# CHAPTER 6 HYDROLOGY AND SEDIMENTOLOGY

**CONTENTS**

## LIST OF TABLES

**LIST OF FIGURES**

# CHAPTER 6 HYDROLOGY AND SEDIMENTOLOGY

## 6.1 Outline

The Project site is located in the upper part of the Seti River, a tributary of the Trishuli River flowing in the central part of Nepal. The Seti River originates at the Annapurna (at an elevation of 7,555 m above sea level) of the Himalayas and joins the Madi River 2 km downstream from the Dam site after flowing roughly from north to south. The length of the Seti River from the origin to the Dam site is about 120 km, and the catchment area at the Dam site is 1,502 km$^2$.

The Seti River basin belongs to a high mountain and a humid subtropical climatic zone. The NEA’s report states that the average annual precipitation in the project basin is 2,973 mm, of which about 80% falls between June and September due to the influence of the southwest monsoon. Records of the Kharini Tar meteorological station, located in the vicinity of the Project site, cite a peak temperature exceeding 36°C from April through June as against a lowest value of approximately 5°C from January through February on average.

## 6.2 Meteorological and Hydrological Stations

Meteorological stations and gauging stations are arranged in the Seti River and surrounding basin, as shown in **Fig. 6.2-1**. The Department of Hydrology and Meteorology (DHM), a subordinate organization of the Ministry of Environment, Science and Technology, carries out meteorological observations and river discharge measurements and provides NEA with those data. A few meteorological stations are also equipped with a thermometer, a hygrometer, an anemometer and an evaporation pan, while the other stations are provided with only a rain gauge. Among the meteorological stations in the table, evaporation is measured at Nos. 804, 809, 811, 814 and 815, and air temperature and wind velocity are measured at No. 804, respectively. The observation period at the main meteorological stations in the Seti River and surrounding basin is shown in **Table 6.2-1,** and an isohyetal map is given in **Fig. 6.2-2**, respectively. The isohyetal map shows that the Seti and Madi River basins have almost identical precipitation patterns, and that the precipitation peaks near the No. 814 meteorological station.

The measurement period at the main gauging stations in the basin is shown in **Table 6.2-2**. Almost all gauging stations are provided with a cableway for discharge measurement, an automatic water surface recorder and a staff gauge.

A new gauging station named No. 430.5 was set up at Patan at Damauli, 500 m downstream from the proposed Dam site, where river discharge measurement have been conducted since 2000.

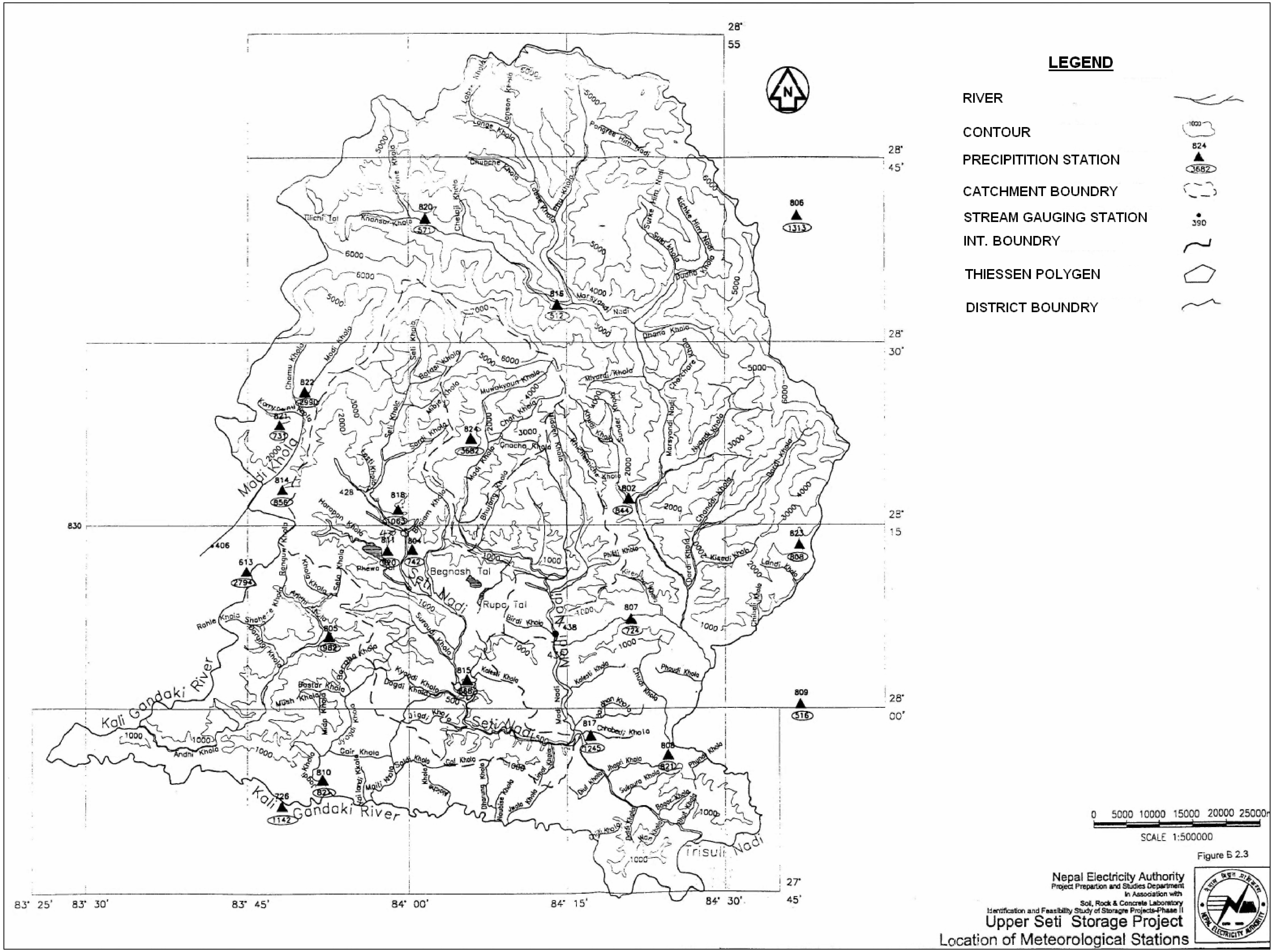


**Fig. 6.2-1 Location Map of the Meteorological Stations and Gauging Stations in the Seti River and Surrounding Basin**

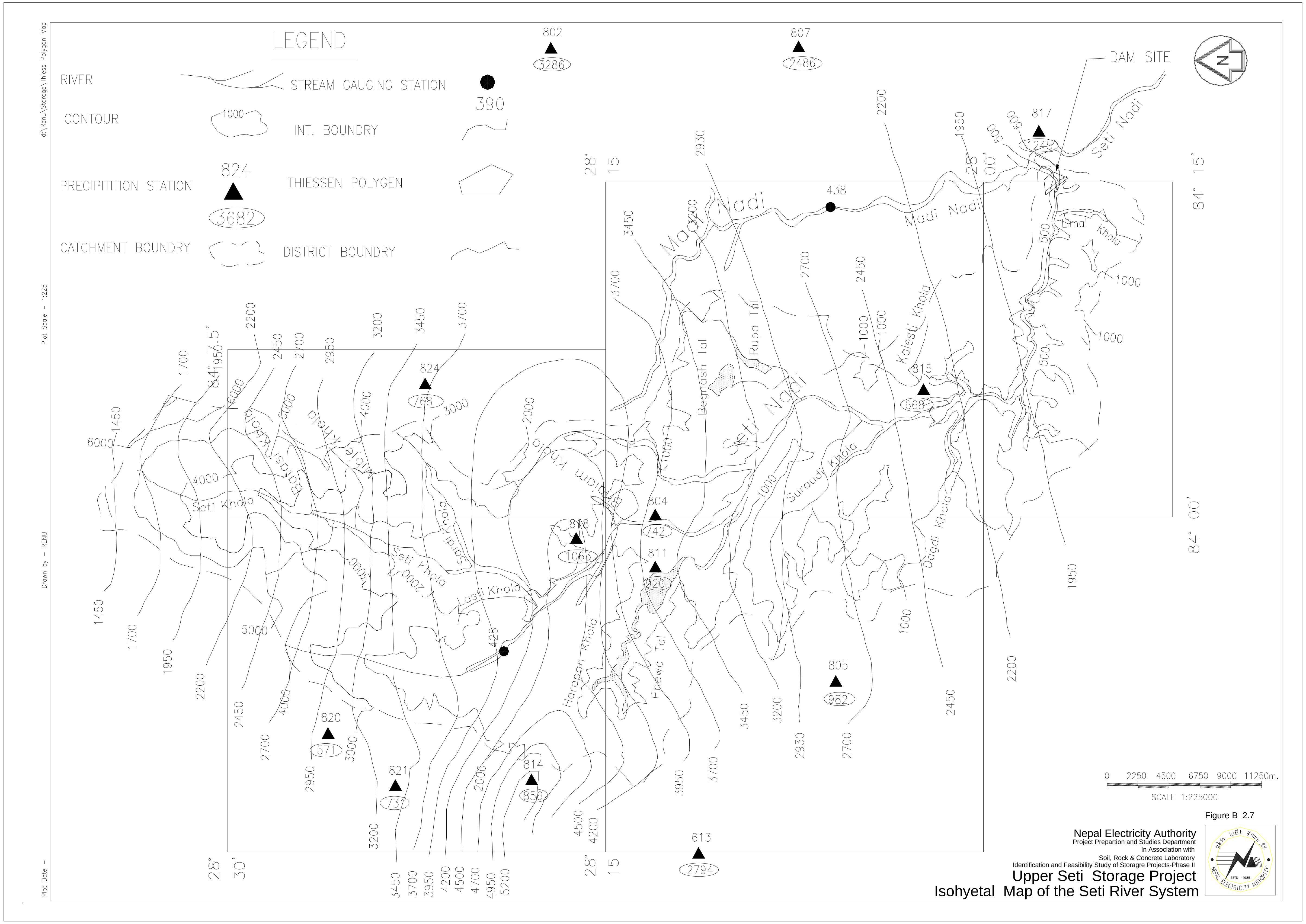


**Fig. 6.2-2 Isohyetal Map of the Seti River and Surrounding Basin**

**Table 6.2-1 List of Meteorological Stations in the Seti River and Surrounding Basin**

| Station No. | Station Name | Elevation (m) | Observation Year | |
|---|---|---|---|---|
| | | | from | to |
| 613 | Karki Neta | 1,720 | 1977 | present |
| 706 | Damkauli | 154 | 1971 | present |
| 726 | Garakot | 500 | 1980 | present |
| 802 | Khudi Bazar | 823 | 1957 | present |
| 803 | Pokhara Hospital | 866 | 1956 | 1975 |
| 804 | Pokhara Airport | 827 | 1968 | present |
| 805 | Shyangja | 868 | 1973 | present |
| 806 | Larke Samdo | 3,650 | 1978 | present |
| 807 | Kuncha | 855 | 1956 | present |
| 808 | Bandipur | 965 | 1956 | present |
| 810 | Chapkot | 460 | 1957 | present |
| 811 | Male Patan | 856 | 1966 | present |
| 813 | Bhadaure Deurali | 1,600 | 1985 | present |
| 814 | Lumle | 1,740 | 1969 | present |
| 815 | Kharini Tar | 500 | 1971 | present |
| 816 | Chame | 2,680 | 1974 | present |
| 817 | Damauli | 358 | 1974 | present |
| 818 | Lamachaur | 1,070 | 1972 | present |
| 820 | Manag Bhot | 3,420 | 1975 | present |
| 821 | Ghandruk | 1,960 | 1976 | present |
| 822 | Khuldi | 2,440 | 1973 | 1986 |
| 823 | Gharedhunga | 1,120 | 1976 | present |
| 824 | Siklesh | 1,820 | 1977 | present |

**Table 6.2-2 List of Gauging Stations in the Seti River and Surrounding Basin**

| Station No. | Station Name | River Name | Drainage Area ($km^2$) | Observation Year | |
|---|---|---|---|---|---|
| | | | | from | to |
| 406.5 | Nayapool | Modi | 647 | 1988 | 1994 |
| 428 | Lahachowk | Mardi | 160 | 1974 | 1990 |
| 430 | Phoolbari | Seti | 582 | 1964 | 1984 |
| 430.5 | Damauli at Patan | Seti | 1,505 | 2000 | present |
| 438 | Shisaghat | Madi | 858 | 1978 | present |
| 439.3 | Khudi Bazar | Khudi | 147 | 1983 | 1993 |
| 439.7 | Bimal Nagar | Marsyangdi | NA | 1987 | 1993 |
| 439.8 | Gopling Ghat | Marsyangdi | 3,850 | 1973 | 1986 |

### 6.3 Discharge

Since the measurement period at No. 430.5 gauging station is relatively short to calculate the probable floods and annual energy production, NEA converted the river discharge data of gauging stations near the project site from 1964 to 1999 into those of the Dam site, with the ratio of the catchment area giving weight to the annual precipitation, as shown in the formula below. The river discharge at the Dam site is converted from those at the No. 430 gauging station between the period between 1964 and 1984 and at No. 438, located in the Madi River basin, adjacent to the Seti River, between 1985 and 1999, because the No. 430 gauging station, located about 50 km upstream from the project site, was closed in 1984.

$$Qseti = Qgauge \times Pseti / Pgauge \times Aseti / Agauge \times 0.9$$

where,

Qseti : river discharge at the Dam site ($m^3/s$)

Qgauge : river discharge at the gauging station ($m^3/s$)

Pseti : average annual precipitation in the project basin (mm) (= 2,973 mm)

Pgauge : average annual precipitation in the basin of the gauging station (mm)
$P_{No.\ 430}$ = 3,189 mm
$P_{No.\ 438}$ = 3,126 mm

Aseti : catchment area of the Dam site ($km^2$) (= 1,502$km^2$)

Agauge : catchment area of the gauging station ($km^2$)
$A_{No.\ 430}$ = 582 $km^2$
$A_{No.\ 438}$ = 858 $km^2$

NEA explains that they added a coefficient of 0.9, comparing the conversion results with the river discharge data at the No. 430.5 gauging station. The generated average monthly river discharge at the Dam site from 1964 to 1999, as calculated by the NEA's conversion formula, is shown in **Table 6.3-1,** and the trend of the generated average annual river discharge is shown in **Fig. 6.3-1**. The average annual river discharge in the estimation period is 107.2 $m^3/s$.

