs from May to July and October. The monthly evaporation is higher than the rainfall from January to March and November to December.

In Ninh Binh, the monthly evaporation in July is the highest (104.9 mm/month). The lowest evaporation is 40.0 mm/month in February. The second highest peak of evaporation (85.5 mm/month) occurs in October. The monthly evaporation is higher than the rainfall from January to February and November to December.

The highest monthly evaporation in Thanh Hóa is 101.3 mm/month observed in July. The second peak is 78.6 mm/month in October, but it is not clear compared with the northern part of the Study Area. The lowest monthly evaporation is 37.0 mm/month in February. The monthly evaporation is higher than the rainfall from January to February and November to December.

The distribution pattern of monthly evaporation in Ha Tinh is different from other provinces. The maximum evaporation of 135.2 mm/month occurs in July, but the second peak cannot be identified. The lowest evaporation is 24.8 mm/month in February. The monthly evaporation is higher than the rainfall only in July.

As a result, it is found that the fluctuation of monthly evaporation is the biggest in Ha Tinh. The monthly evaporation of Ha Tinh in the dry season is the lowest and the evaporation in the rainy season is the highest.

6.1.3 Water Balance Equation

Based on the above data, the water balance in the Study Area can be computed with reasonable accounting from the following water balance equation:

P5Int1Rof1AEP1ATP1SM1RE (6.1.1)

where

P: rainfall
Int: interception loss
Rof: surface runoff
AEP: actual evaporation from soil surface

ATP: actual evapotranspiration
SM: soil moisture recharge
RE: groundwater recharge

In equation (6.1.1), 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 except rainfall 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.

(1) Surface runoff

Generally the amount of surface runoff varies by geomorphology, vegetation, soil, rainfall pattern, etc. There is no detailed information on the surface runoff in the target communes in the Study Area. According to the "Vietnam National Atlas (1996)", average annual surface runoff is estimated as from 400 to 600 mm in Thai Nguyen Province, about 400 mm in Hanoi city, about 300 mm in Ninh Binh and Thanh Hoa Provinces, and from 400 to 800 mm in Ha Tinh Province.

(2) Groundwater recharge

Groundwater recharge can be computed using equation (6.1.1) if the rest of the water balance components are measured or estimated. If daily data of rainfall and evaporation are available, it is possible to compute groundwater recharge using a tank model or others with estimating surface runoff. In that case, actual data of daily groundwater level is required to calibrate the model.

In the Study area, monitoring of groundwater level at the test wells have been started, however, only the data for a few months have been obtained. Further, daily data of rainfall and evaporation have not yet publicized by the authorities. Therefore, it is difficult to estimate groundwater recharge in the Study area at this moment.

According to the existing information such as "Vietnam National Atlas (1996)", the annual average groundwater recharge is roughly estimated as 600 mm.

