



Գերմանական
համագործակցություն
DEUTSCHE ZUSAMMENARBEIT

Consulting Services for the “Programme for the Promotion of Renewable Energies: German-Armenian Renewable Energy Fund (GAF-RE) Phase III”, BMZ ID 2012.7029.7

Small Hydropower Projects (SHPP)

Introduction to Hydropower General Principles and Specifics of SHPPs

Yerevan, 29.06.2017



BMZ



Federal Ministry
for Economic Cooperation
and Development



CENTRAL BANK OF ARMENIA

KFW



CONSULTING & IT



ENERGY



ENVIRONMENT



WATER & INFRASTRUCTURE

Small Hydropower: Technical Aspects



Power



Classification



Hydropower Structures



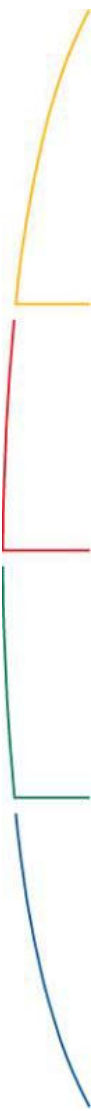
Stages of Development



Elaboration of Feasibility Studies



Cost Estimation



Power

Physical parameters

$$P = \rho * g * H * Q$$

P = Power [W]
 ρ = density of water [kg/m³], 1000 kg/m³
g = acceleration of gravity [m/sec²], 9.81 m/sec²
H = head [m]
Q = discharge [m³/sec]

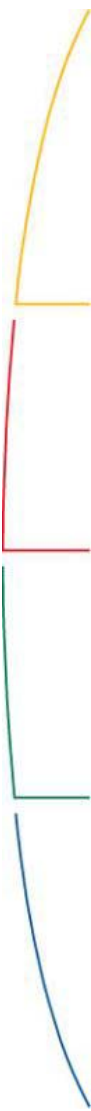
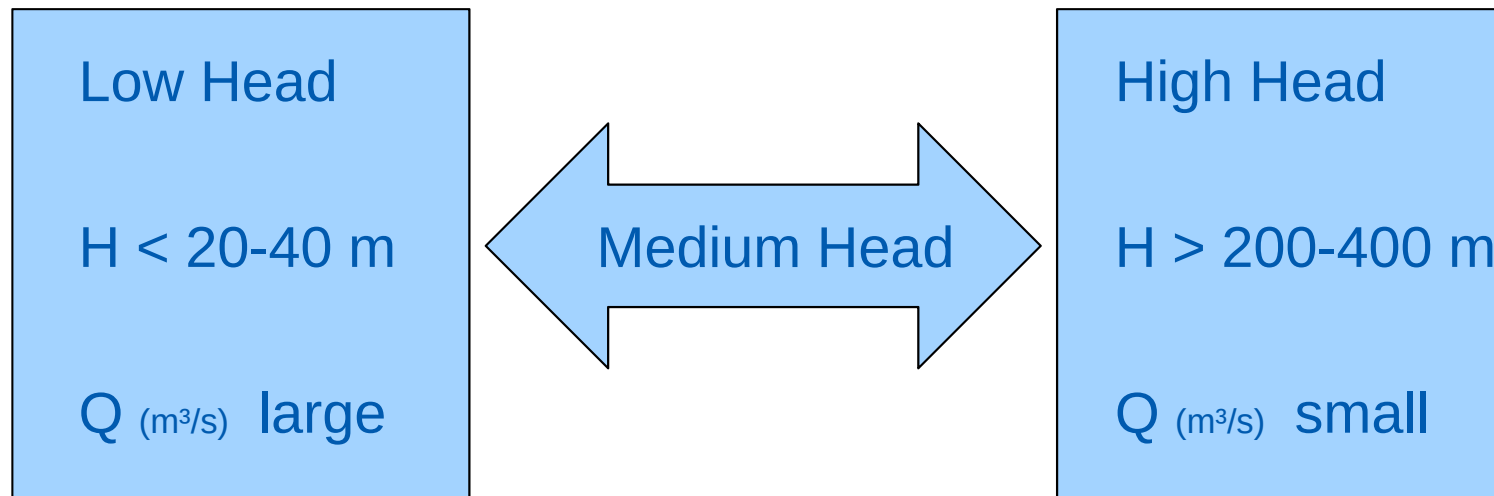
$$P = 9810 * H * Q$$