**Table 6.3-1 Generated Average Monthly River Discharge at the Dam Site**

(Unit: $m^3/s$)

| Month<br>Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 31.8 | 30.4 | 30.1 | 31.9 | 68.9 | 78.0 | 134.3 | 460.5 | 313.1 | 112.4 | 82.0 | 53.8 | 118.92 |
| 1965 | 34.0 | 29.5 | 29.7 | 32.7 | 36.3 | 151.0 | 293.5 | 368.5 | 190.3 | 62.6 | 46.9 | 31.3 | 108.86 |
| 1966 | 24.6 | 22.2 | 21.0 | 19.4 | 22.2 | 63.5 | 228.4 | 259.6 | 159.8 | 66.0 | 38.6 | 25.5 | 79.23 |
| 1967 | 20.6 | 20.7 | 20.1 | 22.8 | 24.5 | 57.8 | 231.3 | 213.2 | 185.8 | 77.2 | 43.5 | 33.8 | 79.28 |
| 1968 | 24.9 | 20.5 | 24.7 | 25.3 | 34.9 | 141.9 | 336.1 | 287.0 | 222.7 | 326.6 | 42.1 | 23.7 | 125.86 |
| 1969 | 18.3 | 14.6 | 15.2 | 15.0 | 16.6 | 34.4 | 128.0 | 315.0 | 264.0 | 79.5 | 40.3 | 26.1 | 80.58 |
| 1970 | 20.2 | 17.3 | 16.3 | 24.6 | 35.3 | 91.2 | 380.8 | 412.0 | 202.1 | 106.1 | 56.8 | 33.4 | 116.34 |
| 1971 | 23.7 | 18.7 | 18.8 | 29.1 | 39.6 | 187.7 | 291.2 | 300.6 | 212.8 | 145.7 | 67.7 | 40.0 | 114.62 |
| 1972 | 25.7 | 20.3 | 19.4 | 20.5 | 52.9 | 106.6 | 325.6 | 362.5 | 251.6 | 108.6 | 51.4 | 33.4 | 114.87 |
| 1973 | 25.1 | 17.6 | 18.0 | 25.8 | 39.2 | 176.3 | 244.0 | 389.0 | 265.3 | 259.4 | 74.4 | 39.1 | 131.10 |
| 1974 | 36.8 | 33.7 | 32.6 | 40.8 | 39.0 | 91.7 | 343.3 | 411.6 | 254.4 | 131.7 | 43.8 | 34.1 | 124.45 |
| 1975 | 33.0 | 32.1 | 30.2 | 22.8 | 24.0 | 84.9 | 427.0 | 328.4 | 305.5 | 139.2 | 54.1 | 30.4 | 125.97 |
| 1976 | 22.3 | 23.1 | 19.8 | 24.9 | 40.9 | 190.2 | 380.3 | 342.3 | 216.0 | 88.4 | 43.6 | 33.8 | 118.80 |
| 1977 | 22.7 | 20.4 | 20.7 | 30.2 | 46.8 | 92.4 | 288.5 | 409.0 | 248.3 | 111.8 | 74.8 | 43.3 | 117.40 |
| 1978 | 32.3 | 29.6 | 27.2 | 29.4 | 68.7 | 162.1 | 381.0 | 349.6 | 215.6 | 106.0 | 64.3 | 47.7 | 126.12 |
| 1979 | 37.7 | 33.7 | 29.8 | 37.7 | 51.9 | 84.7 | 315.0 | 447.0 | 239.4 | 107.2 | 57.5 | 34.6 | 123.00 |
| 1980 | 25.2 | 22.9 | 25.3 | 26.6 | 37.1 | 107.9 | 425.1 | 446.5 | 313.7 | 82.5 | 43.8 | 26.2 | 131.90 |
| 1981 | 18.2 | 14.9 | 15.6 | 28.7 | 40.1 | 95.9 | 400.6 | 376.5 | 242.7 | 97.0 | 50.2 | 36.9 | 118.09 |
| 1982 | 33.3 | 30.8 | 36.1 | 40.1 | 48.9 | 96.9 | 257.7 | 271.3 | 155.5 | 85.9 | 54.5 | 45.3 | 96.37 |
| 1983 | 39.8 | 36.6 | 35.3 | 34.5 | 46.7 | 72.8 | 210.4 | 270.5 | 276.7 | 143.2 | 54.7 | 35.6 | 104.74 |
| 1984 | 28.0 | 21.2 | 21.7 | 24.0 | 62.8 | 151.9 | 445.1 | 287.3 | 243.5 | 96.1 | 58.6 | 41.3 | 123.46 |
| 1985 | 36.9 | 33.5 | 33.0 | 39.1 | 61.1 | 114.9 | 333.4 | 197.5 | 202.9 | 126.2 | 56.5 | 36.0 | 105.90 |
| 1986 | 24.7 | 19.8 | 21.4 | 28.5 | 27.9 | 117.6 | 260.7 | 259.8 | 280.2 | 147.9 | 59.2 | 30.7 | 106.53 |
| 1987 | 23.5 | 20.4 | 21.4 | 23.6 | 31.2 | 72.2 | 280.0 | 279.5 | 183.6 | 87.3 | 54.2 | 39.2 | 93.01 |
| 1988 | 30.2 | 26.8 | 27.0 | 28.8 | 40.7 | 111.7 | 264.4 | 320.5 | 238.9 | 102.6 | 52.9 | 38.6 | 106.93 |
| 1989 | 33.9 | 27.8 | 27.8 | 30.5 | 59.4 | 146.6 | 251.7 | 310.7 | 240.2 | 113.9 | 53.8 | 36.4 | 111.06 |
| 1990 | 28.1 | 24.8 | 26.0 | 35.9 | 55.2 | 152.9 | 271.9 | 237.3 | 194.1 | 102.8 | 44.5 | 27.3 | 100.06 |
| 1991 | 20.0 | 17.6 | 16.8 | 20.3 | 33.4 | 114.9 | 281.0 | 320.4 | 250.2 | 117.2 | 56.3 | 39.0 | 107.25 |
| 1992 | 31.1 | 27.9 | 26.5 | 25.2 | 35.7 | 82.0 | 188.9 | 289.8 | 197.4 | 124.8 | 50.3 | 30.5 | 92.52 |
| 1993 | 23.2 | 20.6 | 14.5 | 14.7 | 30.0 | 97.8 | 218.4 | 321.3 | 215.4 | 122.4 | 56.8 | 33.3 | 97.37 |
| 1994 | 29.3 | 27.5 | 29.8 | 30.1 | 37.0 | 106.8 | 184.2 | 233.9 | 142.8 | 37.7 | 17.7 | 12.9 | 74.14 |
| 1995 | 10.5 | 9.9 | 11.3 | 11.9 | 28.3 | 255.9 | 314.9 | 193.9 | 175.9 | 129.9 | 85.9 | 52.7 | 106.75 |
| 1996 | 30.1 | 21.6 | 30.9 | 31.0 | 37.6 | 69.2 | 227.0 | 319.8 | 252.2 | 107.6 | 45.8 | 31.5 | 100.37 |
| 1997 | 27.2 | 24.0 | 28.4 | 32.6 | 38.4 | 74.9 | 229.6 | 258.9 | 141.6 | 61.8 | 35.0 | 33.1 | 82.12 |
| 1998 | 24.2 | 21.5 | 24.9 | 29.1 | 48.7 | 149.3 | 288.1 | 452.6 | 207.3 | 64.2 | 35.6 | 26.0 | 114.29 |
| 1999 | 21.3 | 18.5 | 17.0 | 18.8 | 34.8 | 93.1 | 264.8 | 238.7 | 174.2 | 67.4 | 23.1 | 15.3 | 82.24 |
| Avg. | 27.0 | 23.7 | 24.0 | 27.4 | 41.0 | 113.3 | 286.8 | 320.6 | 224.3 | 112.4 | 52.0 | 34.2 | 107.24 |

The average monthly river discharges at the Dam site, converted from the data at the No. 438 gauging station for the years of 2000, 2001 and 2003, are compared with those at the No. 430.5 gauging station, as shown in **Table 6.3-2**. In the table, the river discharge of the column “Gen.” is formulated as follows:

$$Qseti = QNo.\ 438 \times Pseti / PNo.\ 438 \times Aseti / ANo.\ 438$$

$$= Q_{No.\ 438} \times 2{,}973 / 3{,}126 \times 1{,}502 / 858$$

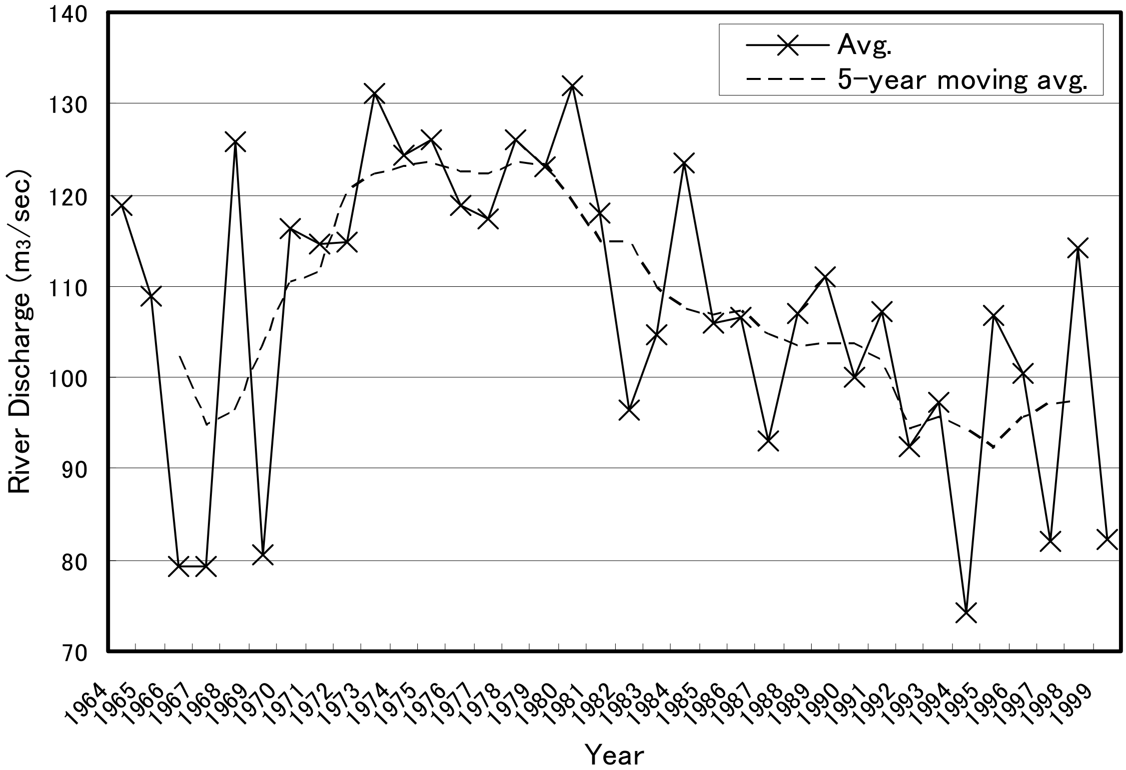


**Fig. 6.3-1 Trend of Generated Average Annual River Discharge at the Dam Site**

**Table 6.3-2 Comparison of Average Monthly River Discharge**

| Year | 2000 | | | 2001 | | | 2003 | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | Ratio | A | B | Ratio | A | B | Ratio |
| Month | Gen. | No. 430.5 | B/A | Gen. | No. 430.5 | B/A | Gen. | No. 430.5 | B/A |
| 1 | 26.53 | 22.39 | 0.84 | 29.27 | 19.74 | 0.67 | 67.88 | 28.20 | 0.42 |
| 2 | 22.49 | 18.76 | 0.83 | 26.09 | 16.83 | 0.65 | 64.79 | 24.13 | 0.37 |
| 3 | 22.06 | 18.08 | 0.82 | 22.71 | 14.34 | 0.63 | 65.72 | 21.52 | 0.33 |
| 4 | 30.10 | 20.74 | 0.69 | 28.21 | 13.31 | 0.47 | 71.48 | 25.87 | 0.36 |
| 5 | 55.25 | 65.37 | 1.18 | 55.04 | 33.79 | 0.61 | 75.66 | 31.38 | 0.41 |
| 6 | 233.89 | 291.45 | 1.25 | 178.85 | 135.67 | 0.76 | 154.86 | 199.15 | 1.29 |
| 7 | 381.46 | 379.31 | 0.99 | 334.35 | 250.83 | 0.75 | 437.60 | 728.28 | 1.66 |
| 8 | 377.01 | 385.22 | 1.02 | 508.41 | 711.66 | 1.40 | 374.50 | 419.83 | 1.12 |
| 9 | 262.36 | 246.10 | 0.94 | 229.28 | 242.51 | 1.06 | 281.72 | 338.69 | 1.20 |
| 10 | 100.97 | 77.68 | 0.77 | 159.31 | 97.33 | 0.61 | 131.18 | 105.53 | 0.80 |
| 11 | 53.38 | 41.34 | 0.77 | 106.87 | 49.81 | 0.47 | 75.70 | 47.75 | 0.63 |
| 12 | 36.50 | 25.56 | 0.70 | 86.18 | 29.17 | 0.34 | 57.44 | 28.13 | 0.49 |
| Avg. | 133.50 | 132.67 | 0.90 | 147.05 | 134.58 | 0.70 | 154.88 | 166.54 | 0.76 |

As shown in the table, the ratio varies widely, and the appropriateness of the conversion method shall be verified. The specific discharge at the gauging stations used for conversion is calculated as shown in **Table 6.3-3** for verification of the discharge data.