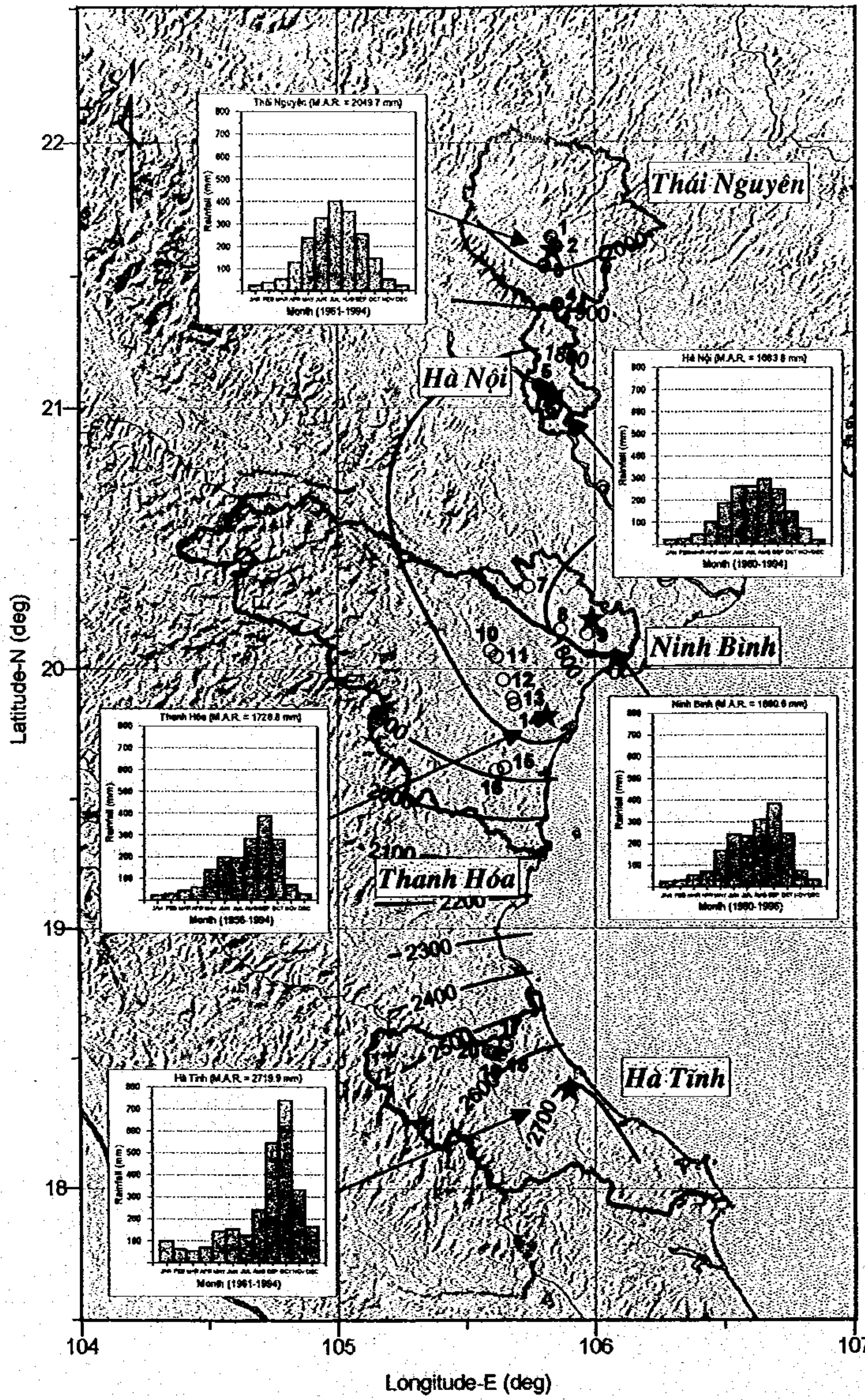
In addition, if an area is located near a river, groundwater recharge will occur from river to groundwater body when the river water level is higher than the groundwater level. To estimate the amount of recharge from river, several kinds of data such as water levels of river and groundwater, permeability of ground and riverbed materials, etc. are required. However, such data are not measured in the Study area.

Table 6.1.1 Average Monthly Rainfall (mm)

Month	Ha Noi	Thai Nguyen	Thanh Hoa	Ninh Binh	Ha Tinh
1	22.6	25.8	21.9	24.8	95.4
2	27.4	38.3	28.1	29.9	62.0
3	44.7	53.4	41.6	52.4	54.2
4	101.4	128.4	58.8	72.8	69.7
5	185.7	240.4	139.7	167.0	142.2
6	262.3	327.9	198.2	241.8	151.9
7	262.0	402.2	194.4	232.8	124.5
8	293.7	354.9	282.3	310.4	242.8
9	248.9	255.5	387.1	381.8	543.5
10	148.3	145.8	278.4	244.3	736.9
11	68.9	51.4	69.8	71.3	332.6
12	18.0	25.7	28.4	31.4	164.2
Annual	1683.9	2049.7	1728.7	1860.7	2719.9
Period	1960-1994	1961-1994	1956-1994	1960-1996	1961-1994

Table 6.1.2 Average Monthly Pan-Evaporation (mm)

Month	Ha Noi	Thai Nguyen	Thanh Hoa	Ninh Binh	Ha Tinh
1	70.6	69.7	50.9	52.5	33.7
2	57.4	61.1	37.0	40.1	24.8
3	56.9	61.3	38.0	40.0	34.3
4	66.2	63.7	46.0	50.5	51.2
5	95.6	94.2	84.5	82.7	95.4
6	96.9	92.1	97.0	98.8	117.6
7	98.5	91.1	101.3	104.9	135.2
8	83.1	78.9	76.8	74.7	103.0
9	85.7	85.8	66.9	71.6	61.0
10	95.1	90.9	78.6	85.5	54.5
11	88.0	85.6	72.2	80.4	47.0
12	82.5	82.3	66.7	72.4	43.1
Annual	976.5	956.9	816.0	851.5	800.9
Period	1960-1997	1965-1995	1965-1997	1965-1997	1965-1998



2000 ———— Equal Line of Average Annual Rainfall (mm)

Figure 6.1.1	Average Monthly and Annual Rainfall in the Study Area

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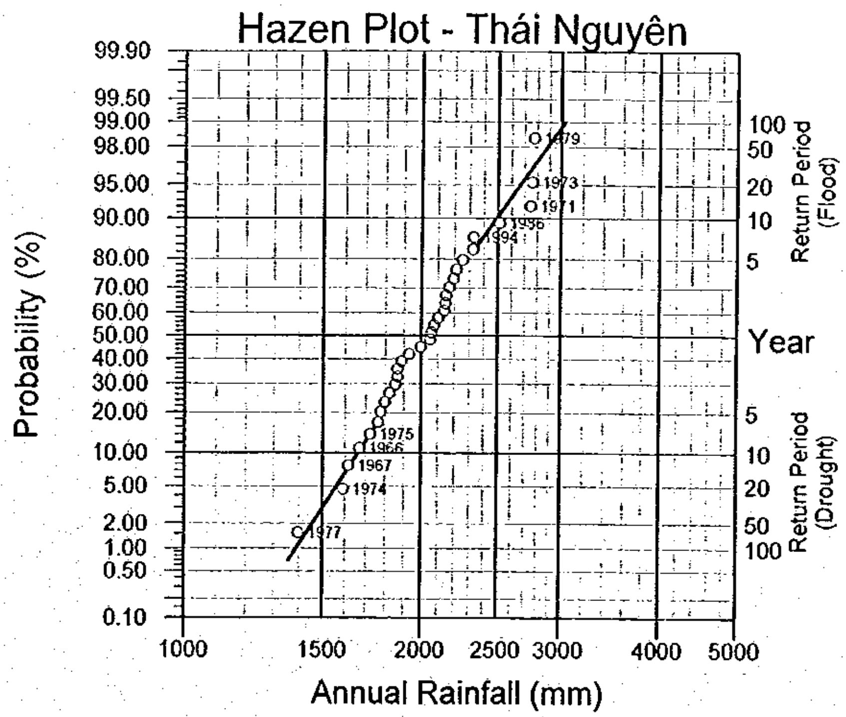

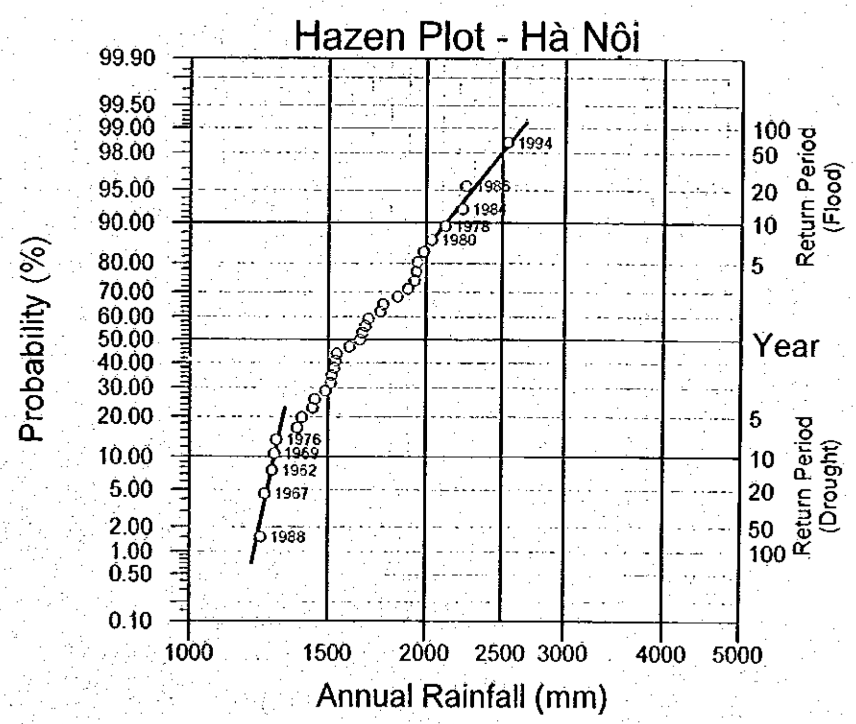

Figure 6.1.2	Probability Analysis of Annual Rainfall (1)