Generator efficiency: 93%
Transformer efficiency: 96%
Turbine efficiency: 90%

$$P \sim 8 * H * Q \text{ [kW]}$$

Classification

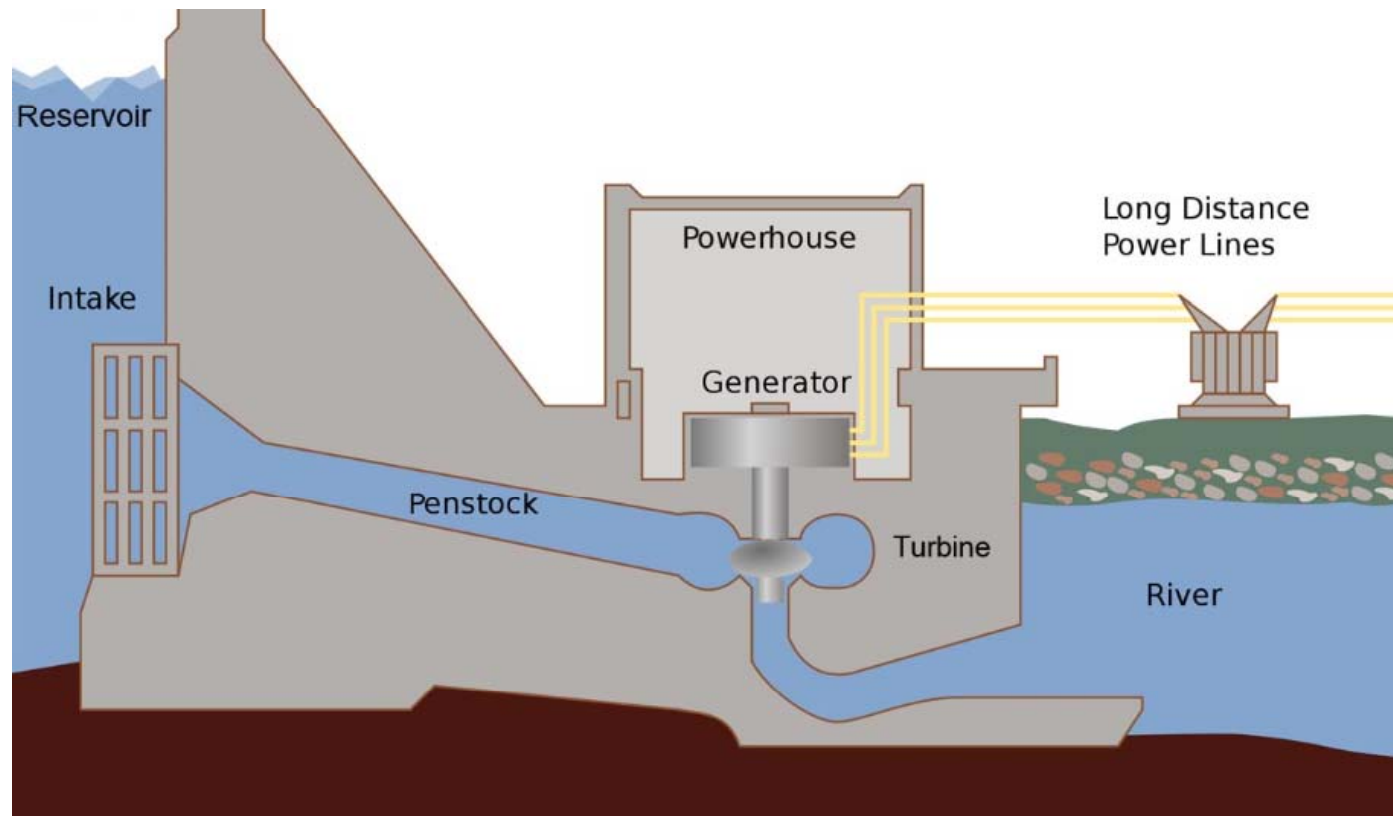
$$P = \rho * g * H * Q$$



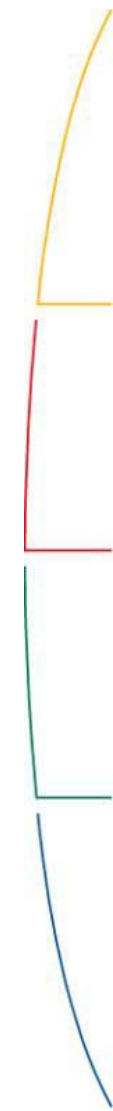
Hydropower Structures

Civil Structures

Layout: Low Head Scheme



Source: portlets.arcticportal.org/energy-portlet/104-renewable-energy/hydro-projects



Hydropower Structures

Civil Structures

Layout: Low Head Scheme

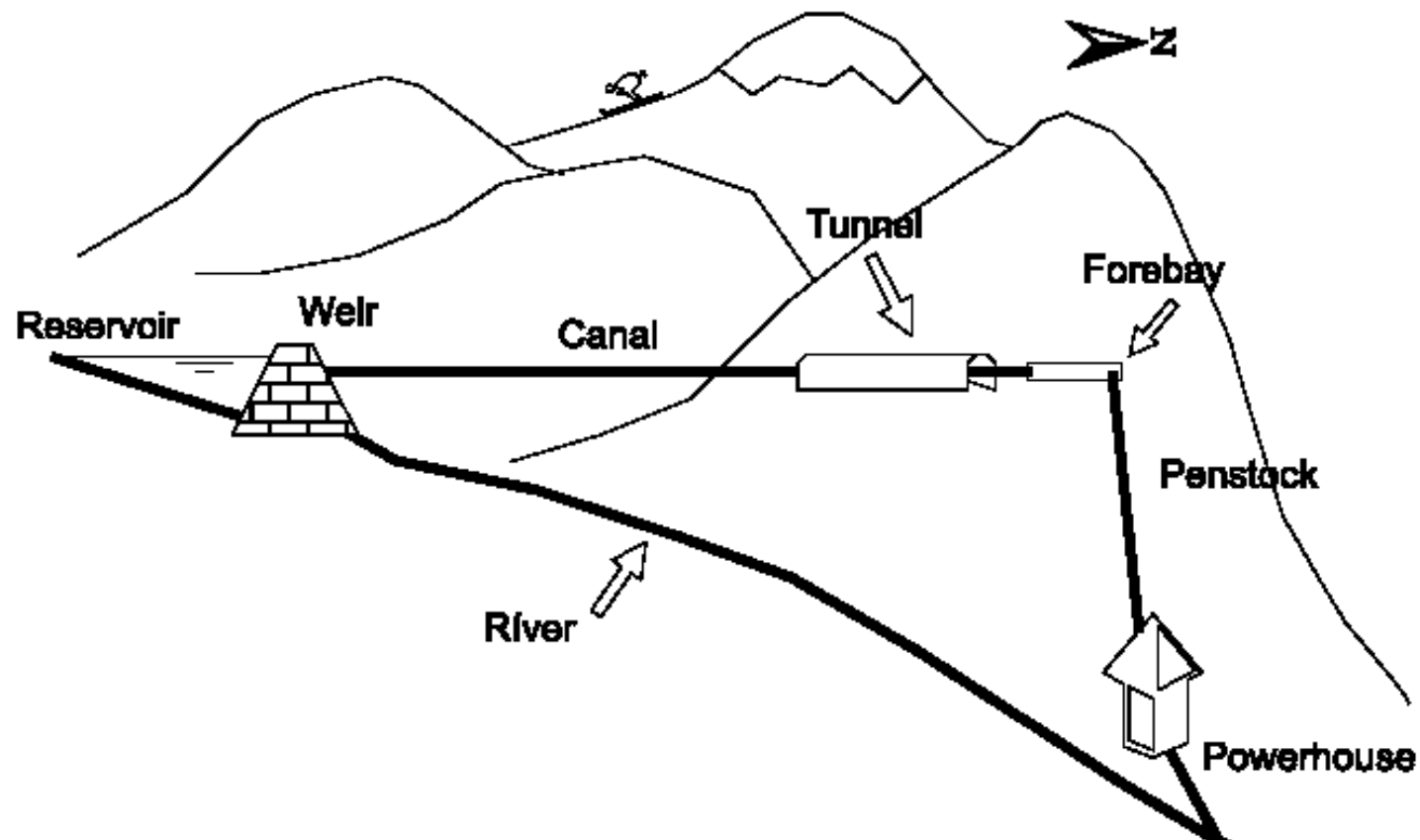


Source: verbund.com/en-at/about-verbund/visitors-centres/freudenau

Hydropower Structures

Civil Structures

Layout: Typical High-Medium Head Scheme



Source: europa.eu.int/comm/energy/library/hydro/layman2.pdf

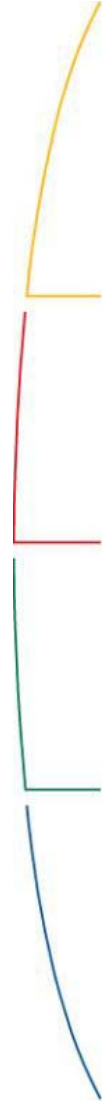
Hydropower Structures

Civil Structures

Layout: Typical High-Medium Head Scheme



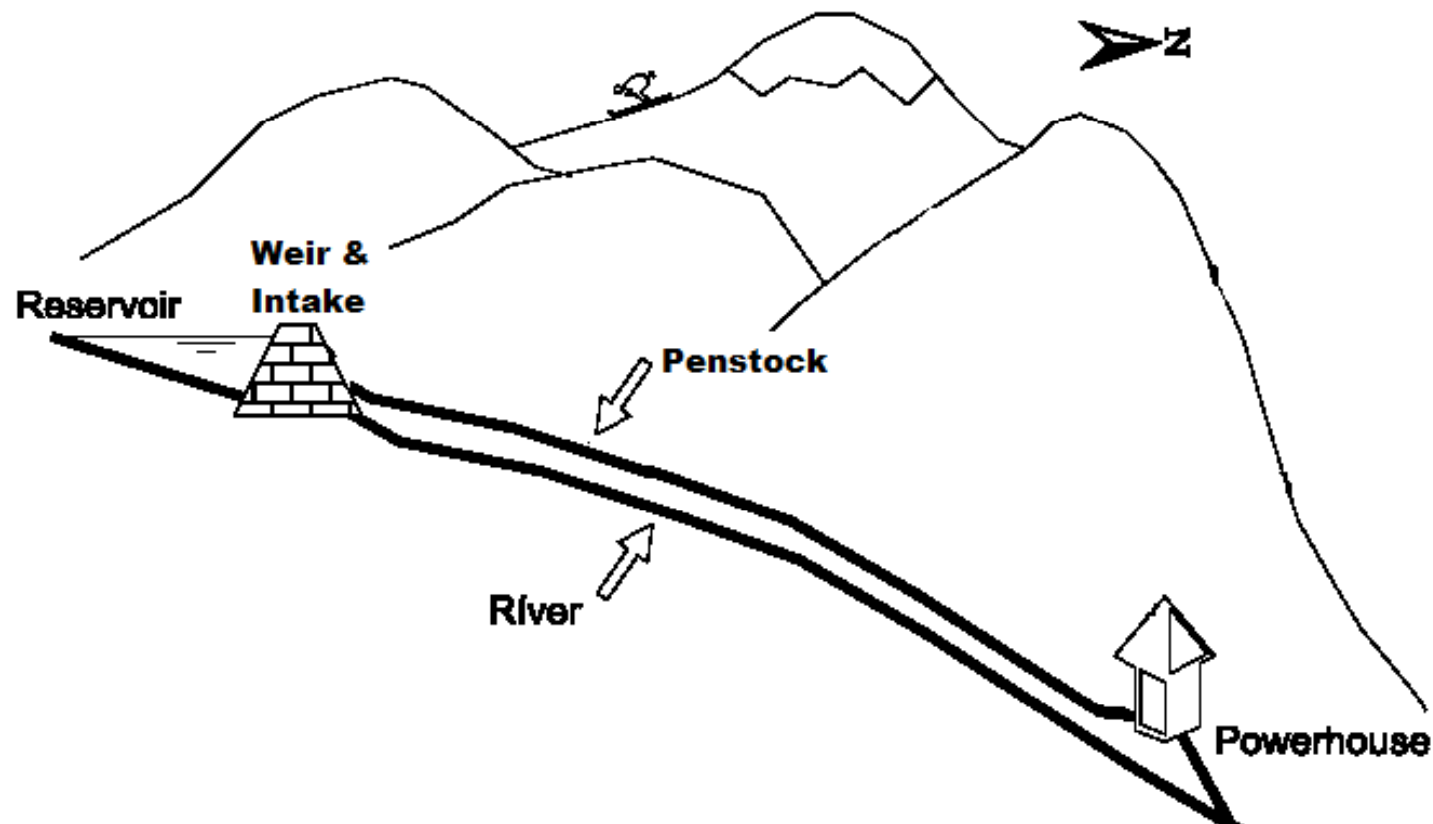
Source: energie-macht-schule.de/sites/default/files/image/W-Wasserkraft-WasserkraftwerkWalchensee.jpg



Hydropower Structures

Civil Structures

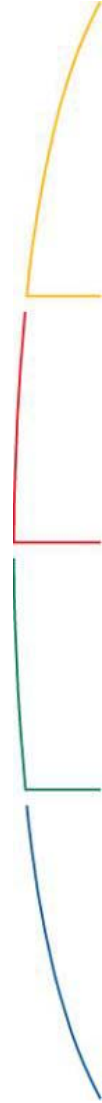
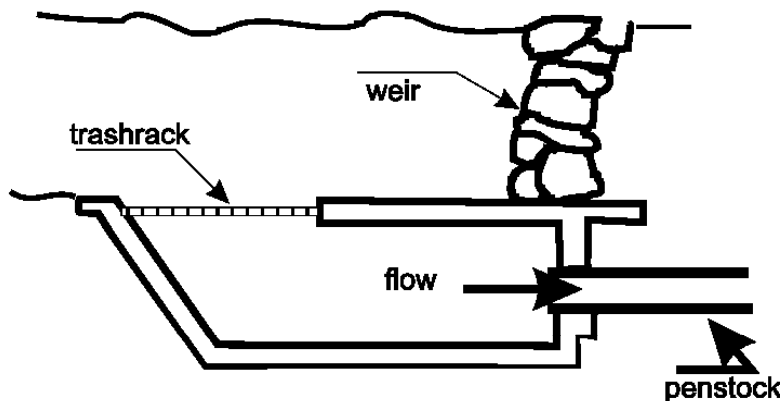
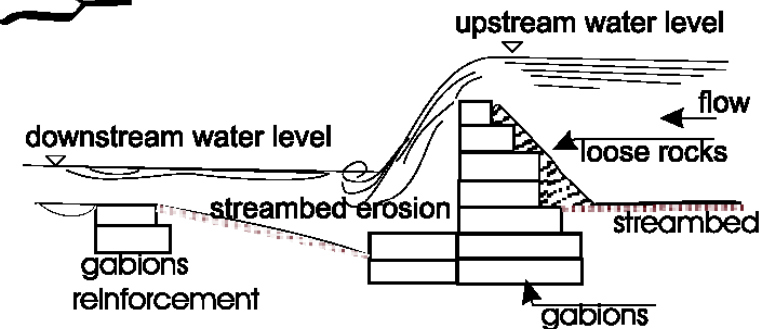
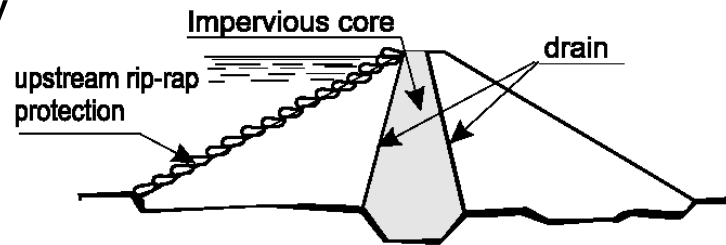
Layout: Typical Armenian Medium Head Scheme



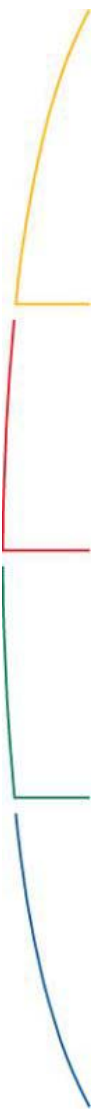
Hydropower Structures - Civil

Headworks

- Dam / Spillway
- Stilling Basin
- Sandtrap
- Trashrack
- Intake
- Fishpass



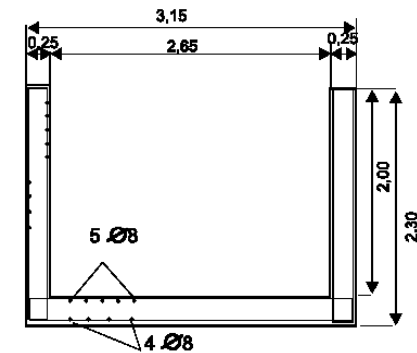
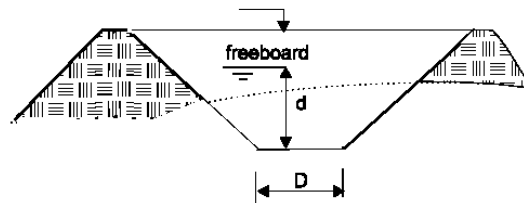
Hydropower Structures - Civil



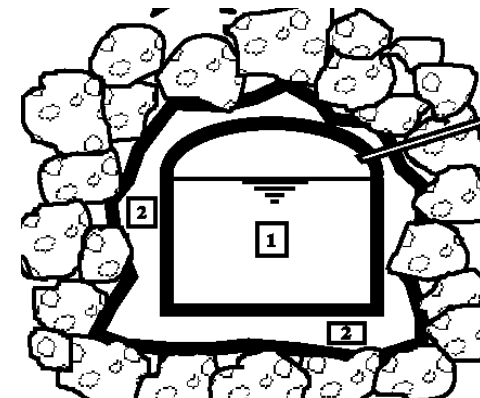
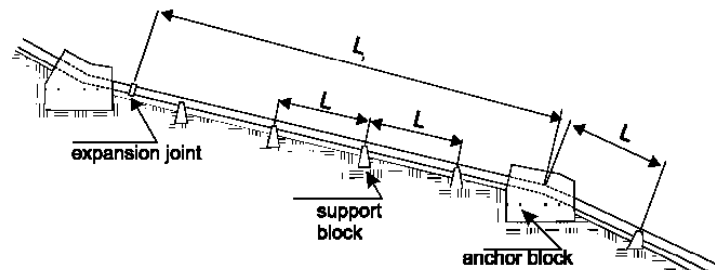
Hydropower Structures - Civil

Waterway

- Free-Flow
Canal
Tunnel

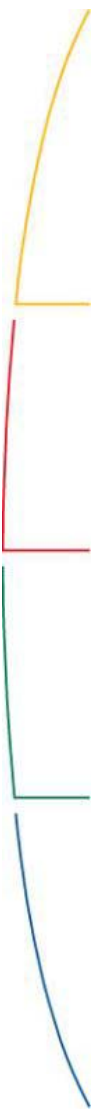


- Pressure Flow
Penstock
Lined Tunnel



- Different Other Structures (Forebay, Surge Tank, etc.)

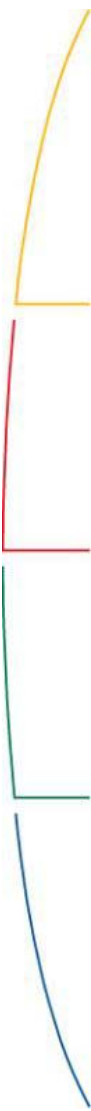
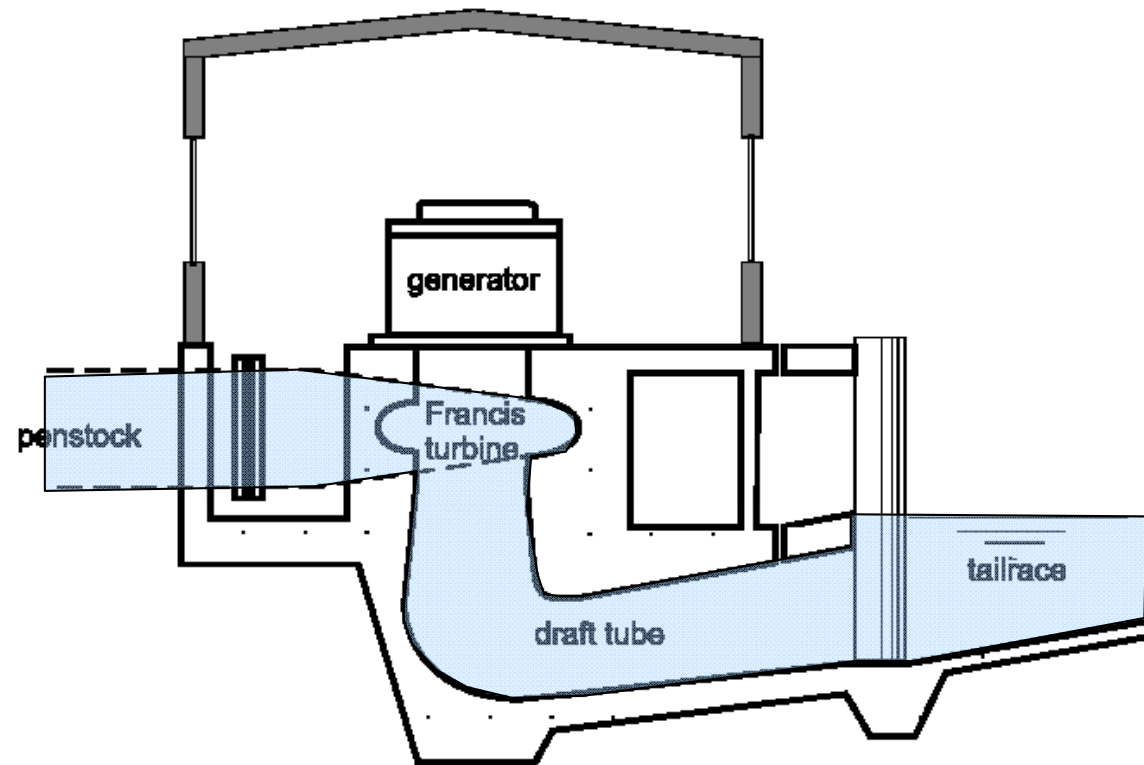
Hydropower Structures - Civil



Hydropower Structures - Civil

Powerhouse

Tailrace



Hydropower Structures - Civil

Powerhouse

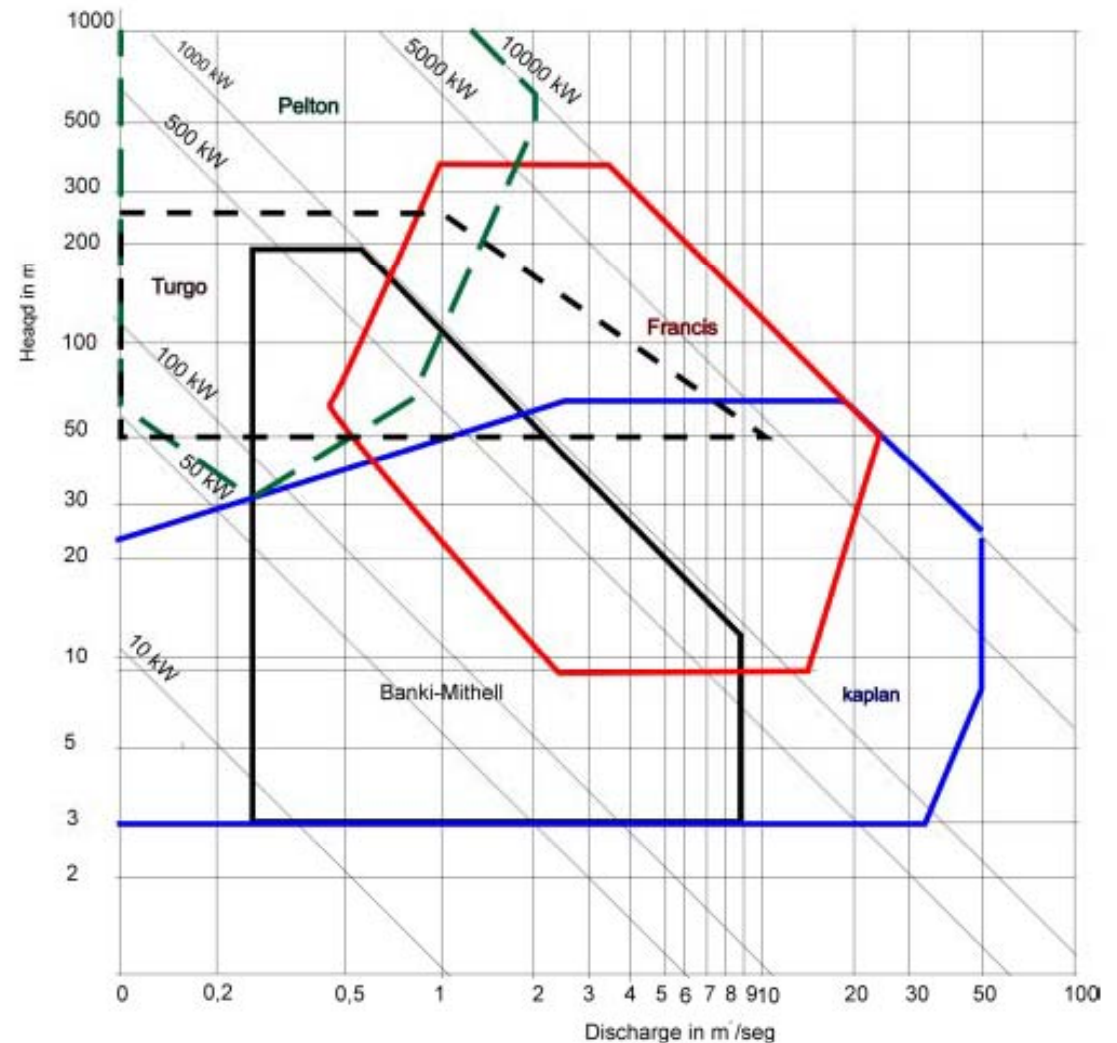
Tailrace



Hydropower Structures - Hydromechanical Equipment

Turbine Types

- Kaplan
- Francis
- Pelton and Turgo
- Cross-Flow



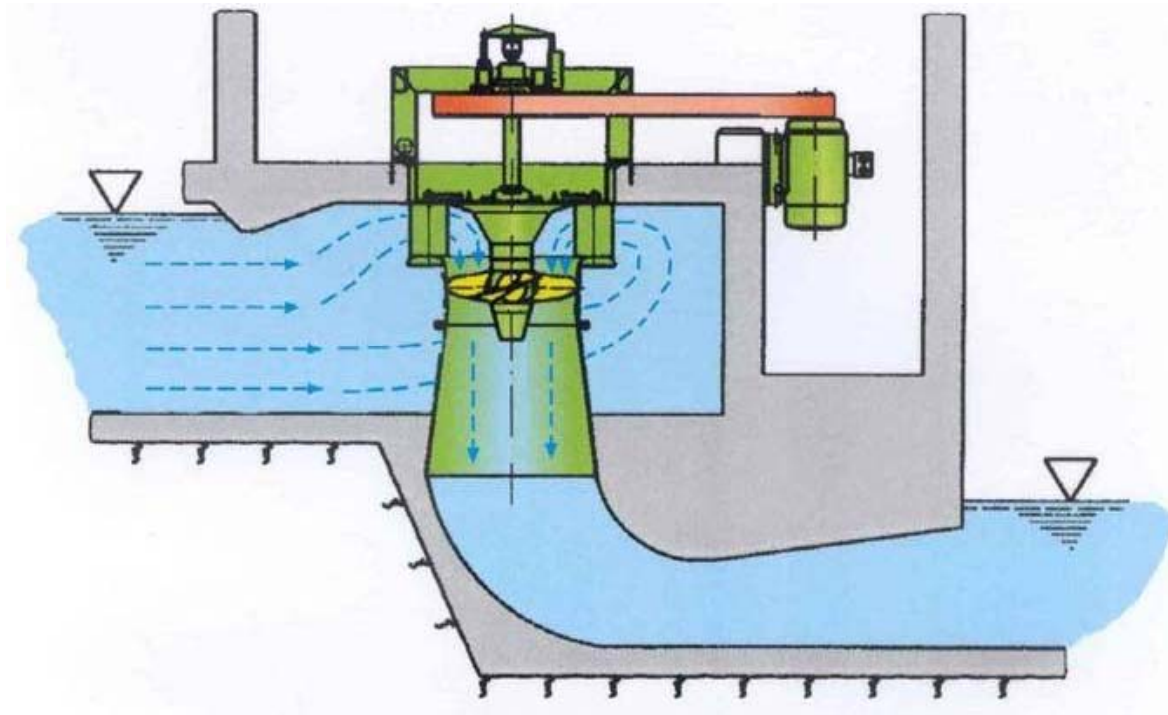
Turbine type	Head range in metres
Kaplan and Propeller	$2 < H < 40$
Francis	$10 < H < 350$
Pelton	$50 < H < 1300$
Michell-Banki	$3 < H < 250$
Turgo	$50 < H < 250$