**Table 6.3-3 Comparison of Specific Discharge**

| No. of station | No. 430 | No. 438 | No. 430.5 |
|---|---|---|---|
| Catchment Area ($km^2$) | 582 | 858 | 1,502 |
| Year | Specific Discharge ($m^{3/s}/km^2$) | | |
| 1964 | 0.0944 | | |
| 1965 | 0.0864 | | |
| 1966 | 0.0629 | | |
| 1967 | 0.0629 | | |
| 1968 | 0.0999 | | |
| 1969 | 0.0639 | | |
| 1970 | 0.0923 | | |
| 1971 | 0.0910 | | |
| 1972 | 0.0911 | | |
| 1973 | 0.1040 | | |
| 1974 | 0.0988 | | |
| 1975 | 0.1000 | | |
| 1976 | 0.0943 | | |
| 1977 | 0.0932 | | |
| 1978 | 0.0921 | 0.1071 | |
| 1979 | 0.0828 | 0.1115 | |
| 1980 | 0.0991 | 0.1093 | |
| 1981 | 0.0951 | 0.0940 | |
| 1982 | 0.0918 | 0.0763 | |
| 1983 | 0.0771 | 0.0917 | |
| 1984 | 0.0866 | 0.1084 | |
| 1985 | | 0.0833 | |
| 1986 | | 0.0838 | |
| 1987 | | 0.0732 | |
| 1988 | | 0.0841 | |
| 1989 | | 0.0874 | |
| 1990 | | 0.0787 | |
| 1991 | | 0.0844 | |
| 1992 | | 0.0728 | |
| 1993 | | 0.0766 | |
| 1994 | | 0.0583 | |
| 1995 | | 0.0840 | |
| 1996 | | 0.0783 | |
| 1997 | | 0.0646 | |
| 1998 | | 0.0836 | |
| 1999 | | 0.0647 | |
| 2000 | | 0.0980 | 0.0883 |
| 2001 | | 0.1070 | 0.0896 |
| 2002 | | | 0.0809 |
| 2003 | | 0.1134 | 0.1109 |

As shown in the table, since the specific discharge at each gauging station varies according to the period, the precision of river discharge data and measurement conditions shall be confirmed.

A double mass curve is drawn with average annual river discharge at a gauging station and annual precipitation at a meteorological station near the gauging station, as shown in **Figs. 6.3-2** and **6.3-3**.

As shown in the figures, the curves form a rough straight line, showing that the river discharge data are reliable.

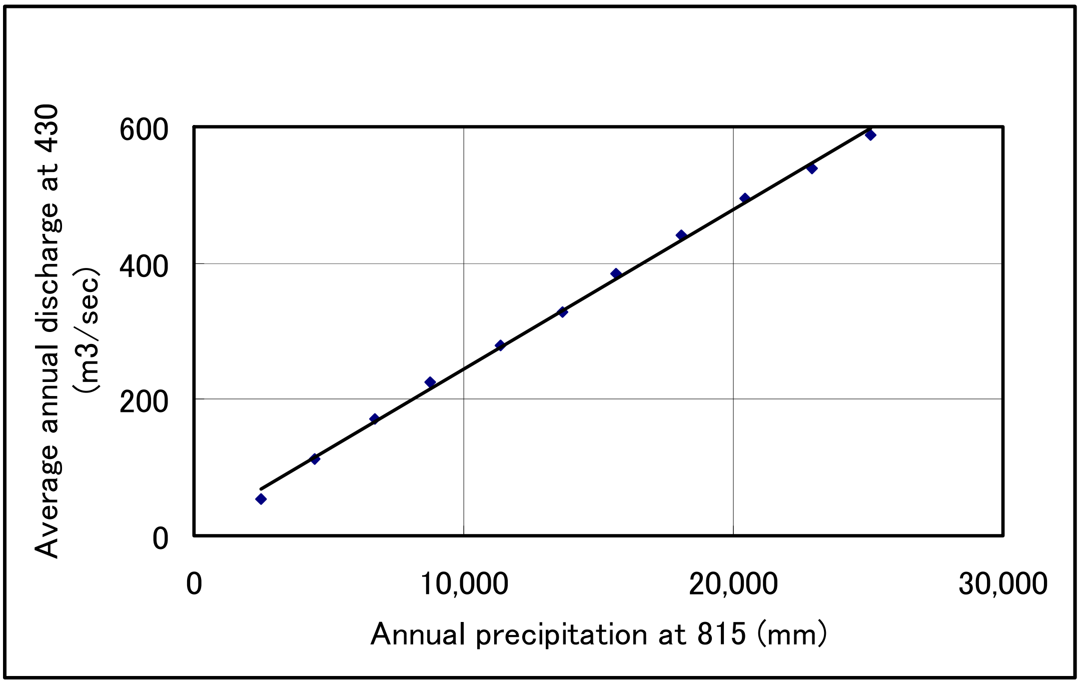


**Fig. 6.3-2 Double Mass Curve of the Sum of Precipitations at No. 815 Station and River Discharge at No. 430 Station (1972-1984)**

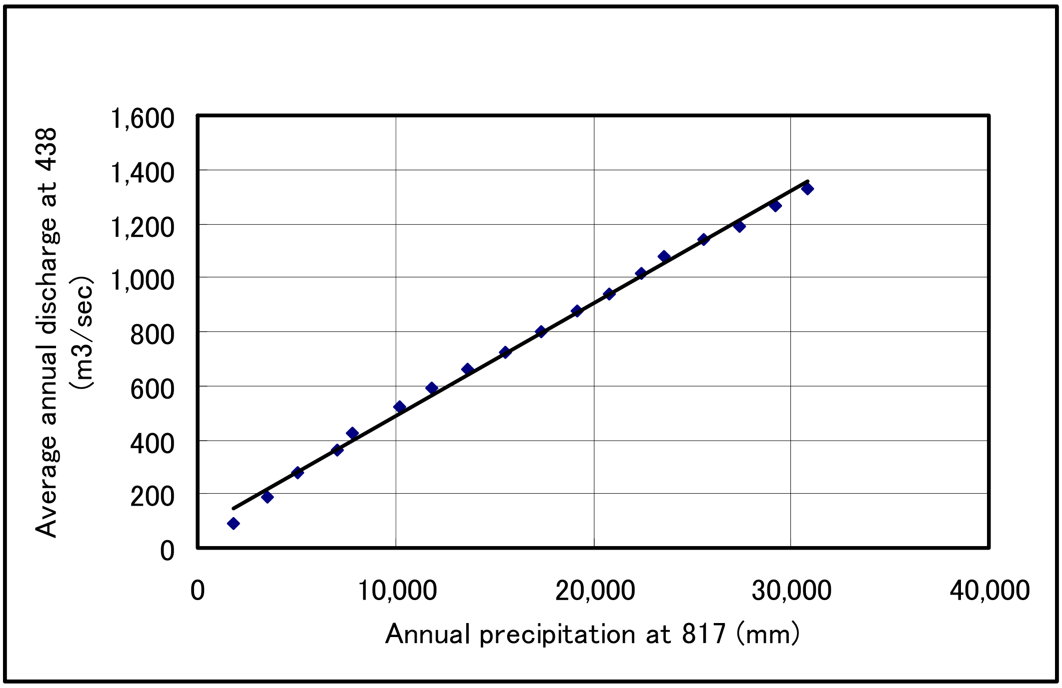


**Fig. 6.3-3 Double Mass Curve of the Sum of Precipitations at No. 817 Station and River Discharge at No. 438 Station (1978-1996)**

The river discharge at the No. 438 gauging station for the years 2000, 2001 and 2003 is made from a rating curve showing the relation between the river water level and river discharge based on river discharge measurement results and daily staff gauge readings obtained from DHM, because no river discharge tables for the years in question were ready. DHM explains that they draw the rating curves using the n'th power curve formula, based on discharge data measured from the beginning of September to the end of next August and that they renewed them every September. The daily river discharge is calculated following the same process as DHM's explanation. In Japan, a parabola is generally used as a rating curve, and a rating curve drawn from an n'th power formula tends to reveal a larger discharge than a parabola formula at a higher water level, as shown in **Fig. 6.3-4.**

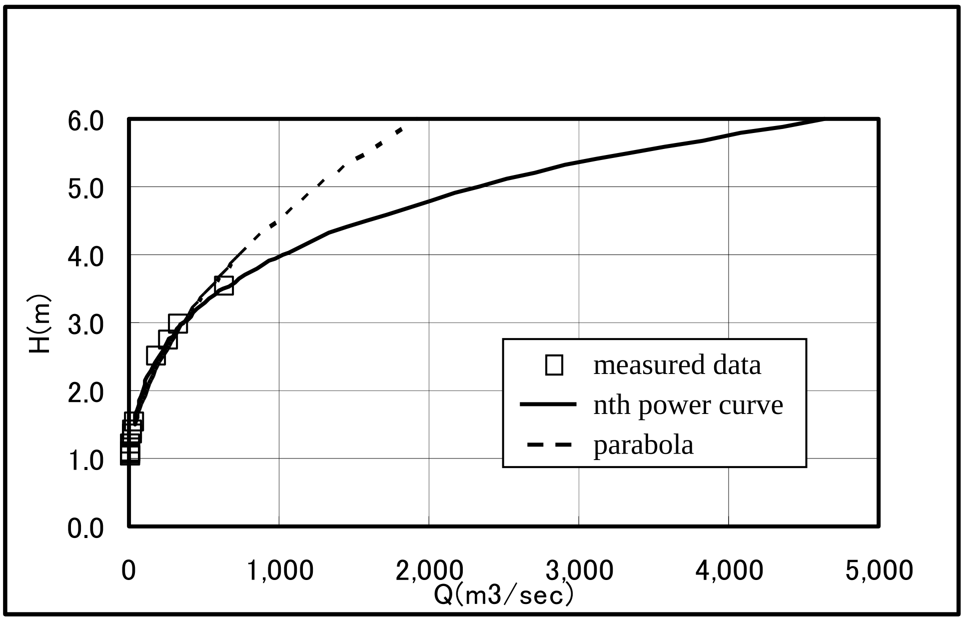


**Fig. 6.3-4 Rating Curve of No. 430.5 Gauging Station**

DHM explains their plans to station a staff member at certain gauging stations during the rainy season in the fiscal year 2005/06 to measure flood discharge so that they could revise the rating curves, because the flood discharge extrapolated from a lower water level may reveal a larger value than is actually the case. However, gauging stations in the Seti River basin are not included in the plan. The Study Team suggests that flood discharge should be measured at gauging stations Nos. 430.5 and 438 to correct the rating curves when carrying out the Study.

## 6.4 Flood

### 6.4.1 Probable Flood

The peak discharge has been measured at No. 430 gauging station from 1964 to 1984 and **Table 6.4.1-1** shows the maximum peak discharge of each year. The maximum peak discharge at the Dam site is converted from values of the gauging station by the ratio of each catchment area.

**Table 6.4.1-1 Maximum Peak Discharge at No.430 Gauging Station**

| Year | Date | Peak Discharge | | Year | Date | Peak Discharge | |
|---|---|---|---|---|---|---|---|
| | | No.430 | Dam Site | | | No.430 | Dam Site |
| 1964 | Aug. 15 | 355.0 | 916.2 | 1975 | July 01 | 552.0 | 1,424.6 |
| 1965 | Aug. 14 | 245.0 | 632.3 | 1976 | July 14 | 679.0 | 1,752.3 |
| 1966 | July 12 | 268.0 | 691.6 | 1977 | Aug. 03 | 577.0 | 1,489.1 |
| 1967 | July 09 | 268.0 | 691.6 | 1978 | July 28 | 290.0 | 748.4 |
| 1968 | Oct. 05 | 645.0 | 1,664.6 | 1979 | July 28 | 215.0 | 554.9 |
| 1969 | Aug. 11 | 266.0 | 686.5 | 1980 | July 16 | 260.0 | 671.0 |
| 1970 | Aug. 07 | 711.0 | 1,834.9 | 1981 | July 27 | 275.0 | 709.7 |
| 1971 | Aug. 06 | 288.0 | 743.3 | 1982 | July 31 | 245.0 | 632.3 |
| 1972 | Aug. 11 | 552.0 | 1,424.6 | 1983 | ----- | 154.0 | 397.4 |
| 1973 | Oct. 13 | 679.0 | 1,752.3 | 1984 | July 28 | 202.0 | 521.3 |
| 1974 | July 29 | 900.0 | 2,322.7 | | | | |

Based on the maximum peak discharge record, frequency analysis is carried out using the Gumbel, Log-normal and Log-Pearson distributions, and the probable flood discharge is converted with the ratio of the catchment area of the gauging station to that of the Dam. The results are summarized in **Table 6.4.1-2**.

