Assessment of hydropower resources

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Assessment of hydropower resources

- Relevance of surveys, data assessment and analyses to the success of the project.
- Required data and field survey.
- Key element: hydrological data.
  Data gathering, analyses, relevance for project.
Why?
Mitigating project risks through sound assessment and analysis.

**Key Challenge:** (Small) hydro power development involves a number of *risks* which deter developers and investors.

- Hydrological Risk
- Construction Risk
- Risk of Design Flaws
- Social and Environmental Risks
- Political Risks

Detailed site assessment, appropriate analysis and project preparation leads to a vast mitigation of these risks.

Most risks can be identified and their potential impact can be quantified in risk and sensitivity analyses.
When?
Right timing reduces the risk of needless cost and conflict.

Site Surveying and Data Collection
• should be conducted, if an Initial Technical Project Assessment (‘Desk Study’) comes to the conclusion that a site is potentially attractive.
• should only be conducted, if there is a realistic chance that a potential project can be funded and implemented (Particularly for rural electrification projects: Avoid raising expectations among local population that can not possibly be fulfilled later!)
• should be conducted during times with potentially lowest stream flows
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During site investigations data is collected which is very critical for successful technical and financial planning

| Hydrological Analysis | • flow duration (→ project optimisation, design flow)  
|                       | • flood flows (technical safety of project components) |
| Topographical Mapping | • head available for power generation  
|                       | • optimum positions and alignment for structures  
|                       | • distances for transmission  
|                       | • accessibility |
| Geological Analysis   | • stability of structures  
|                       | (the degree to which these investigations are conducted depends on type and dimension of structures) |
| Social and Environmental Studies | • identify demand (off-grid electrification)  
|                       | • to identify potential risks / conflicts and means for mitigation  
|                       | • feasibility to fulfil obligations of legislation, donors and lenders |

Neglect in any of these assessments leads to flaws in optimisation and design, eventually reflected in the project’s feasibility
Very critical information during project planning and optimisation are the available flow and head

$$P_{el} = \rho \cdot g \cdot Q_d \cdot H_n \cdot \eta$$

**Design Discharge** $Q_d$
Very critical value, based on complex hydrological analysis.
- **too high** $Q_d$: HPP oversized, expected annual generation not achieved, revenue stream smaller than required, financial viability critical
- **too low** $Q_d$: HPP dimensioned too small, more attractive development solution possible
- **wrong** $Q_d$: not matching peak efficiency point of installed turbine

**Net Head** $H_n$
Very critical value, but relatively easy to determine with topographic survey.
- **wrong** $H_n$: leads to mismatch of turbine (strong impact)
Very critical information during project planning and optimisation are the available flow and head

\[ P_{el} = \rho \cdot g \cdot \eta \cdot Q_d \cdot H_n \]

\[ = 7 \cdot Q_d \cdot H_n \]

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- **wrong \(H_n\)**: leads to mismatch of turbine (strong impact)
The HPP planning from initial assessment to detailed engineering design should follow a proven approach

Project development should be conducted in a stepwise approach:

1. Desk study
2. Initial site assessment / Reconnaissance visit
3. Pre-feasibility study
4. Feasibility study
5. Detailed engineering design & Tender documents
6. *Implementation (Tendering, Contracting, Construction, Testing & commissioning, Operation and Maintenance)*

→ described in more detail in session “Project cycle and planning tools”
### Suitable methods for head measurement and topographic survey

#### Site Reconnaissance
- Altimeter
- Hypsometer

#### pre-Feasibility & Feasibility
- Theodolite, total station
- Stereoscopic aerials, triangulation and control point survey

#### Detailed design
- Additional topographic survey of specific areas, if required

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**only Micro Hydro**
- Clinometer / hypsometer and compass

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[Image of a surveyor taking measurements]
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Catchment hydrology
Why is a hydrological assessment indispensable?

The hydrological study is the basis for the design of the project

- determination of capacity to be installed
  (design of civil structures & electromechanical equipment)
- calculation of yearly energy production
- statement about the profitability of the plant

- Ultimately the economic and overall viability of the project depend on the hydrological analysis.
- If predicted flow is not available, less than planned electricity will be generated.
How to obtain runoff data?
Permanent gauging station

Register water level / stage in regular intervals.

Options
a) data logger
   (automatic recording)
b) staff gauge
   (manual reading)

➔ It is absolutely required to take discharge measurements to relate water level [cm] to runoff [m³/s].
Important aspects for gauging stations

• easy access during low and high river levels
• far from confluences (avoid tailback)
• straight section of the river, no curves or eddies (parallel streamlines)
• well-defined cross section / river bed which does not change in time (no sedimentation, no erosion)
• stage-discharge relation (= rating curve) must be clear and well-defined over the whole measuring range (from low to high runoff!), no lateral overflowing etc.
Flow measurements are required to establish the rating curve

→ Any collected water level (stage) data is completely useless if the relationship between flow and stage is not known!

• The established relationship is used to transform the observed stages into the corresponding discharges.
A large number of different flows must be measured to establish a reliable rating curve.
The most common methods to measure stream flow are the use of a current meter and the salt dilution method.

**Current meter** (velocity-area-method)
- Can be applied from small to large rivers
- Accurate, if measured with appropriate care

**Salt dilution method** (tracer method)
- Small to medium streams
- Using a tracer (commonly salt) to calculate the stream flow as function of the dilution over time
Stage measurements in combination with measuring weirs are a good option, particularly for small streams

- Very accurate flow calculation as (empirical) formulas are available for common weir shapes.
- Only a very limited number of flow measurements are required for check results.
- Recommended mainly for small streams (<0.5 m³/s).
- Possible also in medium size streams but installation difficult.
Further methods to measure stream flow might be applied if their limitations are considered

**float method**
- During initial site assessments only due to very limited accuracy!
- Measurements can be corrected with factors for different types of river beds.

