Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course

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Practical Work : Case study hydropower optimal water allocation and financial study

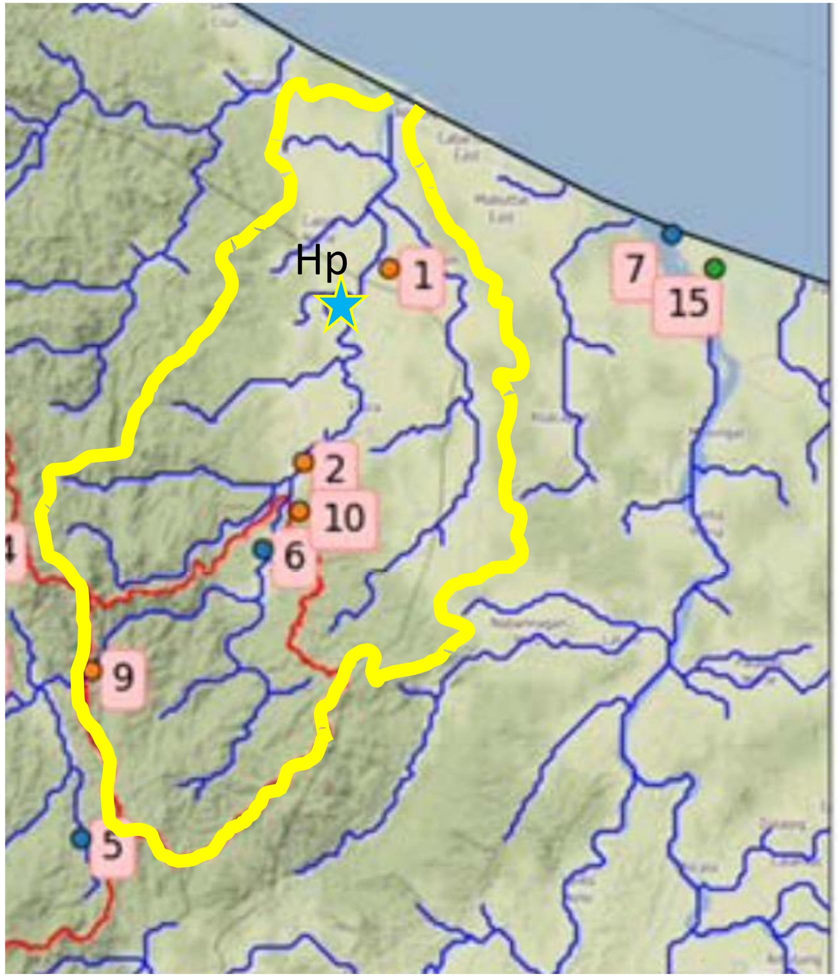
Project description

Consider the following catchment located in the Philippines where a hydropower scheme of mixed type (i.e., cascade without storage) should be built (see slide 2) with the power house located near station 1 and the flow diversion located upstream (cyan star). Near station 1 a flow diversion for irrigation purposes is being considered (see slide 2). The contribution of the small affluent upstream of station 1 can be neglected so that river discharges measured at station 1 are representatives of the flow available for the hydropower generation.

The local hydrology constitutes one of the larger uncertainties and risks for the design, construction and operation of a hydropower project. Hydrological risks can be summarized into two main categories:

> Project revenue: Under or overestimation of available inflow for energy generation;

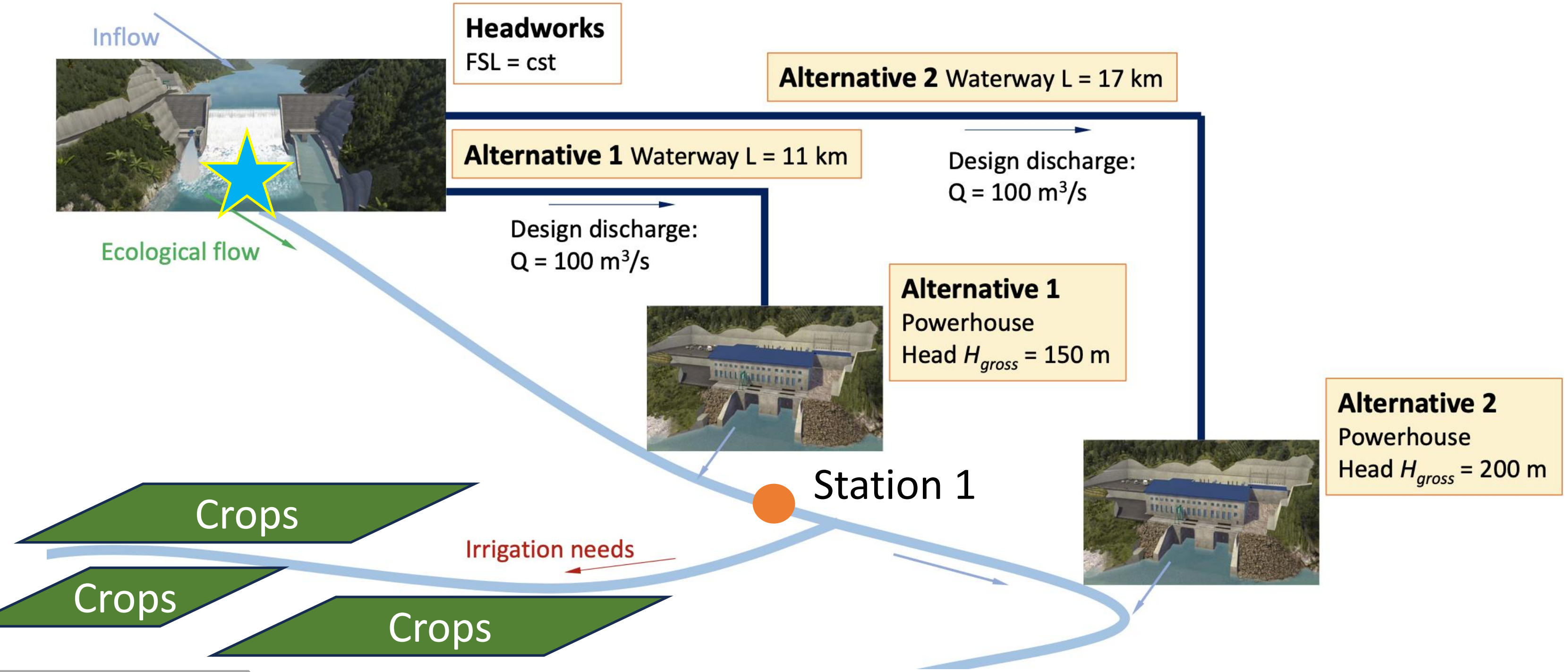
> Natural hazards: Damage to project structures during construction or operation.



Project description

An hydropower scheme (mixed type, i.e. cascade without reservoir) is being considered with two alternative construction plans that need to be assessed for feasibility and costs in order to optimize releases for environmental and irrigation purposes. All discharges can potentially be turbined and water is being withdrawn upstream (star point in slide 1). In alternative 1, the power house is located right before the diversion (station 1) where a water fraction is again withdrawn towards an irrigation setup. In this case ecological flows from the diversion to the power house imply a minimum flow policy plus additional non-proportional releases that need to be assessed. In the alternative 2, the power house is located after the diversion for a higher elevation difference. However, this also means that ecological flow besides non-proportional rules require additional releases to satisfy the irrigation demand.

<u>Project GOALS</u>:
- Assessment of optimal funcitoning policy for both solutions and comparison with Pareto optimum for energy production vs ecological performances;
- Financial benefit-cost analysis to select the best alternative
- Preparation of a basic Environmental Impact Assessment focusing at the hydraulic aspects of the project only.



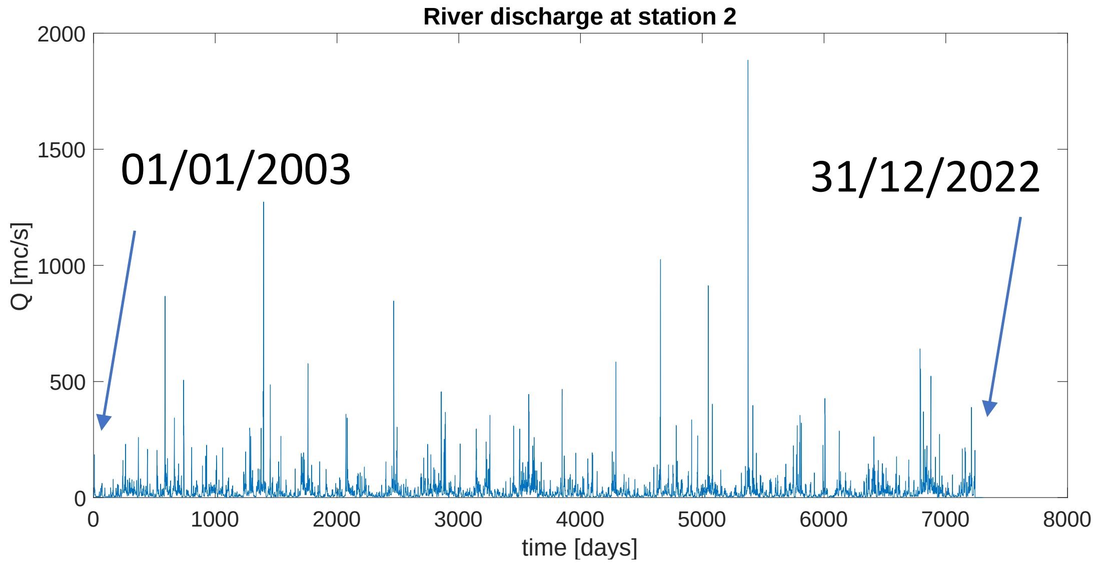
Data description

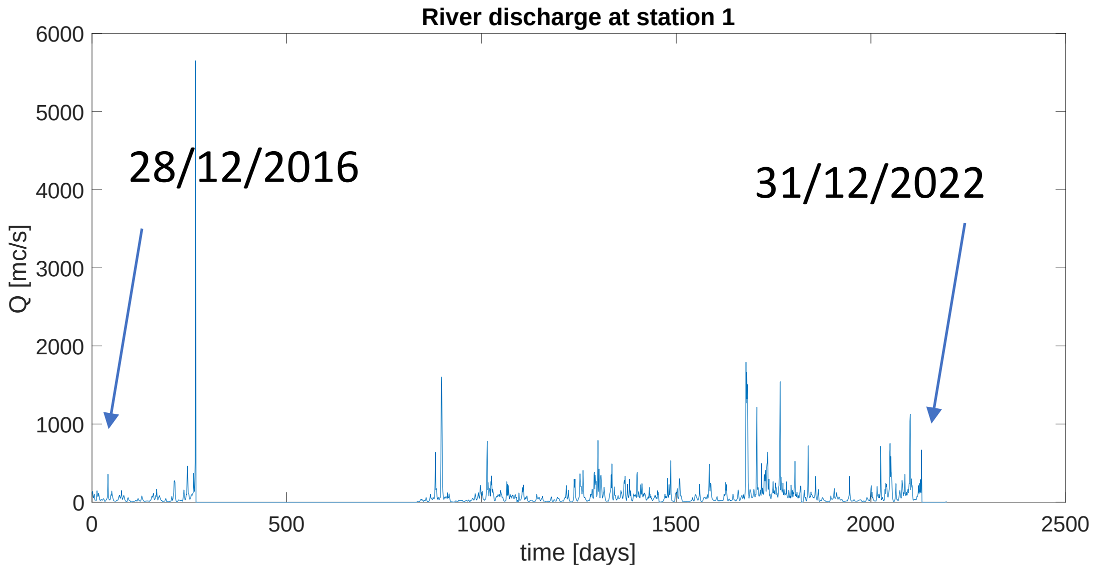
River data are measured in station 1 for a period of 6 years but present interruptions due to a station malfunctioning and a damage occurred because of a destructive event, which caused an interruption of about 1 year.

There are actually two problems:

1) Measured discharges are available for a section upstream (i.e., station 2) but do not correspond to the total catchment area;
2) Data in station 1 of interest presents gaps that need to be filled and a total series of 30 years of daily data must be available for enough statistical reliability;

For further project purposes we therefore need to generate a 30 year series of daily streamflow representative of the discharge in section 1 where the power station has to be built.





Available data

- 20 years of incoming daily mean inflows measured at Station 2;
- 6 years of incomplete incoming daily mean inflows measured at Station 1;
- Basic hydropower technical data and power efficiency curve
- Climatic conditions to calculate potential evaporation $ET_{0;}$
- Crop coefficient k_c and related seasonal variations
- Fish suitability curves for both adults and juveniles
- Electricity tarifs and concession period informations

Hydropower technical data:

Design discharge:	100 m^3/s
Gross head:	H_{gross}
• Alternative 1:	350 m
• Alternative 2:	500 m
Head losses (const.):	$dH = 5\%\ H_{gross}$
Net head:	$H_{net} = H_{gross} - dH$
Planned/unplanned outages:	5%
Efficiency:	90%

Electricity tariff

Base Case Scenario:

• Peak:	8h/day	US Sc 6 /kWh
• Off-peak:	16h/day	US Sc 3 /kWh

High Demand Scenario:

• Peak:	8h/day	US Sc 10 /kWh
• Off-peak:	16h/day	US Sc 5 /kWh

Concession period: 20 years

Operation and Maintenance (OPEX):
2% of CAPEX/year

Project tasks (Week9 – 14/04/2025)

- Purpose of today is to perform a data analysis of the daily streamflows in order to characterize and prepare the hydrological dataset for further project steps. In particular, today tasks are:

  a) Plot the last years of available data for the two stations S1 and S2 one vs the other to see if data are correlated (fit a polynomial function of adequate degree) and use the correlation structure to fill in the missing data. Neglect the noise;

  b) Use the same correlation relationship to prolonge the S1 series to the same length of the data serie in station 2. This will only be 20 years in total and we need to have at least 30 years. The swapping technique might be good, but we need to check if some temporal correlation affects the data before choosing the years to swap. To do this:

    b1) Build a series of the annual maxima of S1 data and check for serial correlation between them;

    b2) Use information from serial correlation to understand the relationship between the different hydrological years and build the additional ten years of data using the swapping technique by selecting the years that allow to respect the serial correlation;

  c) Build the flow duration curve of the 30 years dataset for reconstructed station one data and calculate the reference minimal flow for instream flow protection based on the Q_{347} approach;

  d) Obtain the daily mean annual behaviour from data;

  e) Build the monthly mean annual time series, which will be used for the financial analysis;

  f) Use the reconstructed data for S1 to build two new series as the sequence of wet periods and the sequence of dry periods. To the purpose, use the annual mean as discriminant value for the wet years (above the mean, Aug-Dec) and viceversa. We will use these series later to build the Pareto frontier of the system