**Table 6.4.1-2 Probable Flood**

(Unit: $m^3/s$)

| Return Period | Gumbel | Log-Normal | Log-Pearson |
|---|---|---|---|
| 2 | 994.6 | 934.5 | 569.8 |
| 5 | 1,565.0 | 1,434.9 | 889.8 |
| 10 | 1,942.8 | 1,795.4 | 1,140.8 |
| 20 | 2,305.1 | 2,160.6 | 1,412.2 |
| 50 | 2,774.1 | 2,661.3 | 1,811.8 |
| 100 | 3,125.6 | 3,057.7 | 2,150.7 |
| 200 | 3,475.5 | 3,472.4 | 2,525.7 |
| 500 | 3,937.5 | 4,050.8 | 3,083.8 |
| 1,000 | 4,286.6 | 4,513.0 | 3,558.9 |
| 2,000 | 4,635.6 | 4,779.0 | 4,546.1 |
| 5,000 | 5,097.0 | 5,675.6 | 5,265.4 |
| 10,000 | 5,445.7 | 6,217.3 | 5,529.6 |

The skewness and kurtosis of the maximum daily discharges are 0.79 and -0.66, while those of the logarithmic values are 0.31 and -1.26, respectively. Among three types of distribution, the probable flood discharge by Gumbel distribution is used as the basis because it works out larger flood discharge for return periods of 100 years or less used for project design.

The rating curves utilizing the Seti River for the feasibility design and environmental impact assessment are attached in **Appendix-6**.

### 6.4.2 Probable Maximum Flood (PMF)

(1) General

As this project is anticipated to play a very important role for the economic and social development of Nepal, it will be appropriate to adopt the Probable Maximum Flood (PMF) in the design of the Dam. PMF is defined as the flood that may occur under the theoretical combination of the most severe meteorological and hydrological conditions.

PMF is calculated by following procedure:

- Calculation of Probable Maximum Precipitation (PMP)
- Preparation of Unit Hydrograph
- Distribution of PMP
- Synthesis of Unit Hydrographs
- Determination of Base flow

(2) Calculation of Probable Maximum Precipitation (PMP)

PMP is generally classified in terms of non-orographic and orographic precipitations. The form of precipitation in the Seti River basin is considered to have typical orographic characteristics, because it is observed that precipitation caused by the monsoon from the south is concentrated at the southern slope of the Himalaya Mountains, while precipitation in the plateau, as well as north of the Himalaya Mountains, is extremely small. The following represent the process of estimating PMP[1] in this study:

1) Preparation of the ground profile

The principal ground profiles at the southern slope of the Himalaya Mountains in the Seti River basin are prepared by dividing 1/125,000 maps into meshes, as shown in **Fig. 6.4.2-1**. The elevation therein is converted into atmospheric pressure (hPa) to enhance the convenience of the succeeding calculation.

[1] Manual for Estimation of Probable Maximum Precipitation :WMO* No. 332, *WMO : World Meteorological Organization

Seti River Basin (Unit: EL.m)

| | | | | | |
|---|---|---|---|---|---|
| | 4,770 | 4,910 | | | |
| 2,980 | 3,760 | 3,630 | | | |
| 1,810 | 1,930 | 2,540 | | | |
| 1,350 | 1,160 | 1,380 | | | |
| 1,530 | 970 | 860 | 900 | | |
| | 1,000 | 720 | 820 | | |
| | 960 | 660 | 640 | 790 | |
| | | 680 | 760 | 670 | Dam site |

**Fig. 6.4.2-1 Ground Profile**

2) Setting of air streamlines

Air streamlines are figured at intervals of 50 hPa and the nodal surface, which is unaffected by the topographic conditions, is set at 300 hPa. Precipitation between streamlines is given by the following formula:

$$R = \frac{\overline{V}_1 \cdot \Delta p_1 \left(\overline{q}_1 - \overline{q}_2\right)}{Y} \cdot \frac{1}{g\rho}$$

Where:

| | | |
|---|---|---|
| $R$ | : | Precipitation (cm / sec) |
| $\overline{V}_1$ | : | Mean inflow wind speed (cm / sec) |
| $\Delta p_1$ | : | Inflow pressure difference (hPa) |
| $\overline{q}_1 \cdot \overline{q}_2$ | : | Mean specific humidity (＝density of water vapor / density of humid air, dry air and water vapor) at inflow and outflow (g / kg) |
| $Y$ | : | Horizontal distance (cm) |
| g | : | Acceleration of gravity (cm / sec$^2$) |
| ρ | : | Density of water (g / cm$^3$) |

When mixing the ratio, w (＝density of water vapor / density of dry air), in place of the mean specific humidity and dimensions indicated in the respective data are applied, the above formula will be modified as follows:

$$R = \frac{0.8813 \times \overline{V}_1 \cdot \Delta p_1 \left(\overline{w}_1 - \overline{w}_2\right)}{Y}$$

where

| | | |
|---|---|---|
| $R$ | : | Daily precipitation (mm/day) |
| $\overline{V}_1$ | : | Mean inflow wind speed (m/s) |
| $\Delta p_1$ | : | Inflow pressure difference (hPa) |
| $\overline{w}_1 \cdot \overline{w}_2$ | : | Mean mixing ratio at inflow and outflow (g/kg) |
| $Y$ | : | Horizontal Distance (km) |

3) Selection of meteorological data (boundary condition)

   Atmospheric temperature, relative humidity and wind velocity recorded at the Pokhara Airport meteorological station (EL.827 m, atmospheric temperature and relative humidity from 1987 to 2004, wind velocity form 1987 to 1998) located near the typical topographical profile are applied. As the data availability at present is indicated in daily values, PMP is also to be estimated at daily basis. The representative values of respective meteorological data are assumed as follows:

   **Temperature (γ):**

   The maximum value of 33.6°C is adopted referring to the monthly average value of the daily maximum temperature. Decrement of temperature by altitude is estimated at minus 0.6°C / 100 m.

   **Relative humidity (RH):**

   The lower value of humidity between the two records observed each day is selected as the daily representative humidity and the maximum value (98.3 %) of these representative humidities is adopted. Variation of humidity by altitude is assumed to be linear up to 50% at 300 hPa, referring to measurement in Japan.

   **Wind velocity (V):**

   The maximum value of 1.9 m/s is adopted referring to the daily mean velocities during the monsoon season (June – September). Variation of wind velocity by altitude is assumed to be linear up to 50 m/s at 300 hPa, referring to measurement records in Japan.

4) Setting of the Freezing Level

   Based on the decrement of temperature by altitude, as previously stated, the freezing level is set at 450 hPa. Above or below this level, it snows or rains.

5) Preparation of Precipitation Trajectories

   Precipitation trajectories are to be prepared at every 10 km as shown in **Fig. 6.4.2-2**. Computation of the precipitation trajectory is shown in **Table 6.4.2-1**.

6) Calculation of Precipitation

   Precipitation between each trajectory is to be calculated based on the formula as previously stated and the results are shown in **Table 6.4.2-2**.

Based on the above, the daily average value of PMP in the drainage area at the Dam site is estimated to be 683 mm/day as shown in **Table 6.4-2-3**.

(3) Preparation of the Unit Hydrograph

As unit hydrographs of the Seti River basin are unavailable at present, basin lag and peak flow, etc. of the unit hydrograph are estimated by the Snyder method in this study. The shape of the unit hydrograph is expressed in a function of $t^{2.4}$ at the ascending portion and the exponential function at the descending portion, and is graded in every 6 hours and with a rainfall density of 1 cm, as shown in **Fig. 6.4.2-3**.

(4) Distribution of PMP

Since the unit hydrograph is graded every 6 hours, the PMP values must also be distributed as previously estimated every 6 hours. The following formula, showing the relationship between time and precipitation for the world's greatest observed point of rainfall, are applied for this purpose:

$R = 422 \cdot D^{0.475}$

where

R: Rainfall (mm)

D: Duration (hr)

The results of the calculation are shown in **Table 6.4.2-4**, in which "Arrange" means the arrangement set to cause maximum discharge and the effective precipitation is the value arranged minus an hourly retention loss of 2 mm / hr.

(5) Synthesis of the Unit Hydrographs

The flood hydrograph synthesized with the effective precipitation and unit hydrographs is as shown in **Table 6.4.2-5** and **Fig. 6.4.2-4**. As a result of the synthesis, a peak discharge of 7,251 $m^3/s$ is calculated.

(6) Determination of Base flow and PMF

Moreover, a base flow of 126 $m^3/s$ is determined based on the discharge of 95 % probability during the rainy season (July – September). Therefore, PMF discharge at the Dam site is estimated to be 7,251+126 = 7,377 $m^3$ / sec.

(7) Comparison with other Projects

The relation between an effective catchment area, catchment area in connection with the PMF, and PMF discharge per effective catchment area of the dam projects on rivers originating from the Himalaya Mountains in Nepal and India[2] is as shown in **Fig. 6.4.2-5**. The figure explains that the PMF discharge per effective catchment area of the Dam site lies near the regression line and its value is judged to be reasonable.

[2] Kali Gandaki 'A' Hydroelectric Project Detailed Design, Final Project Formulation Report II, Volume 1, Main Report, Chapter 2 Hydrology, 2.2.2 Probable Maximum Flood (PMF), Kali Gandaki 'A' Associates, May, 1994

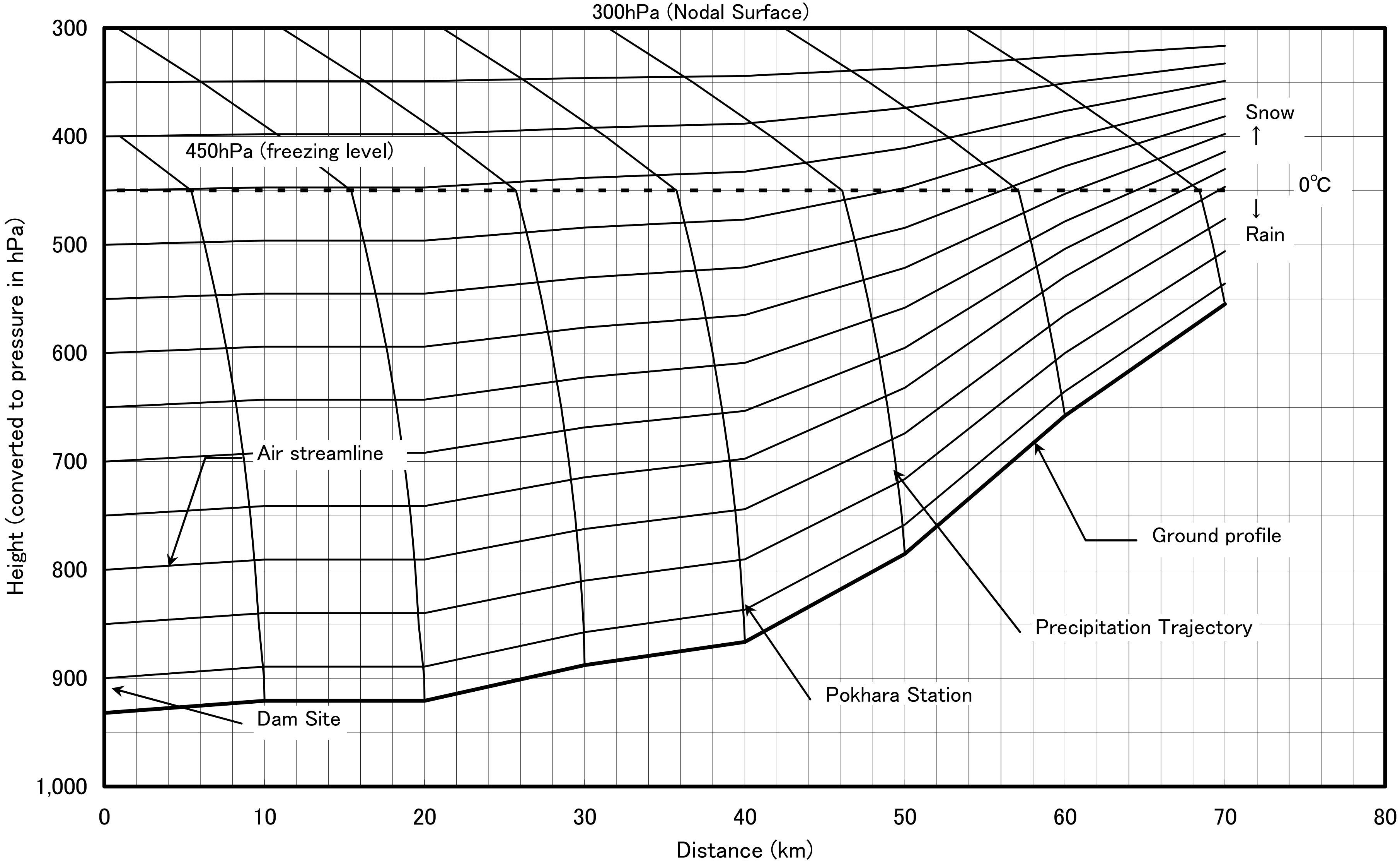


**Fig. 6.4.2-2 Ground Profile, Air Streamlines and Precipitation Trajectories for PMP Estimation**

**Table 6.4.2-1 Computation of the Rain and Snow Drift for Computing the Precipitation Trajectories**

| P (hPa) | V (m/s) | Vav (m/s) | Vav△P | DRR (km) | Σ DRIFT(DRR) (km) | DRS (km) | Σ DRIFT(DRS) (km) |
|---|---|---|---|---|---|---|---|
| 300 | 50.0 | | | | | | |
| 350 | 46.1 | 48.1 | 2,403 | 1.1 | 7.1 | 5.3 | 33.7 |
| 400 | 42.2 | 44.2 | 2,208 | 1.0 | 6.0 | 4.9 | 28.4 |
| 450 | 38.3 | 40.3 | 2,014 | 0.9 | 4.9 | 4.4 | 23.5 |
| 500 | 34.4 | 36.4 | 1,819 | 0.8 | 4.0 | 4.0 | 19.1 |
| 550 | 30.6 | 32.5 | 1,625 | 0.8 | 3.2 | 3.6 | 15.1 |
| 600 | 26.7 | 28.6 | 1,430 | 0.7 | 2.4 | 3.2 | 11.5 |
| 650 | 22.8 | 24.7 | 1,236 | 0.6 | 1.7 | 2.7 | 8.3 |
| 700 | 18.9 | 20.8 | 1,041 | 0.5 | 1.2 | 2.3 | 5.6 |
| 750 | 15.0 | 16.9 | 847 | 0.4 | 0.7 | 1.9 | 3.3 |
| 800 | 11.1 | 13.0 | 652 | 0.3 | 0.3 | 1.4 | 1.4 |

Legend

DRR = Vav△P/2,160 :Horizontal rain drift (2,160hPa/hr = falling velocity of rain)

DRS = Vav△P/453 :Horizontal snow drift (453hPa/hr = falling velocity of snow)

# Table 6.4.2-2 (1/3) Computation of PMP

**10～20km**

| P (hPa) | γ (˚C) | R.H (%) | V (m/s) | Vav (m/s) | VavΔP | Ws (g/kg) | WI (g/kg) | Pc (hPa) | γc (˚C) | $P_{LT}$ (hPa) | $W_{LT}$ (g/kg) | $P_{UT}$ (hPa) | $W_{UT}$ (g/kg) | WIav (g/kg) | $W_{LT}$av (g/kg) | $W_{UT}$av (g/kg) | $\Delta W_{LT}$av =WIav-$W_{LT}$av | VavΔp·$\Delta W_{LT}$av | $\Delta W_{UT}$av =WIav-$W_{UT}$av | VavΔp·$\Delta W_{UT}$av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350.0 | -9.6 | 53.9 | 46.1 | | | 5.2 | 2.8 | 300.0 | -19.2 | 350.0 | 2.8 | 350.0 | 2.8 | | | | | | | |
| 400.0 | -3.6 | 57.8 | 42.2 | 44.2 | 2,208.3 | 7.4 | 4.3 | 360.0 | -12.0 | 400.0 | 4.3 | 398.0 | 4.3 | 3.6 | 3.6 | 3.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 450.0 | 1.2 | 61.7 | 38.3 | 40.3 | 2,013.8 | 9.5 | 5.9 | 410.0 | -6.2 | 448.0 | 5.9 | 447.0 | 5.9 | 5.1 | 5.1 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500.0 | 6.0 | 65.6 | 34.4 | 36.4 | 1,819.3 | 12.0 | 7.9 | 457.0 | -1.8 | 497.0 | 7.9 | 495.0 | 7.9 | 6.9 | 6.9 | 6.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 550.0 | 9.6 | 69.6 | 30.6 | 32.5 | 1,624.8 | 14.0 | 9.7 | 507.0 | 3.2 | 546.0 | 9.7 | 544.0 | 9.7 | 8.8 | 8.8 | 8.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 600.0 | 13.2 | 73.5 | 26.7 | 28.6 | 1,430.3 | 16.2 | 11.9 | 555.0 | 7.8 | 595.0 | 11.9 | 594.0 | 11.9 | 10.8 | 10.8 | 10.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 650.0 | 18.0 | 77.4 | 22.8 | 24.7 | 1,235.8 | 20.5 | 15.9 | 613.0 | 13.3 | 643.0 | 15.9 | 643.0 | 15.9 | 13.9 | 13.9 | 13.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 700.0 | 20.4 | 81.3 | 18.9 | 20.8 | 1,041.3 | 22.5 | 18.3 | 670.0 | 16.5 | 692.0 | 18.3 | 691.0 | 18.3 | 17.1 | 17.1 | 17.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 750.0 | 24.0 | 85.2 | 15.0 | 16.9 | 846.8 | 26.2 | 22.3 | 723.0 | 20.7 | 741.0 | 22.3 | 741.0 | 22.3 | 20.3 | 20.3 | 20.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 800.0 | 26.4 | 89.1 | 11.1 | 13.0 | 652.3 | 28.6 | 25.5 | 780.0 | 24.2 | 791.0 | 25.5 | 791.0 | 25.5 | 23.9 | 23.9 | 23.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 850.0 | 30.0 | 93.0 | 7.2 | 9.2 | 457.8 | 33.4 | 31.1 | 835.0 | 28.5 | 840.0 | 31.1 | 839.0 | 31.1 | 28.3 | 28.3 | 28.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 900.0 | 32.4 | 96.9 | 3.3 | 5.3 | 263.3 | 36.3 | 35.2 | 892.0 | 31.8 | 889.0 | 35.2 | 889.0 | 35.2 | 33.2 | 33.2 | 33.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 930.0 | 34.2 | 99.3 | 1.0 | 2.2 | 64.6 | 38.4 | 38.1 | 930.0 | 34.2 | 920.8 | 38.0 | 920.8 | 38.0 | 36.7 | 36.6 | 36.6 | 0.1 | 3.2 | 0.1 | 3.2 |

Legend
P : Atmospheric pressure
γ : Atmospheric temperature
R.H : Relative humidity
V : Wind velocity
av : average
Ws : Saturation mixing ratio
WI : Mixing ratio at inflow =R.H×Ws
Pc, γc : Condensation pressure, temperature
$_{LT}$ : Lower precipitation trajectory
$_{UT}$ : Upper precipitation trajectory

| | | |
|---|---|---|
| TOTAL = | 3.2 | 3.2 |
| 24hr Volume(mm(km)) = 0.8813×TOTAL = | 2.8 =A | 2.8 =B |
| Unit Horizontal Area (km)= | 10.0 =C | 20.0 =D |
| 24hr Average Rainfall Over Last Leg = | (B-A)/(D-C) = | 0.0 mm |

**20～30km**

| P (hPa) | γ (˚C) | R.H (%) | V (m/s) | Vav (m/s) | VavΔP | Ws (g/kg) | WI (g/kg) | Pc (hPa) | γc (˚C) | $P_{LT}$ (hPa) | $W_{LT}$ (g/kg) | $P_{UT}$ (hPa) | $W_{UT}$ (g/kg) | WIav (g/kg) | $W_{LT}$av (g/kg) | $W_{UT}$av (g/kg) | $\Delta W_{LT}$av =WIav-$W_{LT}$av | VavΔp·$\Delta W_{LT}$av | $\Delta W_{UT}$av =WIav-$W_{UT}$av | VavΔp·$\Delta W_{UT}$av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350.0 | -9.6 | 53.9 | 46.1 | | | 5.2 | 2.8 | 300.0 | -19.2 | 350.0 | 2.8 | 349.0 | 2.8 | | | | | | | |
| 400.0 | -3.6 | 57.8 | 42.2 | 44.2 | 2,208.3 | 7.4 | 4.3 | 360.0 | -12.0 | 398.0 | 4.3 | 397.0 | 4.3 | 3.6 | 3.6 | 3.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 450.0 | 1.2 | 61.7 | 38.3 | 40.3 | 2,013.8 | 9.5 | 5.9 | 410.0 | -6.2 | 447.0 | 5.9 | 442.0 | 5.9 | 5.1 | 5.1 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500.0 | 6.0 | 65.6 | 34.4 | 36.4 | 1,819.3 | 12.0 | 7.9 | 457.0 | -1.8 | 495.0 | 7.9 | 489.0 | 7.9 | 6.9 | 6.9 | 6.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 550.0 | 9.6 | 69.6 | 30.6 | 32.5 | 1,624.8 | 14.0 | 9.7 | 507.0 | 3.2 | 544.0 | 9.7 | 535.0 | 9.7 | 8.8 | 8.8 | 8.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 600.0 | 13.2 | 73.5 | 26.7 | 28.6 | 1,430.3 | 16.2 | 11.9 | 555.0 | 7.8 | 594.0 | 11.9 | 580.0 | 11.9 | 10.8 | 10.8 | 10.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 650.0 | 18.0 | 77.4 | 22.8 | 24.7 | 1,235.8 | 20.5 | 15.9 | 613.0 | 13.3 | 643.0 | 15.9 | 626.0 | 15.9 | 13.9 | 13.9 | 13.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 700.0 | 20.4 | 81.3 | 18.9 | 20.8 | 1,041.3 | 22.5 | 18.3 | 670.0 | 16.5 | 691.0 | 18.3 | 672.0 | 18.3 | 17.1 | 17.1 | 17.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 750.0 | 24.0 | 85.2 | 15.0 | 16.9 | 846.8 | 26.2 | 22.3 | 723.0 | 20.7 | 741.0 | 22.3 | 717.0 | 22.3 | 20.3 | 20.3 | 20.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 800.0 | 26.4 | 89.1 | 11.1 | 13.0 | 652.3 | 28.6 | 25.5 | 780.0 | 24.2 | 791.0 | 25.5 | 764.0 | 25.0 | 23.9 | 23.9 | 23.7 | 0.0 | 0.0 | 0.3 | 163.1 |
| 850.0 | 30.0 | 93.0 | 7.2 | 9.2 | 457.8 | 33.4 | 31.1 | 835.0 | 28.5 | 839.0 | 31.1 | 810.0 | 30.3 | 28.3 | 28.3 | 27.7 | 0.0 | 0.0 | 0.7 | 297.5 |
| 900.0 | 32.4 | 96.9 | 3.3 | 5.3 | 263.3 | 36.3 | 35.2 | 892.0 | 31.8 | 889.0 | 35.2 | 858.0 | 34.5 | 33.2 | 33.2 | 32.4 | 0.0 | 0.0 | 0.8 | 197.4 |
| 930.0 | 34.2 | 99.3 | 1.0 | 2.2 | 64.6 | 38.4 | 38.1 | 930.0 | 34.2 | 920.8 | 38.0 | 888.0 | 37.8 | 36.7 | 36.6 | 36.2 | 0.1 | 3.2 | 0.5 | 32.3 |

Legend
P : Atmospheric pressure
γ : Atmospheric temperature
R.H : Relative humidity
V : Wind velocity
av : average
Ws : Saturation mixing ratio
WI : Mixing ratio at inflow =R.H×Ws
Pc, γc : Condensation pressure, temperature
$_{LT}$ : Lower precipitation trajectory
$_{UT}$ : Upper precipitation trajectory

| | | |
|---|---|---|
| TOTAL = | 3.2 | 690.3 |
| 24hr Volume(mm(km)) = 0.8813×TOTAL = | 2.8 =A | 608.4 =B |
| Unit Horizontal Area (km)= | 20.0 =C | 30.0 =D |
| 24hr Average Rainfall Over Last Leg = | (B-A)/(D-C) = | 60.6 mm |

