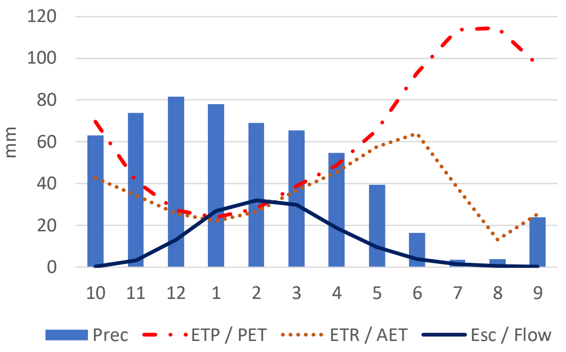
**INSTITUTO SUPERIOR TÉCNICO**
**Master in Environmental Engineering**
**Joint Master Programme on Groundwater and Global Change, Impacts and Adaptation**
**Hydrology, environment and water resources**
**School year 2018/19 – Exam 1 – Duration: 2 hours**

Answer each of the following questions, if needed using the formulas presented at the end of the exam.

1. Consider a reservoir that inundates 15 km$^2$ of land and that has a hydrographic basin with 450 km$^2$. (excluding the 15 km$^2$ of the reservoir). In a given year this river basin receives an annual precipitation equal to 1200 mm and loses 750 mm by evapotranspiration. Knowing that the same precipitation values occurs over the reservoir and that 950 mm evaporate from the reservoir, as well as that it is necessary to ensure a flow of 3 m$^3$/s downstream of the reservoir for ecological purposes, estimate the annual volume that can be supplied for various uses.
2. The solar radiation reaching the Earth surface varies from 25% to 75% of the solar radiation at the top of the atmosphere. Explain why this happens and justify the limits of this range.
3. The figure on the left represents the variation within a hydrological year of the monthly averages of precipitation, potential evapotranspiration, actual evapotranspiration and runoff. Explain the variation of each of the curves and why they peak at different times of the year.




4. Consider the flow duration curve presented in the table. Estimate the annual volume that can be used by a mini-hydropower plant installed in the water course and that can operate for a flow range between 5 and 10 m$^3$/s.

| Average duration (days) | 1 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 365 |
|---|---|---|---|---|---|---|---|---|---|
| Avg daily discharge (m$^3$/s) | 35 | 20 | 12 | 7 | 3 | 1 | 0 | 0 | 0 |

5. The statistical analysis of a sample of annual maxima discharge values generated in a river basin has an average of 100 m$^3$/s and indicates that the distribution of these values can be explained by Gumbel's law. According to this law the estimated annual maximum discharge for a return period of 50 years is 500 m$^3$/s. Estimate the annual maximum discharge associated with the return period of 100 years.
6. Consider a soil with a depth of 80 cm, a porosity of 30% and a field capacity of 200 mm.
   a. If the soil moisture content is 180 mm, what is the degree of soil saturation?
   b. If, under the conditions of the previous paragraph, there is an infiltration of 30 mm, what is the resulting soil water content and the amount of water that drains vertically to the lower layers of the lithologic column?
7. Consider a soil with an infiltration capacity when dry of 40 mm/h, an infiltration capacity of 5 mm/h when saturated and an Horton formula' k constant of 0,6 h$^{-1}$. Following a severe and long drought the soil received significant precipitation which lasted 30 min. Draw the graphs representing the evolution of infiltration rate and cumulative infiltration, defining at least 4 points in each of those graphs.
8. The table shows the net precipitation and discharge records from a flood registered at a river cross section.
   a. What is the area and time of concentration of the watershed?
   b. Estimate the hydrograph produced by an event in which precipitate 15, 30, and 18 mm in three consecutive 30-minute periods.

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| Time interval (min) | 0-30 | 30-60 | 60-90 | 90-120 | 120-150 | 150-180 | 180-210 | |
|---|---|---|---|---|---|---|---|---|
| Net precipitation (mm) | 10 | 20 | 12 | 0 | 0 | 0 | 0 | |
| Time (min) | 0 | 30 | 60 | 90 | 120 | 150 | 180 | 210 |
| Discharge (m3/s) | 0 | 30 | 110 | 176 | 160 | 88 | 24 | 0 |

9. Consider a watershed with an area of 50 $km^2$ and a time of concentration equal to 1.5 h. The IDF curve for a return period of 100 years applicable to that watershed is represented by the following equation: i (mm/h) = 350 $t(min)^{-0.524}$. Using the rational formula (assuming an aggravating factor), compute the watershed flood peak flow for the same return period (use C=0.75).

10. During drought periods groundwater reveals to be a resilient resource. What is its importance in water catchment management?

## Formulas

Standard normal table

Tabela de valores da normal reduzida

| F(X) | 0.500 | 0.600 | 0.700 | 0.800 | 0.900 | 0.990 | 0.999 |
|---|---|---|---|---|---|---|---|
| Kn | 0.000 | 0.253 | 0.524 | 0.842 | 1.282 | 2.326 | 3.090 |

Gumbel probability factor: $K_p = -\frac{\sqrt{6}}{\pi}\left[0.5772 + ln\left(-ln(p)\right)\right]$

Horton model:

$$\begin{cases} f = f_c + (f_0 - f_c)\, e^{-k\,t} \\ F = \int_0^t f \cdot dt = f_c\, t + \frac{f_0 - f_c}{k}\left(1 - e^{-k\,t}\right) \end{cases}$$

with f in mm/h; F in mm; k in 1/h and t in h

Majoration factor: $f = 2 - \sqrt{n}$