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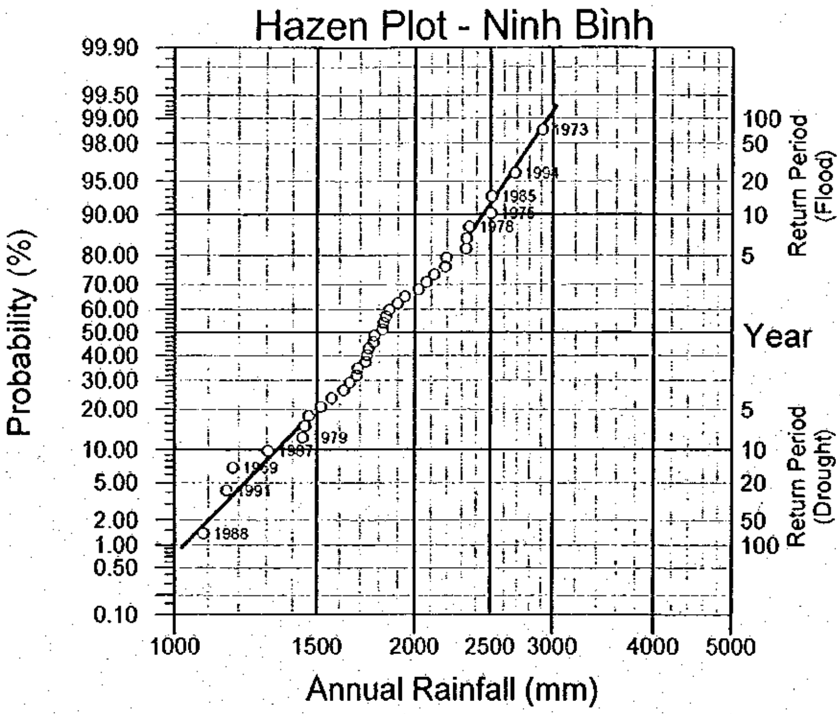

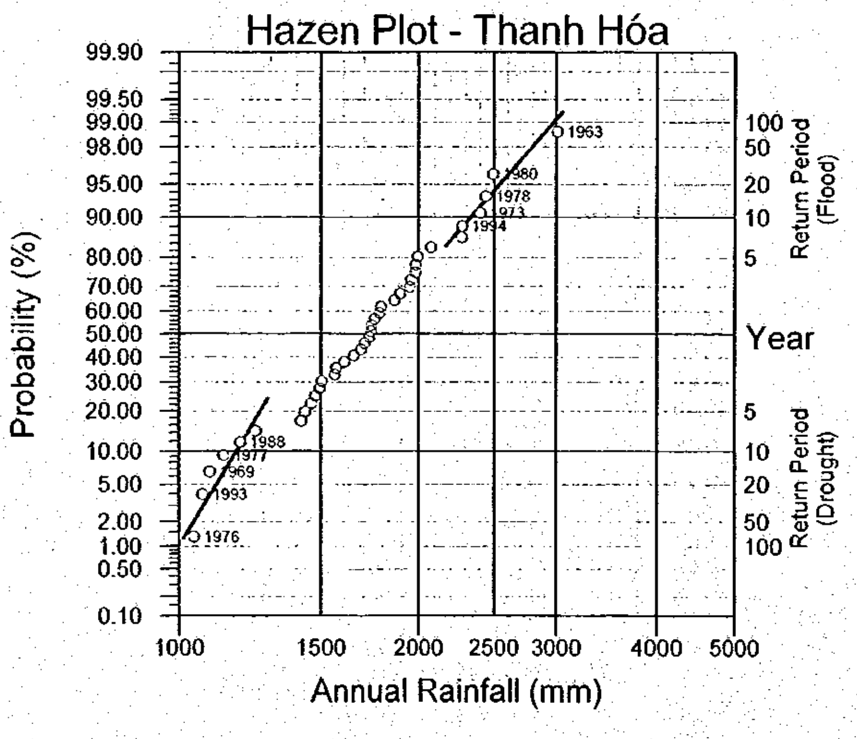

Figure 6.1.3	**Probability Analysis of Annual Rainfall (2)**
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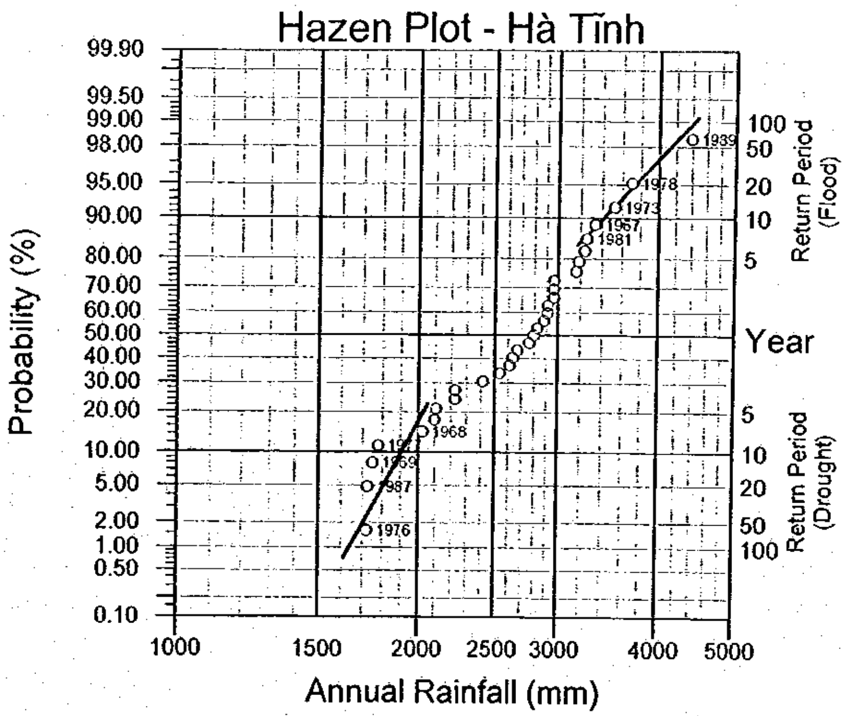

Drought Probability

Probability	Thai Nguyen	Ha Noi	Ninh Binh	Thanh Hoa	Ha Tinh
1/50	1450	1230	1100	1040	1700
1/20	1560	1260	1220	1110	1805
1/10	1660	1280	1330	1180	1905
1/5	1795	1320	1500	1260	2030

(Unit: mm/year)

Flood Probability

Probability	Thai Nguyen	Ha Noi	Ninh Binh	Thanh Hoa	Ha Tinh
1/50	2890	2500	2820	2800	4140
1/20	2670	2290	2620	2540	3720
1/10	2490	2120	2450	2330	3420
1/5	2295	1930	2260	2110	3050

(Unit: mm/year)

Figure 6.1.4 **Probability Analysis of Annual Rainfall (3)**

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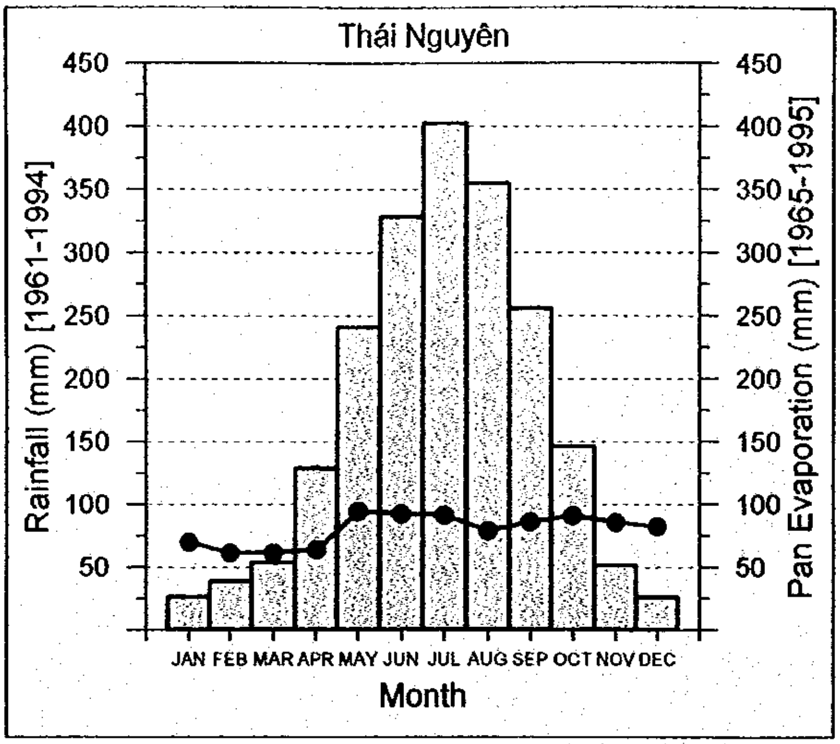

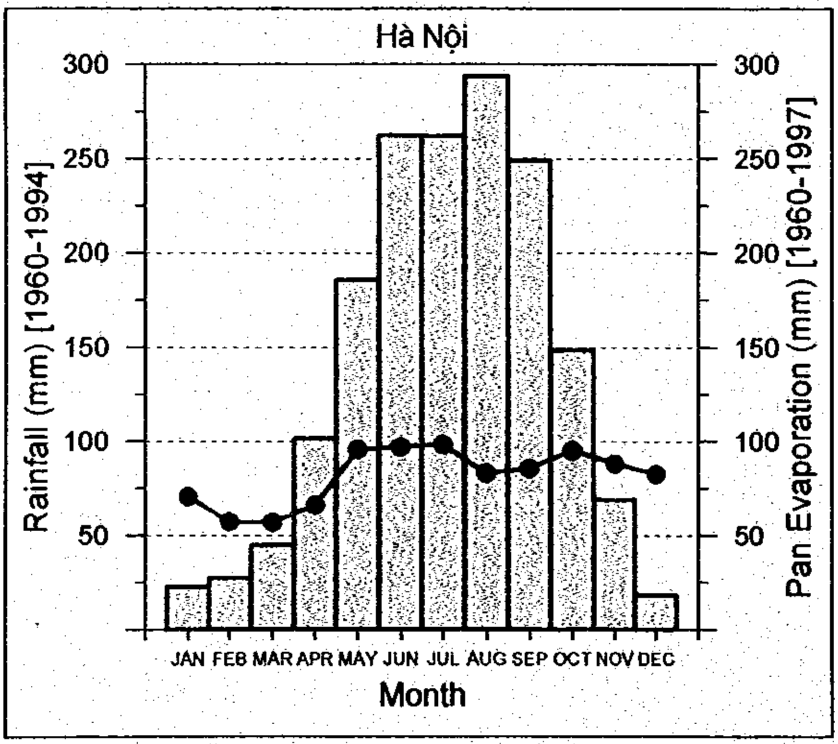

Figure 6.1.5	Average Monthly Rainfall and Pan-Evaporation by Province (1)
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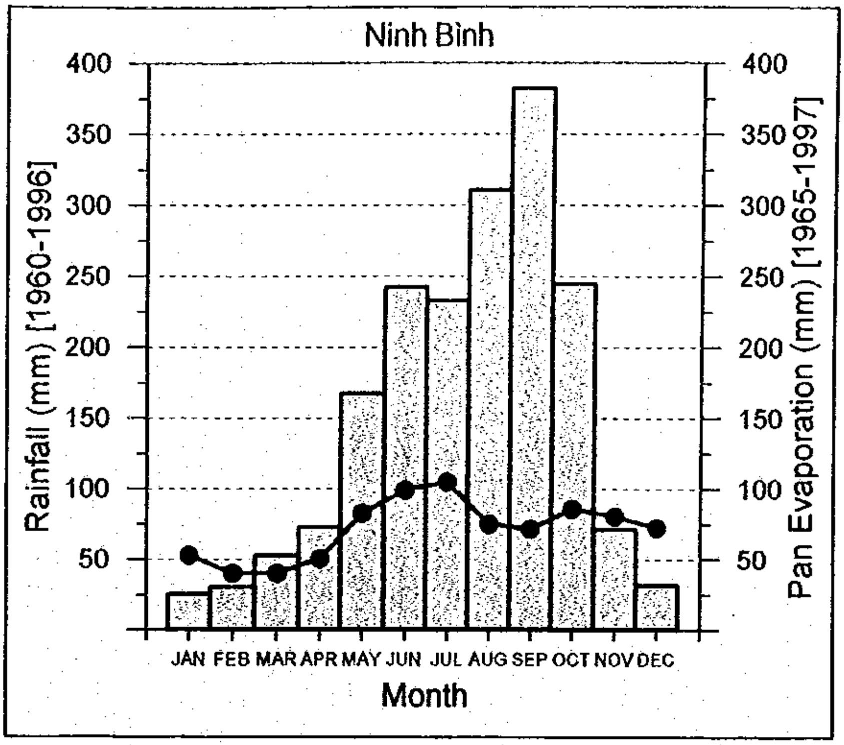

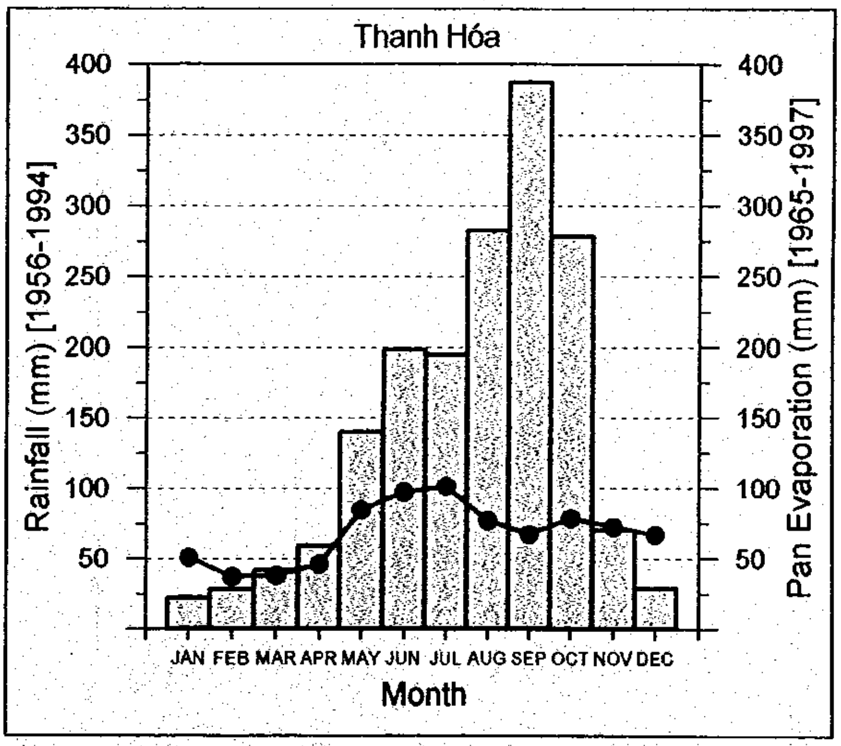

Figure 6.1.6	Average Monthly Rainfall and Pan-Evaporation by Province (2)

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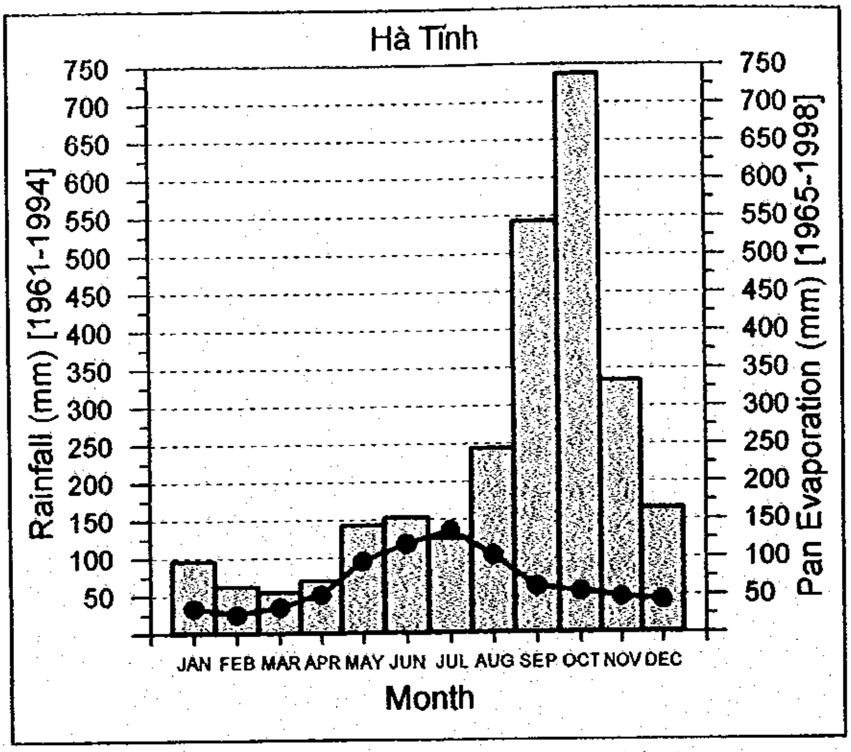

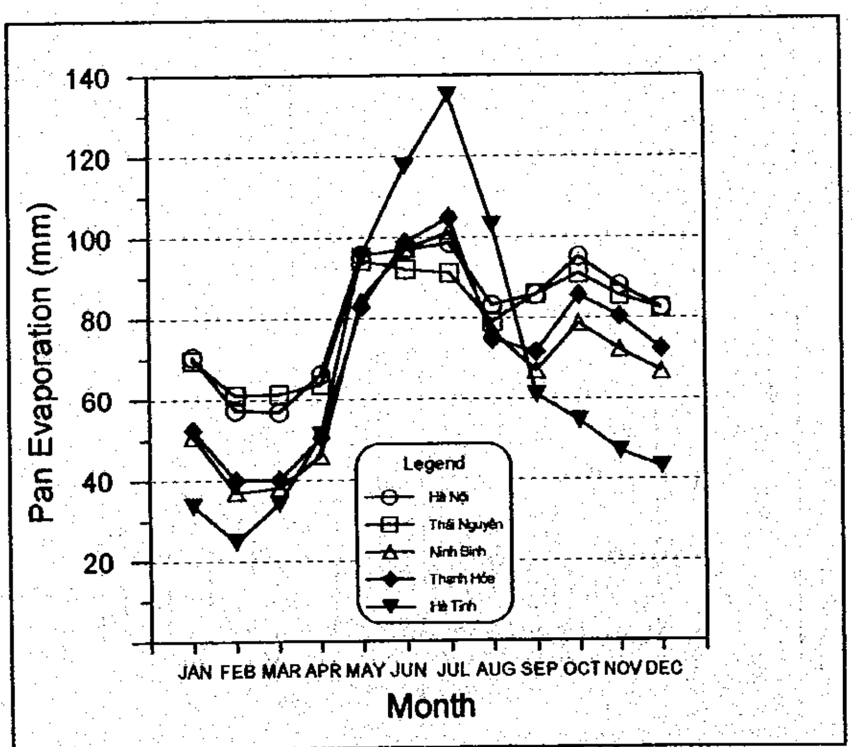

Figure 6.1.7	Average Monthly Rainfall and Pan-Evaporation by Province (3)

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

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6.2 Optimal Well Yield

Except the target communes in Hanoi city, the designed groundwater demand for the drinking water supply is much less than the amount of average groundwater recharge mentioned above. Therefore, it is evaluated that groundwater potential in the target communes in the Study area except in Hanoi city can meet the water demand from water balance point of view. However it is necessary to examine an optimal yield of each test well considering aquifer productivity and hydrogeological conditions not to cause groundwater hazards such as excessive decline of water level, well interference, land subsidence, worsening of groundwater quality, etc.

At present, there is no existing large-scale groundwater development in the target communes except Hanoi, an optimal yield of each test well is examined with considering productivity of the target aquifer and well structure. In this chapter, he term "optimal yield" is defined as a pumping rate for sustainable operation of a designed submersible pump with maintaining a necessary dynamic groundwater level (permissible dynamic groundwater level) in the well for the pump operation.

The optimal yield of each well is determined based on the well structure such as well depth and screen location(s), and productivity of the target aquifer(s). Table 6.2.1 shows the optimal yield of the test wells examined from the results of the step-drawdown test.

Table 6.2.1 Optimal Yield and Permissible Groundwater Level of The Test Wells

Well Name	Commune	Optimal Yield (m3/day)	Permissible Dynamic Groundwater Level (m below G.L.)
JICA-2	Hoa Thuong	1,000	10
JICA-3	Nam Tien	100	10
JICA-4	Thinh Duc	150	20
JICA-5	Quang Son	250	30
JICA-6	Yen Thang	120	30
JICA-7	Dong Phong	1,500	10
JICA-8	Van Thang	300	30
JICA-9	Thieu Hung	1,400	15
JICA-10	Dinh Tuong	1,700	15
JICA-11	Vinh Thanh	1,500	20
JICA-12	Duc Yen	250	10
JICA-13	Trung Le	10	10
JICA-14	Thieu Do	1,800	20
JICA-15	Trung Le	250	15