# Table 6.4.2-2 (2/3) Computation of PMP

**30～40km**

| P (hPa) | γ (˚C) | R.H (%) | V (m/s) | Vav (m/s) | VavΔP | Ws (g/kg) | WI (g/kg) | Pc (hPa) | γc (˚C) | $P_{LT}$ (hPa) | $W_{LT}$ (g/kg) | $P_{UT}$ (hPa) | $W_{UT}$ (g/kg) | WIav (g/kg) | $W_{LT}$av (g/kg) | $W_{UT}$av (g/kg) | $\Delta W_{LT}$av =WIav-$W_{LT}$av | VavΔp·$\Delta W_{LT}$av | $\Delta W_{UT}$av =WIav-$W_{UT}$av | VavΔp·$\Delta W_{UT}$av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350.0 | -9.6 | 53.9 | 46.1 | | | 5.2 | 2.8 | 300.0 | -19.2 | 349.0 | 2.8 | 347.0 | 2.8 | | | | | | | |
| 400.0 | -3.6 | 57.8 | 42.2 | 44.2 | 2,208.3 | 7.4 | 4.3 | 360.0 | -12.0 | 397.0 | 4.3 | 391.0 | 4.3 | 3.6 | 3.6 | 3.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 450.0 | 1.2 | 61.7 | 38.3 | 40.3 | 2,013.8 | 9.5 | 5.9 | 410.0 | -6.2 | 442.0 | 5.9 | 435.0 | 5.9 | 5.1 | 5.1 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500.0 | 6.0 | 65.6 | 34.4 | 36.4 | 1,819.3 | 12.0 | 7.9 | 457.0 | -1.8 | 489.0 | 7.9 | 478.0 | 7.9 | 6.9 | 6.9 | 6.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 550.0 | 9.6 | 69.6 | 30.6 | 32.5 | 1,624.8 | 14.0 | 9.7 | 507.0 | 3.2 | 535.0 | 9.7 | 523.0 | 9.7 | 8.8 | 8.8 | 8.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 600.0 | 13.2 | 73.5 | 26.7 | 28.6 | 1,430.3 | 16.2 | 11.9 | 555.0 | 7.8 | 580.0 | 11.9 | 568.0 | 11.9 | 10.8 | 10.8 | 10.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 650.0 | 18.0 | 77.4 | 22.8 | 24.7 | 1,235.8 | 20.5 | 15.9 | 613.0 | 13.3 | 626.0 | 15.9 | 611.0 | 15.9 | 13.9 | 13.9 | 13.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 700.0 | 20.4 | 81.3 | 18.9 | 20.8 | 1,041.3 | 22.5 | 18.3 | 670.0 | 16.5 | 672.0 | 18.3 | 655.0 | 18.3 | 17.1 | 17.1 | 17.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 750.0 | 24.0 | 85.2 | 15.0 | 16.9 | 846.8 | 26.2 | 22.3 | 723.0 | 20.7 | 717.0 | 22.3 | 700.0 | 21.7 | 20.3 | 20.3 | 20.0 | 0.0 | 0.0 | 0.3 | 254.0 |
| 800.0 | 26.4 | 89.1 | 11.1 | 13.0 | 652.3 | 28.6 | 25.5 | 780.0 | 24.2 | 764.0 | 25.0 | 744.0 | 24.8 | 23.9 | 23.7 | 23.3 | 0.3 | 163.1 | 0.6 | 424.0 |
| 850.0 | 30.0 | 93.0 | 7.2 | 9.2 | 457.8 | 33.4 | 31.1 | 835.0 | 28.5 | 810.0 | 30.3 | 791.0 | 29.0 | 28.3 | 27.7 | 26.9 | 0.7 | 297.5 | 1.4 | 640.9 |
| 900.0 | 32.4 | 96.9 | 3.3 | 5.3 | 263.3 | 36.3 | 35.2 | 892.0 | 31.8 | 858.0 | 34.5 | 835.0 | 33.8 | 33.2 | 32.4 | 31.4 | 0.8 | 197.4 | 1.8 | 460.7 |
| 930.0 | 34.2 | 99.3 | 1.0 | 2.2 | 64.6 | 38.4 | 38.1 | 930.0 | 34.2 | 888.0 | 37.8 | 866.6 | 37.3 | 36.7 | 36.2 | 35.6 | 0.5 | 32.3 | 1.1 | 71.0 |

Legend
P : Atmospheric pressure
γ : Atmospheric temperature
R.H : Relative humidity
V : Wind velocity
av : average
Ws : Saturation mixing ratio
WI : Mixing ratio at inflow =R.H×Ws
Pc, γc : Condensation pressure, temperature
$_{LT}$ : Lower precipitation trajectory
$_{UT}$ : Upper precipitation trajectory

| | | |
|---|---|---|
| TOTAL = | 690.3 | 1,850.6 |
| 24hr Volume(mm(km)) = 0.8813×TOTAL = | 608.4 =A | 1,630.9 =B |
| Unit Horizontal Area (km)= | 30.0 =C | 40.0 =D |
| 24hr Average Rainfall Over Last Leg = | (B-A)/(D-C) = | 102.3 mm |

**40～50km**

| P (hPa) | γ (˚C) | R.H (%) | V (m/s) | Vav (m/s) | VavΔP | Ws (g/kg) | WI (g/kg) | Pc (hPa) | γc (˚C) | $P_{LT}$ (hPa) | $W_{LT}$ (g/kg) | $P_{UT}$ (hPa) | $W_{UT}$ (g/kg) | WIav (g/kg) | $W_{LT}$av (g/kg) | $W_{UT}$av (g/kg) | $\Delta W_{LT}$av =WIav-$W_{LT}$av | VavΔp·$\Delta W_{LT}$av | $\Delta W_{UT}$av =WIav-$W_{UT}$av | VavΔp·$\Delta W_{UT}$av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350.0 | -9.6 | 53.9 | 46.1 | | | 5.2 | 2.8 | 300.0 | -19.2 | 347.0 | 2.8 | 344.0 | 2.8 | | | | | | | |
| 400.0 | -3.6 | 57.8 | 42.2 | 44.2 | 2,208.3 | 7.4 | 4.3 | 360.0 | -12.0 | 391.0 | 4.3 | 387.0 | 4.3 | 3.6 | 3.6 | 3.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 450.0 | 1.2 | 61.7 | 38.3 | 40.3 | 2,013.8 | 9.5 | 5.9 | 410.0 | -6.2 | 435.0 | 5.9 | 424.0 | 5.9 | 5.1 | 5.1 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500.0 | 6.0 | 65.6 | 34.4 | 36.4 | 1,819.3 | 12.0 | 7.9 | 457.0 | -1.8 | 478.0 | 7.9 | 459.0 | 7.9 | 6.9 | 6.9 | 6.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 550.0 | 9.6 | 69.6 | 30.6 | 32.5 | 1,624.8 | 14.0 | 9.7 | 507.0 | 3.2 | 523.0 | 9.7 | 495.0 | 9.3 | 8.8 | 8.8 | 8.6 | 0.0 | 0.0 | 0.2 | 324.9 |
| 600.0 | 13.2 | 73.5 | 26.7 | 28.6 | 1,430.3 | 16.2 | 11.9 | 555.0 | 7.8 | 568.0 | 11.9 | 532.0 | 11.0 | 10.8 | 10.8 | 10.2 | 0.0 | 0.0 | 0.7 | 929.7 |
| 650.0 | 18.0 | 77.4 | 22.8 | 24.7 | 1,235.8 | 20.5 | 15.9 | 613.0 | 13.3 | 611.0 | 15.9 | 568.0 | 14.3 | 13.9 | 13.9 | 12.7 | 0.0 | 0.0 | 1.3 | 1,544.7 |
| 700.0 | 20.4 | 81.3 | 18.9 | 20.8 | 1,041.3 | 22.5 | 18.3 | 670.0 | 16.5 | 655.0 | 18.3 | 603.0 | 15.7 | 17.1 | 17.1 | 15.0 | 0.0 | 0.0 | 2.1 | 2,186.6 |
| 750.0 | 24.0 | 85.2 | 15.0 | 16.9 | 846.8 | 26.2 | 22.3 | 723.0 | 20.7 | 700.0 | 21.7 | 639.0 | 19.3 | 20.3 | 20.0 | 17.5 | 0.3 | 254.0 | 2.8 | 2,370.9 |
| 800.0 | 26.4 | 89.1 | 11.1 | 13.0 | 652.3 | 28.6 | 25.5 | 780.0 | 24.2 | 744.0 | 24.8 | 679.0 | 23.0 | 23.9 | 23.3 | 21.2 | 0.6 | 424.0 | 2.8 | 1,793.7 |
| 850.0 | 30.0 | 93.0 | 7.2 | 9.2 | 457.8 | 33.4 | 31.1 | 835.0 | 28.5 | 791.0 | 29.0 | 719.0 | 27.8 | 28.3 | 26.9 | 25.4 | 1.4 | 640.9 | 2.9 | 1,327.5 |
| 900.0 | 32.4 | 96.9 | 3.3 | 5.3 | 263.3 | 36.3 | 35.2 | 892.0 | 31.8 | 835.0 | 33.8 | 759.0 | 31.9 | 33.2 | 31.4 | 29.9 | 1.8 | 460.7 | 3.3 | 868.7 |
| 930.0 | 34.2 | 99.3 | 1.0 | 2.2 | 64.6 | 38.4 | 38.1 | 930.0 | 34.2 | 866.6 | 37.3 | 785.2 | 32.3 | 36.7 | 35.6 | 32.1 | 1.1 | 71.0 | 4.6 | 293.9 |

Legend
P : Atmospheric pressure
γ : Atmospheric temperature
R.H : Relative humidity
V : Wind velocity
av : average
Ws : Saturation mixing ratio
WI : Mixing ratio at inflow =R.H×Ws
Pc, γc : Condensation pressure, temperature
$_{LT}$ : Lower precipitation trajectory
$_{UT}$ : Upper precipitation trajectory

| | | |
|---|---|---|
| TOTAL = | 1,850.6 | 11,640.6 |
| 24hr Volume(mm(km)) = 0.8813×TOTAL = | 1,630.9 =A | 10,258.9 =B |
| Unit Horizontal Area (km)= | 40.0 =C | 50.0 =D |
| 24hr Average Rainfall Over Last Leg = | (B-A)/(D-C) = | 862.8 mm |

## Table 6.4.2-2 (3/3) Computation of PMP

**50～60km**

| P (hPa) | $\gamma$ (°C) | R.H (%) | V (m/s) | Vav (m/s) | VavΔP | Ws (g/kg) | WI (g/kg) | Pc (hPa) | $\gamma$c (°C) | $P_{LT}$ (hPa) | $W_{LT}$ (g/kg) | $P_{UT}$ (hPa) | $W_{UT}$ (g/kg) | WIav (g/kg) | $W_{LT}$av (g/kg) | $W_{UT}$av (g/kg) | $\Delta W_{LT}$av =WIav-$W_{LT}$av | VavΔp·$\Delta W_{LT}$av | $\Delta W_{UT}$av =WIav-$W_{UT}$av | VavΔp·$\Delta W_{UT}$av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350.0 | -9.6 | 53.9 | 46.1 | | | 5.2 | 2.8 | 300.0 | -19.2 | 344.0 | 2.8 | 339.0 | 2.8 | | | | | | | |
| 400.0 | -3.6 | 57.8 | 42.2 | 44.2 | 2,208.3 | 7.4 | 4.3 | 360.0 | -12.0 | 387.0 | 4.3 | 373.0 | 4.3 | 3.6 | 3.6 | 3.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 450.0 | 1.2 | 61.7 | 38.3 | 40.3 | 2,013.8 | 9.5 | 5.9 | 410.0 | -6.2 | 424.0 | 5.9 | 403.0 | 5.5 | 5.1 | 5.1 | 4.9 | 0.0 | 0.0 | 0.2 | 402.7 |
| 500.0 | 6.0 | 65.6 | 34.4 | 36.4 | 1,819.3 | 12.0 | 7.9 | 457.0 | -1.8 | 459.0 | 7.9 | 425.0 | 7.0 | 6.9 | 6.9 | 6.3 | 0.0 | 0.0 | 0.7 | 1,182.5 |
| 550.0 | 9.6 | 69.6 | 30.6 | 32.5 | 1,624.8 | 14.0 | 9.7 | 507.0 | 3.2 | 495.0 | 9.3 | 445.0 | 7.7 | 8.8 | 8.6 | 7.4 | 0.2 | 324.9 | 1.5 | 2,355.9 |
| 600.0 | 13.2 | 73.5 | 26.7 | 28.6 | 1,430.3 | 16.2 | 11.9 | 555.0 | 7.8 | 532.0 | 11.0 | 471.0 | 9.0 | 10.8 | 10.2 | 8.4 | 0.7 | 929.7 | 2.5 | 3,504.1 |
| 650.0 | 18.0 | 77.4 | 22.8 | 24.7 | 1,235.8 | 20.5 | 15.9 | 613.0 | 13.3 | 568.0 | 14.3 | 496.0 | 11.5 | 13.9 | 12.7 | 10.3 | 1.3 | 1,544.7 | 3.7 | 4,510.5 |
| 700.0 | 20.4 | 81.3 | 18.9 | 20.8 | 1,041.3 | 22.5 | 18.3 | 670.0 | 16.5 | 603.0 | 15.7 | 520.0 | 12.6 | 17.1 | 15.0 | 12.1 | 2.1 | 2,186.6 | 5.1 | 5,258.3 |
| 750.0 | 24.0 | 85.2 | 15.0 | 16.9 | 846.8 | 26.2 | 22.3 | 723.0 | 20.7 | 639.0 | 19.3 | 544.0 | 15.7 | 20.3 | 17.5 | 14.2 | 2.8 | 2,370.9 | 6.2 | 5,207.5 |
| 800.0 | 26.4 | 89.1 | 11.1 | 13.0 | 652.3 | 28.6 | 25.5 | 780.0 | 24.2 | 679.0 | 23.0 | 575.0 | 20.0 | 23.9 | 21.2 | 17.9 | 2.8 | 1,793.7 | 6.1 | 3,946.1 |
| 850.0 | 30.0 | 93.0 | 7.2 | 9.2 | 457.8 | 33.4 | 31.1 | 835.0 | 28.5 | 719.0 | 27.8 | 606.0 | 24.0 | 28.3 | 25.4 | 22.0 | 2.9 | 1,327.5 | 6.3 | 2,883.8 |
| 900.0 | 32.4 | 96.9 | 3.3 | 5.3 | 263.3 | 36.3 | 35.2 | 892.0 | 31.8 | 759.0 | 31.9 | 638.0 | 27.6 | 33.2 | 29.9 | 25.8 | 3.3 | 868.7 | 7.4 | 1,934.9 |
| 930.0 | 34.2 | 99.3 | 1.0 | 2.2 | 64.6 | 38.4 | 38.1 | 930.0 | 34.2 | 785.2 | 32.3 | 657.7 | 30.5 | 36.7 | 32.1 | 29.1 | 4.6 | 293.9 | 7.6 | 490.9 |

Legend
P : Atmospheric pressure
$\gamma$ : Atmospheric temperature
R.H : Relative humidity
V : Wind velocity
av : average
Ws : Saturation mixing ratio
WI : Mixing ratio at inflow =R.H×Ws
Pc, $\gamma$c : Condensation pressure, temperature
$_{LT}$ : Lower precipitation trajectory
$_{UT}$ : Upper precipitation trajectory

TOTAL = 11,640.6 31,677.3
24hr Volume(mm(km)) = 0.8813×TOTAL = 10,258.9 =A 27,917.2 =B
Unit Horizontal Area (km)= 50.0 =C 60.0 =D
24hr Average Rainfall Over Last Leg = (B-A)/(D-C) = 1,765.8 mm

**60～70km**

| P (hPa) | $\gamma$ (°C) | R.H (%) | V (m/s) | Vav (m/s) | VavΔP | Ws (g/kg) | WI (g/kg) | Pc (hPa) | $\gamma$c (°C) | $P_{LT}$ (hPa) | $W_{LT}$ (g/kg) | $P_{UT}$ (hPa) | $W_{UT}$ (g/kg) | WIav (g/kg) | $W_{LT}$av (g/kg) | $W_{UT}$av (g/kg) | $\Delta W_{LT}$av =WIav-$W_{LT}$av | VavΔp·$\Delta W_{LT}$av | $\Delta W_{UT}$av =WIav-$W_{UT}$av | VavΔp·$\Delta W_{UT}$av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350.0 | -9.6 | 53.9 | 46.1 | | | 5.2 | 2.8 | 300.0 | -19.2 | 339.0 | 2.8 | 328.0 | 2.8 | | | | | | | |
| 400.0 | -3.6 | 57.8 | 42.2 | 44.2 | 2,208.3 | 7.4 | 4.3 | 360.0 | -12.0 | 373.0 | 4.3 | 353.0 | 4.3 | 3.6 | 3.6 | 3.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 450.0 | 1.2 | 61.7 | 38.3 | 40.3 | 2,013.8 | 9.5 | 5.9 | 410.0 | -6.2 | 403.0 | 5.8 | 372.0 | 4.7 | 5.1 | 5.1 | 4.5 | 0.0 | 100.7 | 0.6 | 1,208.3 |
| 500.0 | 6.0 | 65.6 | 34.4 | 36.4 | 1,819.3 | 12.0 | 7.9 | 457.0 | -1.8 | 425.0 | 7.0 | 391.0 | 6.0 | 6.9 | 6.4 | 5.4 | 0.5 | 909.6 | 1.6 | 2,819.8 |
| 550.0 | 9.6 | 69.6 | 30.6 | 32.5 | 1,624.8 | 14.0 | 9.7 | 507.0 | 3.2 | 445.0 | 7.7 | 407.0 | 6.5 | 8.8 | 7.4 | 6.3 | 1.5 | 2,355.9 | 2.6 | 4,143.1 |
| 600.0 | 13.2 | 73.5 | 26.7 | 28.6 | 1,430.3 | 16.2 | 11.9 | 555.0 | 7.8 | 471.0 | 9.0 | 420.0 | 7.3 | 10.8 | 8.4 | 6.9 | 2.5 | 3,504.1 | 3.9 | 5,578.0 |
| 650.0 | 18.0 | 77.4 | 22.8 | 24.7 | 1,235.8 | 20.5 | 15.9 | 613.0 | 13.3 | 496.0 | 11.5 | 433.0 | 9.2 | 13.9 | 10.3 | 8.3 | 3.7 | 4,510.5 | 5.7 | 6,982.0 |
| 700.0 | 20.4 | 81.3 | 18.9 | 20.8 | 1,041.3 | 22.5 | 18.3 | 670.0 | 16.5 | 520.0 | 12.6 | 444.0 | 9.7 | 17.1 | 12.1 | 9.5 | 5.1 | 5,258.3 | 7.7 | 7,965.6 |
| 750.0 | 24.0 | 85.2 | 15.0 | 16.9 | 846.8 | 26.2 | 22.3 | 723.0 | 20.7 | 544.0 | 15.7 | 459.0 | 12.2 | 20.3 | 14.2 | 11.0 | 6.2 | 5,207.5 | 9.4 | 7,917.1 |
| 800.0 | 26.4 | 89.1 | 11.1 | 13.0 | 652.3 | 28.6 | 25.5 | 780.0 | 24.2 | 575.0 | 20.0 | 485.0 | 17.0 | 23.9 | 17.9 | 14.6 | 6.1 | 3,946.1 | 9.3 | 6,065.9 |
| 850.0 | 30.0 | 93.0 | 7.2 | 9.2 | 457.8 | 33.4 | 31.1 | 835.0 | 28.5 | 606.0 | 24.0 | 511.0 | 20.7 | 28.3 | 22.0 | 18.9 | 6.3 | 2,883.8 | 9.5 | 4,325.7 |
| 900.0 | 32.4 | 96.9 | 3.3 | 5.3 | 263.3 | 36.3 | 35.2 | 892.0 | 31.8 | 638.0 | 27.6 | 538.0 | 24.0 | 33.2 | 25.8 | 22.4 | 7.4 | 1,934.9 | 10.8 | 2,843.1 |
| 930.0 | 34.2 | 99.3 | 1.0 | 2.2 | 64.6 | 38.4 | 38.1 | 930.0 | 34.2 | 657.7 | 30.5 | 554.8 | 26.6 | 36.7 | 29.1 | 25.3 | 7.6 | 490.9 | 11.4 | 733.1 |

Legend
P : Atmospheric pressure
$\gamma$ : Atmospheric temperature
R.H : Relative humidity
V : Wind velocity
av : average
Ws : Saturation mixing ratio
WI : Mixing ratio at inflow =R.H×Ws
Pc, $\gamma$c : Condensation pressure, temperature
$_{LT}$ : Lower precipitation trajectory
$_{UT}$ : Upper precipitation trajectory

TOTAL = 31,102.3 50,581.7
24hr Volume(mm(km)) = 0.8813×TOTAL = 27,410.5 =A 44,577.6 =B
Unit Horizontal Area (km)= 60.0 =C 70.0 =D
24hr Average Rainfall Over Last Leg = (B-A)/(D-C) = 1,716.7 mm

**Table 6.4.2-3 Average PMP of the Basin**

| Section (km) | PMP (mm/day) | Area ($km^2$) | PMP × Area |
|---|---|---|---|
| 10-20 | 0.0 | 222.2 | 0 |
| 20-30 | 60.6 | 204.3 | 12,371 |
| 30-40 | 102.3 | 257.0 | 26,281 |
| 40-50 | 862.8 | 242.5 | 209,210 |
| 50-60 | 1,765.8 | 199.6 | 352,531 |
| 60-70 | 1,716.7 | 162.9 | 279,687 |
| Total | | 1,289 | 880,080 |
| | | A | B |
| Average | 683 | mm =B/A | |

**Table 6.4.2-4 PMP Distribution and Effective Rainfall**

| Time (hour) | Max. Rain (mm) | Rate | PMP (mm) | 6 hour increment s (mm) | Arrange (mm) | Retention Loss (mm) | Effective Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 6 | 988 | 0.518 | 354 | 354 | 47 | 12 | 35 |
| 12 | 1,374 | 0.719 | 491 | 137 | 51 | 12 | 39 |
| 18 | 1,666 | 0.872 | 596 | 105 | 58 | 12 | 46 |
| 24 | 1,909 | 1.000 | 683 | 87 | 69 | 12 | 57 |
| 30 | 2,123 | 1.112 | 759 | 76 | 87 | 12 | 75 |
| 36 | 2,315 | 1.212 | 828 | 69 | 137 | 12 | 125 |
| 42 | 2,491 | 1.304 | 891 | 63 | 354 | 12 | 342 |
| 48 | 2,654 | 1.390 | 949 | 58 | 105 | 12 | 93 |
| 54 | 2,807 | 1.470 | 1,004 | 55 | 76 | 12 | 64 |
| 60 | 2,951 | 1.545 | 1,055 | 51 | 63 | 12 | 51 |
| 66 | 3,087 | 1.617 | 1,104 | 49 | 55 | 12 | 43 |
| 72 | 3,218 | 1.685 | 1,151 | 47 | 49 | 12 | 37 |

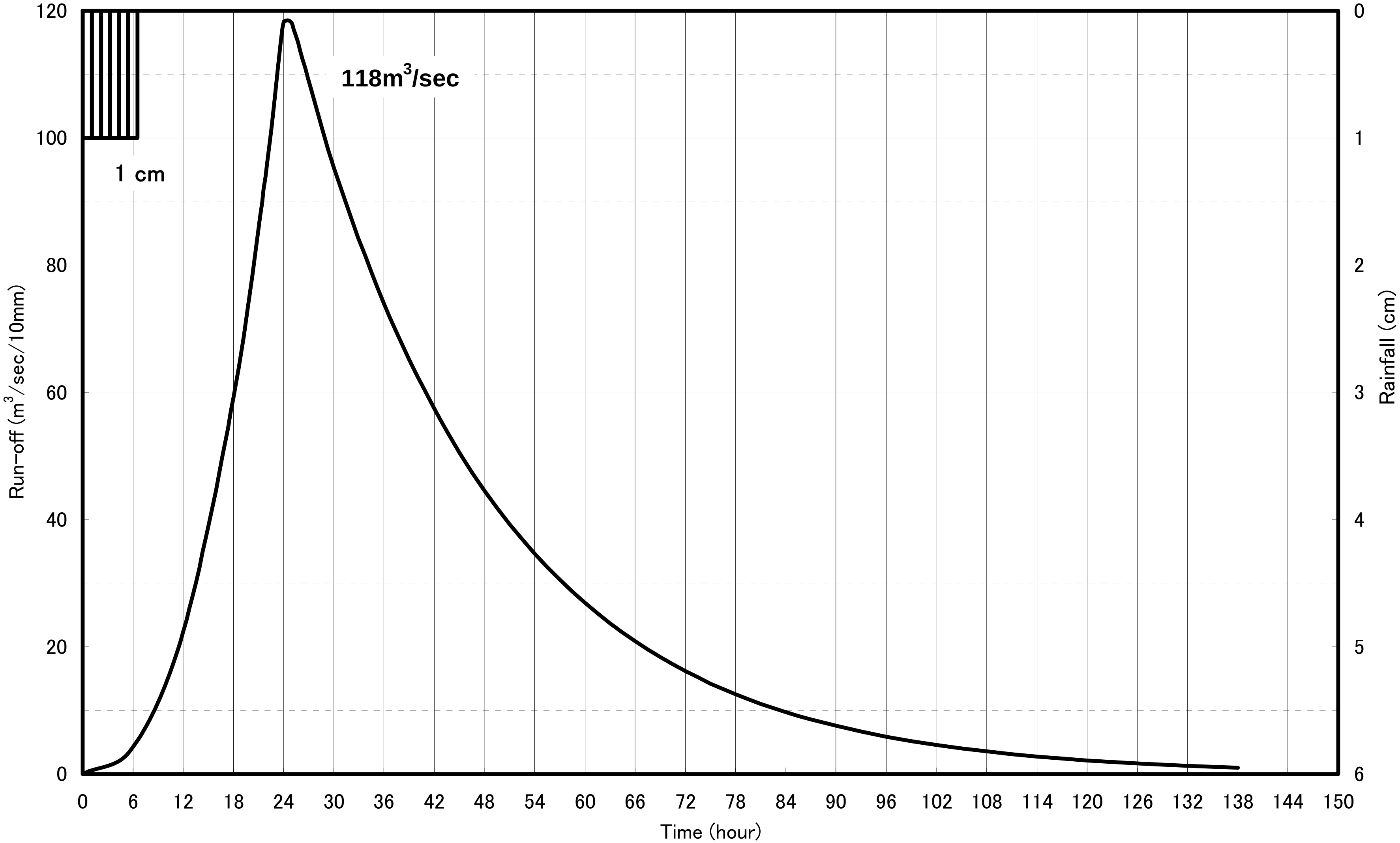


**Fig. 6.4.2-3 Unit Hydrograph at the Dam Site**

## Table 6.4.2-5 Synthesis of Unit Hydrographs

| Time | Rainfall | Loss | Effective | Time (hour) | 0 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 | 102 | 108 | 114 | 120 | 126 | 132 | 138 | 144 | Discharge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (hr) | (cm) | (cm) | (cm) | Unit ($m^3/s$) | 0 | 4 | 22 | 59 | 118 | 95 | 74 | 57 | 45 | 35 | 27 | 21 | 16 | 13 | 10 | 8 | 6 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 0 | ($m^3/s$) |
| 0 | 0 | 0 | 0.0 | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 6 | 4.7 | 1.2 | 3.5 | | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 12 | 5.1 | 1.2 | 3.9 | | 0 | 14 | 0 | | | | | | | | | | | | | | | | | | | | | | | 14 |
| 18 | 5.8 | 1.2 | 4.6 | | 0 | 16 | 77 | 0 | | | | | | | | | | | | | | | | | | | | | | 93 |
| 24 | 6.9 | 1.2 | 5.7 | | 0 | 18 | 86 | 207 | 0 | | | | | | | | | | | | | | | | | | | | | 311 |
| 30 | 8.7 | 1.2 | 7.5 | | 0 | 23 | 101 | 230 | 413 | 0 | | | | | | | | | | | | | | | | | | | | 767 |
| 36 | 13.7 | 1.2 | 12.5 | | 0 | 30 | 125 | 271 | 460 | 333 | 0 | | | | | | | | | | | | | | | | | | | 1,220 |
| 42 | 35.4 | 1.2 | 34.2 | | 0 | 50 | 165 | 336 | 543 | 371 | 259 | 0 | | | | | | | | | | | | | | | | | | 1,724 |
| 48 | 10.5 | 1.2 | 9.3 | | 0 | 137 | 275 | 443 | 673 | 437 | 289 | 200 | 0 | | | | | | | | | | | | | | | | | 2,452 |
| 54 | 7.6 | 1.2 | 6.4 | | 0 | 37 | 752 | 738 | 885 | 542 | 340 | 222 | 158 | 0 | | | | | | | | | | | | | | | | 3,674 |
| 60 | 6.3 | 1.2 | 5.1 | | 0 | 26 | 205 | 2,018 | 1,475 | 713 | 422 | 262 | 176 | 123 | 0 | | | | | | | | | | | | | | | 5,418 |
| 66 | 5.5 | 1.2 | 4.3 | | 0 | 20 | 141 | 549 | 4,036 | 1,188 | 555 | 325 | 207 | 137 | 95 | 0 | | | | | | | | | | | | | | 7,251 |
| 72 | 4.9 | 1.2 | 3.7 | | 0 | 17 | 112 | 378 | 1,097 | 3,249 | 925 | 428 | 257 | 161 | 105 | 74 | 0 | | | | | | | | | | | | | 6,802 |
| 78 | | | | | | 15 | 95 | 301 | 755 | 884 | 2,531 | 713 | 338 | 200 | 124 | 82 | 56 | 0 | | | | | | | | | | | | 6,091 |
| 84 | | | | | | | 81 | 254 | 602 | 608 | 688 | 1,949 | 563 | 263 | 154 | 97 | 62 | 46 | 0 | | | | | | | | | | | 5,366 |
| 90 | | | | | | | | 218 | 507 | 485 | 474 | 530 | 1,539 | 438 | 203 | 120 | 74 | 51 | 35 | 0 | | | | | | | | | | 4,672 |
| 96 | | | | | | | | | 437 | 409 | 377 | 365 | 419 | 1,197 | 338 | 158 | 91 | 60 | 39 | 28 | 0 | | | | | | | | | 3,916 |
| 102 | | | | | | | | | | 352 | 318 | 291 | 288 | 326 | 923 | 263 | 120 | 74 | 46 | 31 | 21 | 0 | | | | | | | | 3,052 |
| 108 | | | | | | | | | | | 274 | 245 | 230 | 224 | 251 | 718 | 200 | 98 | 57 | 37 | 23 | 18 | 0 | | | | | | | 2,374 |
| 114 | | | | | | | | | | | | 211 | 194 | 179 | 173 | 195 | 547 | 163 | 75 | 46 | 28 | 20 | 14 | 0 | | | | | | 1,842 |
| 120 | | | | | | | | | | | | | 167 | 151 | 138 | 134 | 149 | 445 | 125 | 60 | 34 | 23 | 16 | 11 | 0 | | | | | 1,451 |
| 126 | | | | | | | | | | | | | | 130 | 116 | 107 | 102 | 121 | 342 | 100 | 45 | 29 | 18 | 12 | 7 | 0 | | | | 1,129 |
| 132 | | | | | | | | | | | | | | | 100 | 90 | 82 | 83 | 93 | 274 | 75 | 38 | 23 | 14 | 8 | 7 | 0 | | | 886 |
| 138 | | | | | | | | | | | | | | | | 78 | 69 | 66 | 64 | 74 | 205 | 63 | 30 | 17 | 9 | 8 | 4 | 0 | | 687 |
| 144 | | | | | | | | | | | | | | | | | 59 | 56 | 51 | 51 | 56 | 171 | 50 | 23 | 11 | 9 | 4 | 4 | 0 | 545 |
| 150 | | | | | | | | | | | | | | | | | | 48 | 43 | 41 | 38 | 47 | 137 | 38 | 15 | 11 | 5 | 4 | 0 | 426 |
| 156 | | | | | | | | | | | | | | | | | | | 37 | 34 | 31 | 32 | 37 | 103 | 25 | 15 | 6 | 5 | 0 | 324 |
| 162 | | | | | | | | | | | | | | | | | | | | 30 | 26 | 26 | 26 | 28 | 68 | 25 | 8 | 6 | 0 | 241 |
| 168 | | | | | | | | | | | | | | | | | | | | | 22 | 22 | 20 | 19 | 19 | 68 | 13 | 8 | 0 | 190 |
| 174 | | | | | | | | | | | | | | | | | | | | | | 19 | 17 | 15 | 13 | 19 | 34 | 13 | 0 | 129 |
| 180 | | | | | | | | | | | | | | | | | | | | | | | 15 | 13 | 10 | 13 | 9 | 34 | 0 | 94 |
| 186 | | | | | | | | | | | | | | | | | | | | | | | | 11 | 9 | 10 | 6 | 9 | 0 | 46 |
| 192 | | | | | | | | | | | | | | | | | | | | | | | | | 7 | 9 | 5 | 6 | 0 | 28 |
| 198 | | | | | | | | | | | | | | | | | | | | | | | | | | 7 | 4 | 5 | 0 | 17 |
| 204 | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 4 | 0 | 8 |
| 210 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 0 | 4 |
| 216 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 |

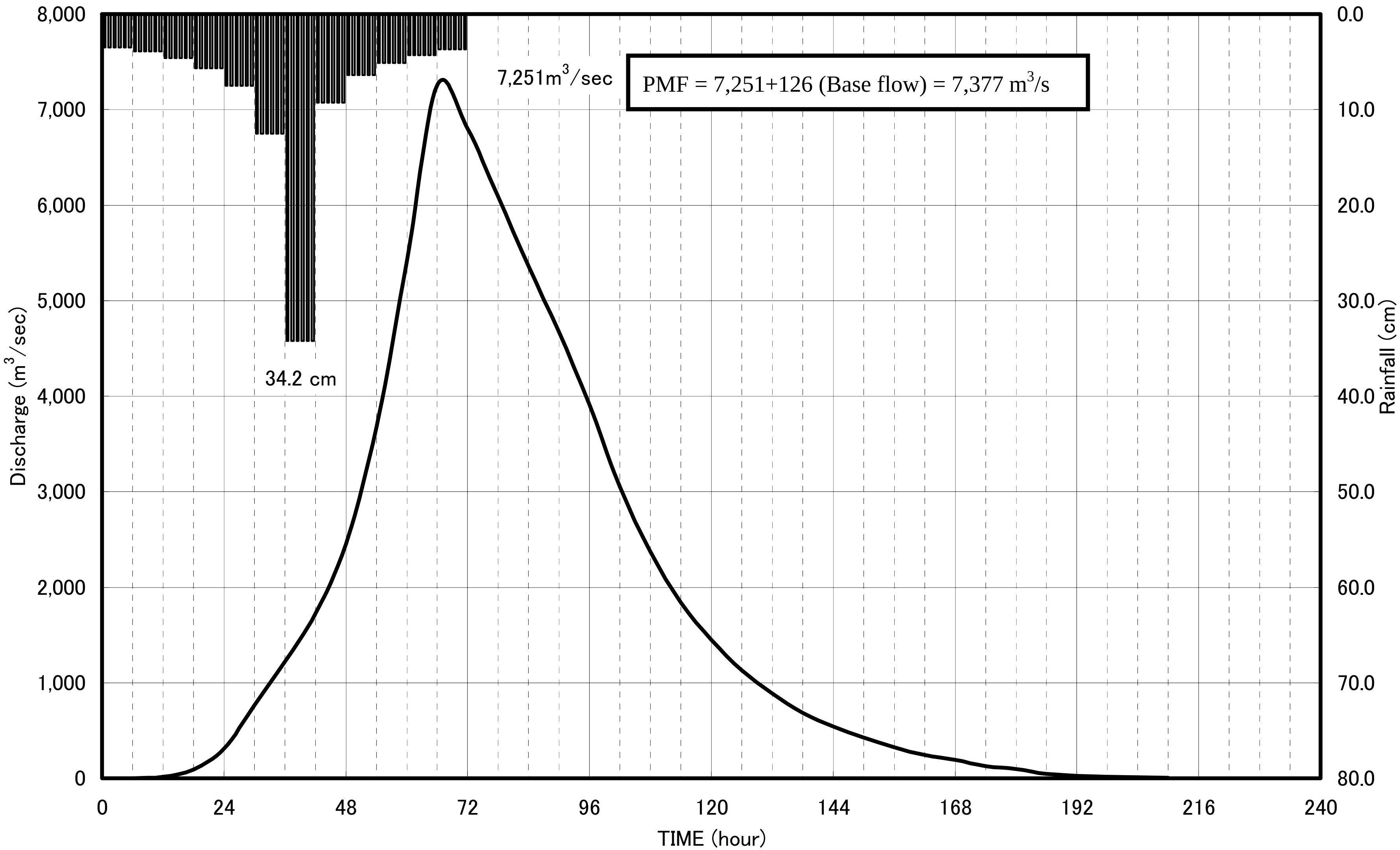


**Fig. 6.4.2-4 Synthesis of Unit Hydrographs**

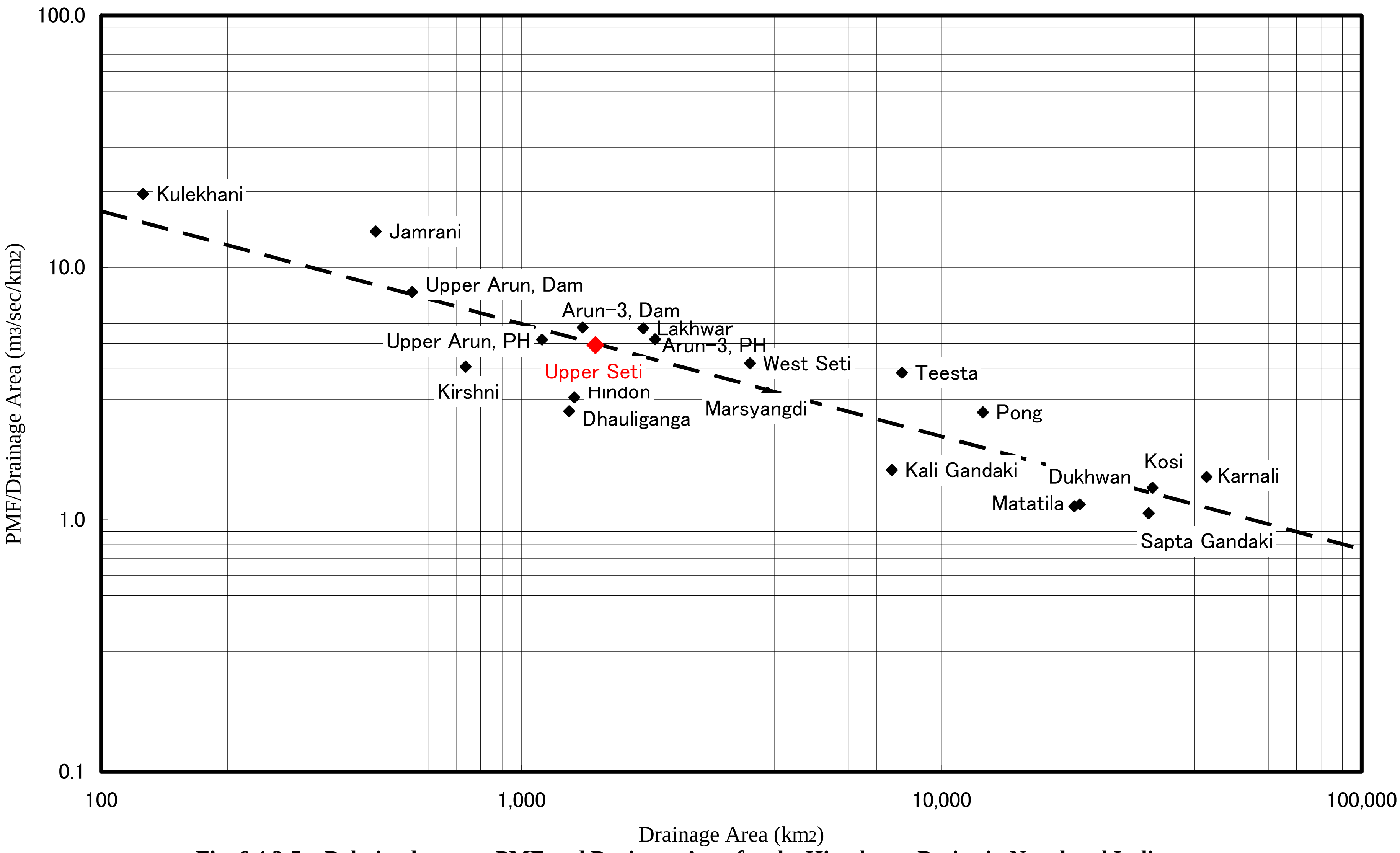


**Fig. 6.4.2-5 Relation between PMF and Drainage Area for the Himalayan Basins in Nepal and India**