**bucket method**
- Accurate, but suitable for very small streams only (<20l/s).

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Recap: Procedure to establish a flow duration curve (FDC)

Continuous water level registration + Rating curve

Hydrograph + Flow Duration Curve (FDC)

Recap: Procedure to establish a flow duration curve (FDC)
A number of methods with different pros and cons are possible

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy</th>
<th>Time</th>
<th>~ Price</th>
<th>Mobility</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RECOMMENDED:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current meter</td>
<td>good</td>
<td>1-3 hrs</td>
<td>&gt; 1 500 $</td>
<td>good *</td>
<td>only steady streams with smooth bed</td>
</tr>
<tr>
<td>Salt dilution</td>
<td>good</td>
<td>½ hr</td>
<td>&gt; 400 $</td>
<td>very good</td>
<td>good for rough mountain streams</td>
</tr>
<tr>
<td>Measuring weir</td>
<td>good</td>
<td>dpd. site cond.</td>
<td>-</td>
<td></td>
<td>&gt; 0.5 m³/s difficult, suitable location</td>
</tr>
<tr>
<td><strong>OTHER METHODS:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bucket / Drum</td>
<td>good</td>
<td>1 hr</td>
<td>5 $</td>
<td>+/-</td>
<td>only small streams</td>
</tr>
<tr>
<td>Float</td>
<td>low **</td>
<td>1 hr</td>
<td>-</td>
<td>++</td>
<td>steady streams with smooth bed</td>
</tr>
</tbody>
</table>

* For wading set-up. Suspended measurements require additional installation and specific equipment.

** Medium, if correction of results with appropriate factors for morphology.
Results should be verified by correlation of flows in similar catchment areas

This method provides a good option to relate to long term (decades long) flow data from gauged streams with similar catchment areas.

**Important!**
This method is not suitable as ‘stand alone’ method to determine the FDC for a site!
Flow data available from other sources: FDCs based on monthly averages tend to provide higher flows than available for power generation.
Specific hydrological problems in W-Africa ‘in a Nutshell’

• Small rivers with high gradients tend to have very low to zero flow during the dry season
• Large rivers with reliable flow (and possibly existing flow data) have usually very low gradients and hence low hydropower potential
Flow available for power generation for a maximum turbine capacity of (2.25 - 0.60 =) \( 1.65 \) m\(^3\)/s (104 kW)

Residual flow for aquatic life = 0.60 m\(^3\)/s
Results of the hydrological analysis

- **Average flow duration curve** → for optimum design discharge
- **Residual flow** → for yearly energy production
- **Flow duration curve of the driest year** → Economic sensitivity analysis
- **Flood events and water depths** → Design of civil structures (e.g. intake, power house)
Thank you for your attention!

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Technical characteristics of promising projects

A hydro power site is more likely to be technically attractive the more of the following criteria are fulfilled:

1. **Overall slope of the water conveyance system** is 8% or more
2. **Pressure head** of more than 40m
3. **Technical risks** and degree of difficulty is low.
4. **Distance** from powerhouse to load centre / grid connection point is less than 1 km per 100 kW installed capacity.
5. (off-grid) **Flow**: firm capacity is more than demand estimate
6. (off-grid) **Consumer density** is greater than 30 connections per 1km of transmission and distribution lines.
General Characteristics of Promising Projects

Note: Technically attractive projects are not necessarily promising projects!

- Economic, financial, social, political and institutional aspects are equally important as purely technical aspects!

→ Broad perspective required to identify promising projects
**Clinometer**

Measurement of vertical angle and distance required

\[ H = D \times \tan \alpha \quad \text{or} \quad H = D_s \times \sin \alpha \]

provided that \( a_1 = a_2 \) (instrument height = target height)
backup hydrology
Matching Power Supply and Demand
Load Predictions

![Daily Load on Tea Estate (Indonesia)](image)
Stand-alone Electricity Generation

- The objective of stand-alone schemes is to meet the peak demand of the load centre all year round.
- Using the flow duration curve established in the previous chapter a design flow can be determined which should be available on 365 days per year.
- Note: The design flow should be below the minimum flow on the flow duration curve for the following reasons:
  - Residual flow should be maintained for ecological reasons
  - Minimum flow might be overestimated
If the minimum stream flow is not sufficient to cover the demand:

• Storage ponds or basins can be designed to store water during periods of low power demand
• Non-hydropower energy sources can be used as a back-up to the hydro during the dry season such as diesel generating sets (hybrid systems)
• Load management can be envisaged, whereby base loads such as refrigerators, boilers or water pumps are cut out during the (evening) peak hours to make the necessary power available for other appliances such lighting, radios and TV sets
Main methods to calculate residual flows
(‘ecological flow’ remaining in the river during operation)

1. **Methods based on hydrological or statistics values**
   - Referring to the average flow rate (MQ) (e.g. 10% of MQ)
   - Referring to the minimum mean flow (MNQ) (e.g. 33% of MNQ)
   - Referring to prefixed values on the Flow Duration Curve (FDC)
     (e.g. in Switzerland the residual flow depends on Q347)

2. **Methods based on physiographic principles**
   - Catchment area with catchment-specific coefficients
   - Constant specific residual flow
     (e.g. depending on geological conditions)
   - Formulas based on velocity and water depth

3. **Methods based on ‘multi-objective planning’ taking into consideration ecological parameters**

An overview of common methods can be downloaded on the web site of ESHA: