Banjšice, which further aggravates the comprehension of hydrological conditions. These are the unspecified discharges of the Mrzlek spring which flows into the Soča in the area of the Solkan HPP reservoir and, thus, cannot be directly gauged.

## 2.3. THE CLIMATE OF THE TRNOVSKO-BANJŠKA PLANOTA (J. PRISTOV)

### 2.3.1. Meteorological conditions

The Trnovski Gozd, the Banjšice and the Nanos are the first mountain barrier (the altitudes of peaks between 1000 and 1500 m above sea level) on the way from the Mediterranean, or the Northern Adriatic, towards the north and the north-east. Naturally, there is the Kras plateau before it, yet, it mainly does not exceed the altitude of 600 m. Therefore, the orographic precipitation are modest on the Kras, but they already become rather abundant at the barrier running from the Banjšice to the Nanos, and they are the most abundant at the southern part of the Julian Alps. There, the altitudes of the peaks already reach approximately 2000 m, and the average annual precipitation already amounts to 4000 mm, which is the highest value in the Alps. This barrier represents a divide between the Mediterranean and the Alpine climates. The Vipavska Dolina and Goriško region, both located at the southern rims of the Trnovski Gozd, are under the intense influence of the Mediterranean climate. Yet, the Trnovski Gozd, the Banjšice and the Nanos already have the real Alpine climate with the abundant snow during the rather cold winters.

The precipitation are abundant all year round, with the explicit maximum in October and November. In the heart of the Trnovski Gozd, i.e. the area of Golaki, they exceed the precipitation average over the period of 30-years, which is 3000 mm, and also the entire area of the Banjšice, the Trnovski Gozd and the Nanos, annually receives over 2000 mm of precipitation, on the average.

The most intense precipitation very often occur in October, up to 900 mm (Vojsko 888 mm; Mrzla Rupa 855 mm; Otlica 702 mm), but on the average, October is not the wettest month. Namely, oscillations of precipitation quantity are extremely sharp in this month: on the one hand, the monthly precipitation extremes occur with heavy precipitation, and on the other, this month often receives the minimum precipitation and sometimes - although it happens rarely - they do not fall at all (in 1965). November is the month with the largest average quantity of precipitation, yet the oscillations are not as sharp as in October, and therefore, the annual extremes do not occur in this month. Although rarely, but very heavy precipitation also occur in the month of September.

It is typical of autumn precipitation that they are very intense in shorter periods, and they are often unevenly distributed over the discussed area. It happens that the intensity of precipitation in individual areas differs a lot (the ratio of 1:5), which is not the case with the convective precipitation, but with the orographic precipitation related to the front system. For determining the quantities of precipitation by individual precipitation situations, a rather dense network of precipitation gauging stations would be necessary, or, great errors could occur due to the intensely agitated precipitation area.

The Trnovski Gozd receives the majority of precipitation in autumn, when the sea is still rather warm, and the very warm and humid air, driven by the SW winds, flows in from above the Mediterranean. When on its way during the precipitation situation this air reaches the first higher mountain barrier, it must ascend to pass it, which results in the orographic precipitation. Such situations often occur during the generation of secondary cyclones in the Genoa bay or above the Northern Adriatic. It is in autumn and spring when the secondary cyclones are most frequent, only that the warm air in autumn contains quite a lot of humidity. The humidity of air is considerably lower in spring due to the cooler northern Mediterranean, and therefore, the orographic precipitation are not so abundant.

The monthly quantity of precipitation considerably exceeds the evaporation. July is the least wet month, and even then, more than 160 mm of precipitation fall; concurrently, it is also the month with the most intense evaporation, when the potential evapotranspiration (ETP) on the Nanos amounts to 130 mm, and at Čepovan, to 122 mm (Fig. 2.10 and 2.11). Since the monthly precipitation, on the average, always exceed the ETP, it is assumed that the actual evapo-

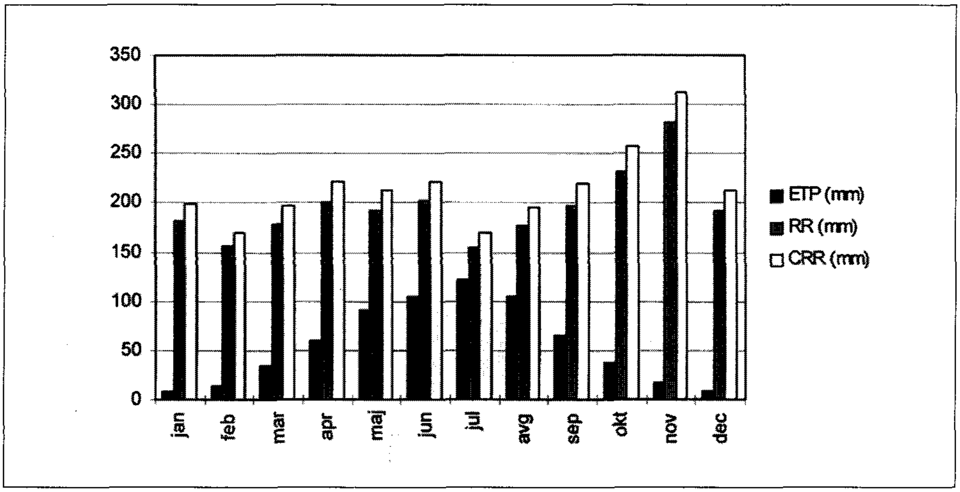

*Fig. 2.10: Mean monthly values of potential evapotranspiration (ETP), precipitation (RR) and corrected precipitation (CRR) on the station Čepovan.*

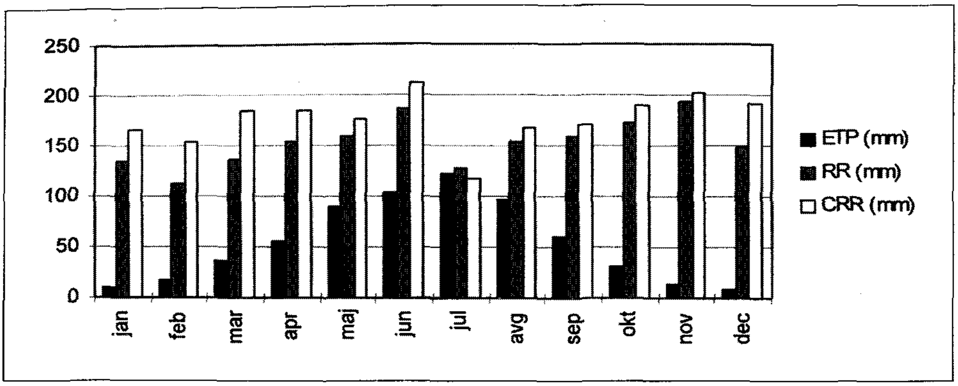

*Fig. 2.11: Mean monthly values of potential evapotranspiration (ETP), precipitation(RR) and corrected precipitation (CRR) on the station Nanos-Ravnik.*

transpiration (ET) equals to the potential evapotranspiration (ETP); therefore, in the continuation of this paper, only the term evaporation is used and is equalised with the ETP. On the average, more than 300 mm of precipitation fall in November at Vojsko and Mrzla Rupa, but only 15 mm evaporate. In October, the same area receives more than 250 mm of precipitation, but only about 35 mm evaporate.

On the average, the greatest discharges occur in October, although the greatest quantity of precipitation fall in November. The air in the inland of Slovenia is already so cold in this month that the higher altitudes of the Trnovski Gozd are already covered with snow, which is immediately manifested in the reduced discharges. The secondary maximum of discharges occurs in the spring months when the snow cover is melting.

As it has already been mentioned, the Trnovski Gozd and Nanos represent the divide between the Mediterranean and the Alpine climates. When the inland of Slovenia is filled with the cold air from the north or the Northeast, great temperature differences originate at the foregoing barrier, as well as great pressure gradients. When the air descends from above the Trnovski Gozd and the Nanos towards the Vipavska Dolina and the Kras, it is adiabatically warmed, yet, it is still cooler than the air above the northern Adriatic. The result of this temperature difference is that the cold air cascades down the slopes, and reaches great velocities, while due to the agitated landforms, violent turbulences are generated. This strong wind is known under the name of bora, and reaches the velocities of up to 200 km/h with individual gusts. Relatively frequent occurrence of the bora, of smaller velocity of course, is also the cause that the air above the Kras and the Vipavska Dolina is dryer than the air above the other regions of Slovenia. Such relatively dry atmosphere provides for the natural drying of ham which is famous as a speciality under the name *kraški pršut* (i.e. the karstic crude ham).

## 2.3.2. The water balance

The equation of water balance

$$P = Q + E + N^* + R \quad (1)$$

expresses that in a specified area the precipitation, P, equal the sum of water discharges, Q, evaporation, E, the changes in water reserve, N*, and the water captured for the biological and industrial consumption, which is pumped from the studied area, R. In our case, the amount of the pumped water is small in comparison to the possible errors at precipitation gauging and making the precipitation maps, and therefore, it is not directly taken into consideration.

For the longer periods it can be assumed that the changes in water reserves in an average year are negligible, and the equation is reduced to the following items only:

$$P = Q + E \qquad (2)$$

which means that the precipitation in a specified area equal the sum of discharges and evaporation.

For the needs of evaluating tracing experiments we wished to obtain water balance for the short periods, i.e., for the individual precipitation situations, or, at least for the periods of several months during which the individual tracing experiments were performed.

The results of water balance for the shorter periods were not encouraging although we tried to do our best when making the basic maps.

For the precipitation map of wider area of the Nanos and the Trnovsko-Banjška Planota, the data were made use of from 40 precipitation stations where daily precipitation were gauged at 7 hrs (Archives of the Hydrometeorological Institute, Slovenia).

In individual precipitation situations, very explicit minor precipitation cells occurred, which were impossible to be correctly presented through such low density of precipitation gauging station network.

During the relatively stationary precipitation situations, the differences of precipitation between individual areas (from the north towards the south, or, from the west towards the east), even reached the ratio of 10:1. At such sharp precipitation changes, errors occur in the making of precipitation maps, especially at the determining of precipitation for the relatively small contributing areas, particularly if the watersheds are not strictly defined.

The equation of water balance in which the precipitation are equal to the sum of water runoff and evaporation, apply only in case when the changes in the water reserve N* are negligible, which is almost impossible to expect at precipitation situations. With heavy precipitation the water reserve in the ground considerably increases. In the late autumn months, the higher altitudes of the Trnovski Gozd are already under the snow cover which can contain quite large water quantities.

To avoid all these troubles, the 30-year water balance was taken as a basis. Let it be assumed in this case, that the water reserve at the end of the period equals to that at the beginning, since the difference in an average year is minimal in so long a period, thus, it means $N^* = 0$.

Also at the gauging of precipitation, the casual errors are eliminated by averaging; however, the systematic errors remain, which can be considerably reduced by applying supplementary procedures (precipitation correction due to wind, etc.).

Due to the considerable oscillation of annual precipitation in the 30-year period, the water balances were determined also for the 5-year and the 2-year periods, and it was also assumed that $N^*$ was negligible. Although this is a rough premise, yet, it is acceptable were the accuracy taken into consideration, of the precipitation gauging, which is particularly problematic at the higher altitudes due to wind, while the terrain configuration does not allow that the vertical precipitation gradients be directly applied.

## Precipitation determining

Precipitation are gauged with a gauge of Hellmann type which collects too little precipitation in windy weather. The experiments proved that, at wind speed of more than 5 m/sec, only 22 % of the actual snow precipitation are gauged, and 87 % of the actual rain precipitation (YANG et al. 1994). Experiments on precipitation gauging in wind conditions were not carried out in Slovenia; therefore, we assumed the WMO intercomparison results.

For the stations registering wind observations, force of wind was reduced for each precipitation day, to the altitude of Hellmann's gauge, and then, the adequate coefficient or the anticipated precipitation quantity was calculated. On the basis of gauge locations and direct obstacles, the precipitation stations were ranked into classes. For each class, the monthly and annual coefficients for the correction of precipitation were specified, on the basis of data from the stations with wind observations. By means of these coefficients, the quantities of precipitation were also corrected for the stations without wind observations.

Because the precipitation in Slovenia are heavier than in the places where the experiments were performed, it is assumed that also the rain drops and the snow flakes, on average, are slightly greater and heavier, respectively. Therefore, we reduced the corrective coefficients by 20 % for the places at the altitudes between 1000 m and 1500 m, and by 35 % for the places lying higher than 1500 m. Thus, the corrective coefficients amount to between 1.01 and 1.05; for the very exposed locations only, between 1.05 and 1.08; for the exposed locations above 1000 m in the area of the Nanos and the Trnovsko-Banjška Planota, up to 1.14.

Besides the increase of precipitation due to wind, we also took into account the increase of precipitation due to the gauge moistening. Whenever the gauge is emptied, a slight amount of water remains on the bottom and the sides of container. Following the results of laboratory testing, we took for the precipitation days with more than 1 mm of precipitation, the correction of 0.3 mm for a rainy day, and the correction of 0.15 mm for a day with snow precipitation. For all the precipitation maps, the corrected precipitation data were made use of.

In the making of precipitation maps (Fig. 2.12), the vertical precipitation gradients were not taken into account (a rather even increase of precipitation with the altitude), but the distribution was assessed subjectively, depending on the terrain configuration and precipitation data. Namely, it turned out that certain lower-lying places had received more precipitation than the higher-lying ones (Mrzla Rupa, 930 m above sea level - 2940 mm; Vojsko, 1070 m above sea level - 2800 mm; similar situation occurs in some other stations).

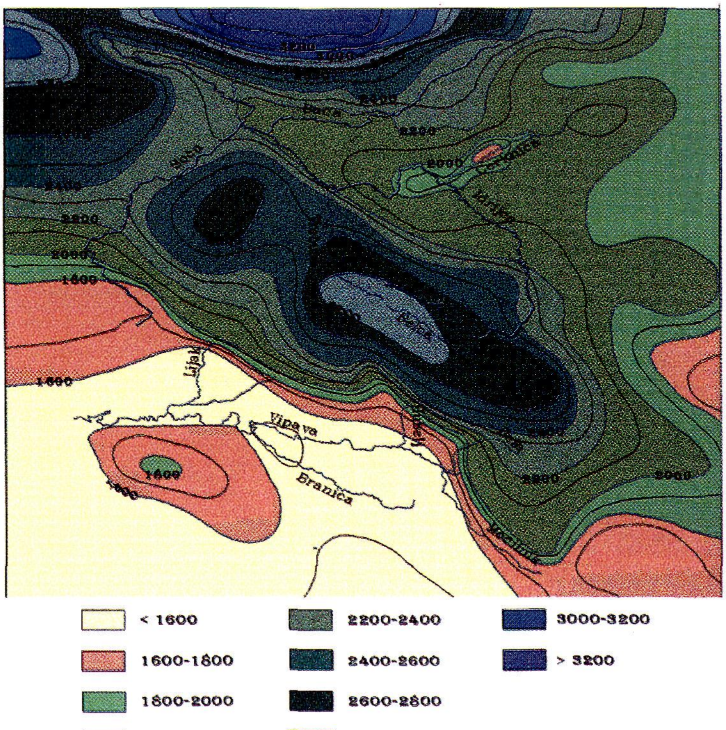

*Fig. 2.12: The 1961-90 period precipitation map (mm).*

The quantity of precipitation depends on the location of the valleys and mountain ridges. Certain laws were taken into consideration which, however, are based on the physics related explanation (the narrow valleys lying perpendicular to the direction of SW winds receive abundant precipitation, much more than the valleys lying in the direction of SW winds, especially if these valleys are located in the lee of mountain ridges, etc.).

## Evaporation

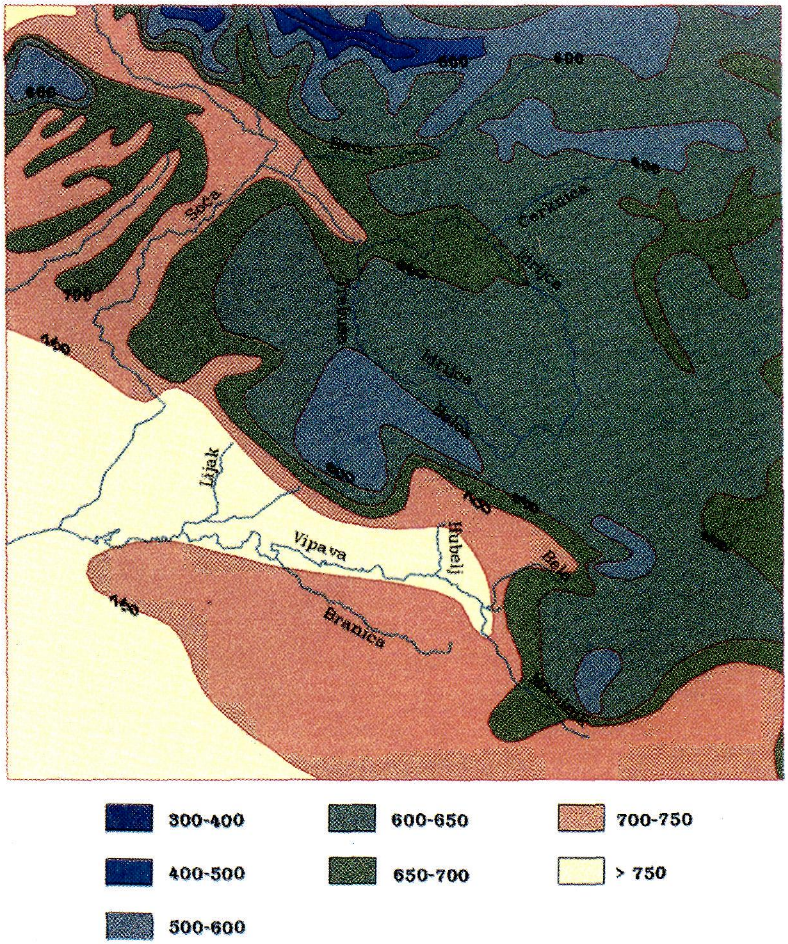

*Fig. 2.13: The 1961-90 period evaporation map (mm).*

For the calculation of runoffs on the basis of precipitation and evaporation, an evaporation map is indispensable. Since the precipitation in our case are much more abundant than the evaporation, considerable simplifications are applied to the evaporation data; yet, approximately equal accuracy is obtained with both maps. Calculated for the climatological stations was the potential evapotranspiration (ETP), following the corrected Penman method, by making use of the daily values of four weather parameters: air temperature, relative humidity of air, wind, and insulation (DOORENBOS et al. 1986). Since the monthly precipitation above the discussed area are always greater than the calculated ETP, we assumed that the evaporation is equal to the ETP, only for the lower-lying Kras plateau where the stone surface dries fast, we reduced the ETP by 10-15 % to obtain the evaporation.

The annual quantity of precipitation on the Trnovski Gozd is often greater than the evaporation. If the accuracy of precipitation gauging and simplification are taken into consideration, the accuracy of evaporation data is soon satisfactory. For the areas where not enough data were available, we applied the vertical gradients of evaporation which had been calculated on the basis of data from this area.

The difference between the actual surface area and its horizontal projection which is presented on the maps is taken into account in such a way that the calculated evaporation is being evenly increased with the altitude, and at the altitude of 1500 m, the addition amounts to approx. 10 %; on the plateaux, this increase is not taken into account (Fig. 2.13).

## Runoff

The precipitation map (Fig. 2.12) and the evaporation map (Fig. 2.13) were digitised and then, the evaporation field was deduced from the precipitation field. Thus, we obtained a runoff map, specified in mm. Since all the maps were made for an average year in the thirty-, five-, and two-year periods, the values presented in mm also represent the annual runoff in litres per square meter (Fig. 2.14). This map has similar deficiencies as the precipitation map, because the values of precipitation are much greater than the values of evaporation. The calculated discharges for various gauging profiles are obtained from the runoff map by means of planimeter on the basis of hypothetical watersheds. The comparison of the gauged discharges with the calculated discharges and their deviations are a warning signal for the problems of watersheds and the deficiencies in the analysis of individual parameters. Usually, the greatest relative deviations occur at very small river basins, while at larger river basins, the relative correspondence is much better.

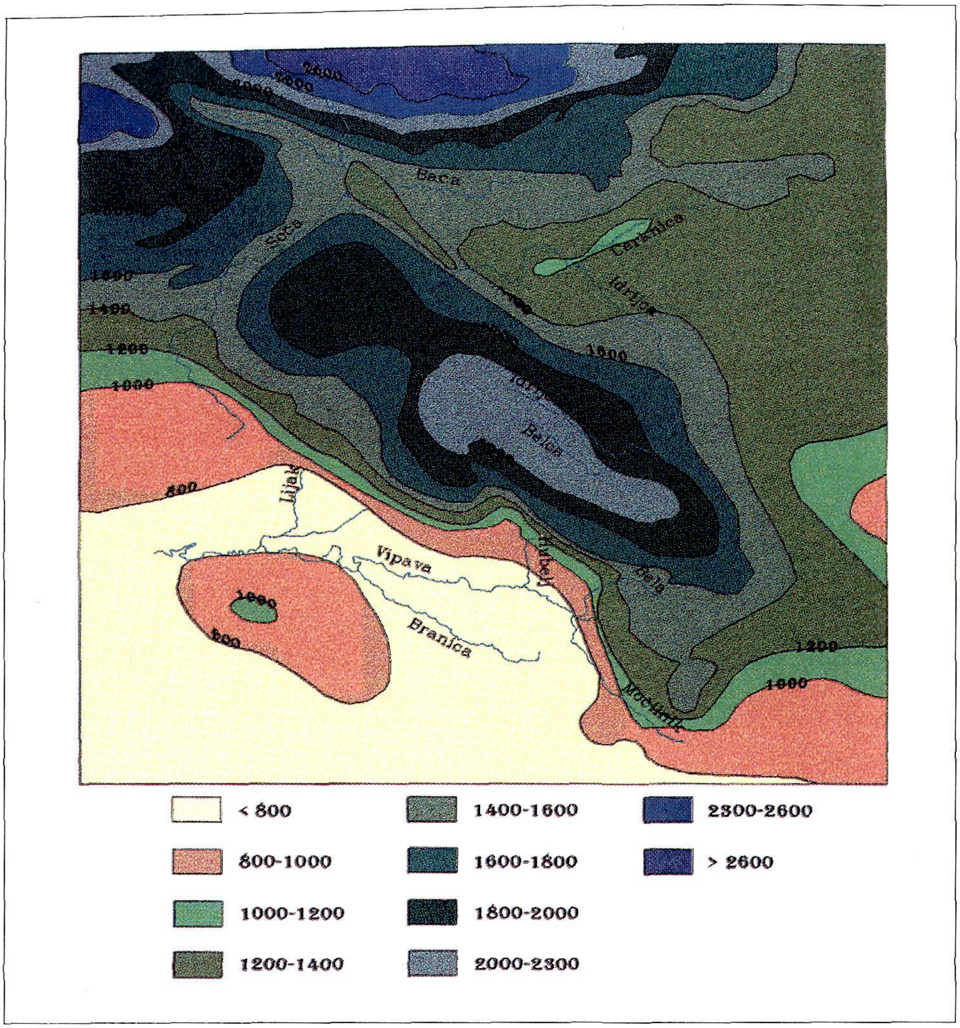

*Fig. 2.14: The 1961-90 period discharge map (mm).*

## 2.4. GEOMORPHOLOGIC REVIEW OF TRNOVSKO-BANJŠKA PLANOTA (P. HABIČ)

### 2.4.1. General orographic-hypsographic properties

Among the valleys of the Soča, Idrijca, Pivka and Vipava rivers in western Slovenia lies a mountain ridge of the High Karst, called Trnovsko-Banjška