turbine envelopes

—	Propeller- Kaplan - Bulbo
—	Francis
—	Pelton
—	Turgo
—	Banki - Michell

Hydropower Structures - Hydromechanical Equipment

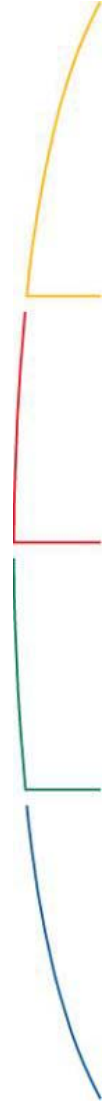
Kaplan



Source: renewablesfirst.co.uk

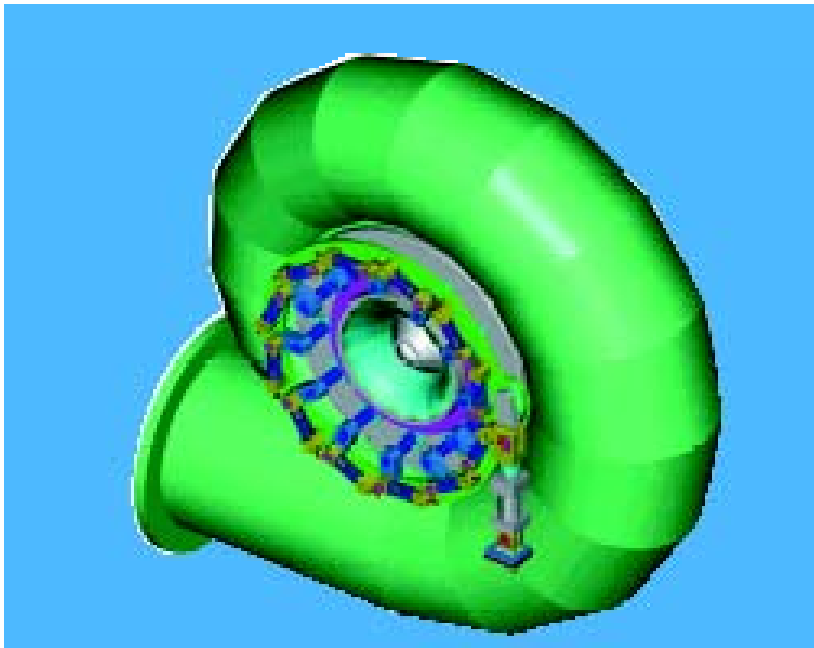


Source: hydroquebec.com



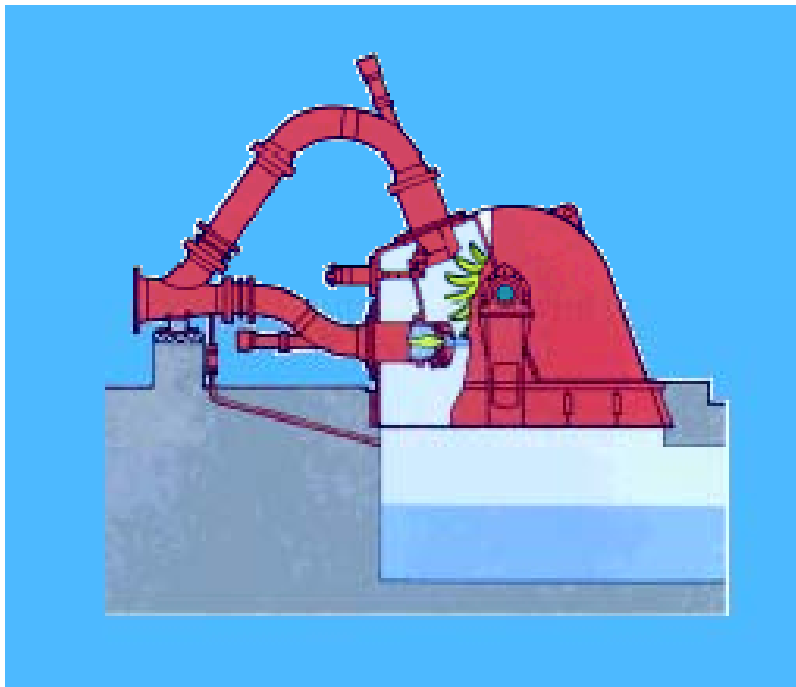
Hydropower Structures - Hydromechanical Equipment

Francis



Hydropower Structures - Hydromechanical Equipment

Pelton, Turgo



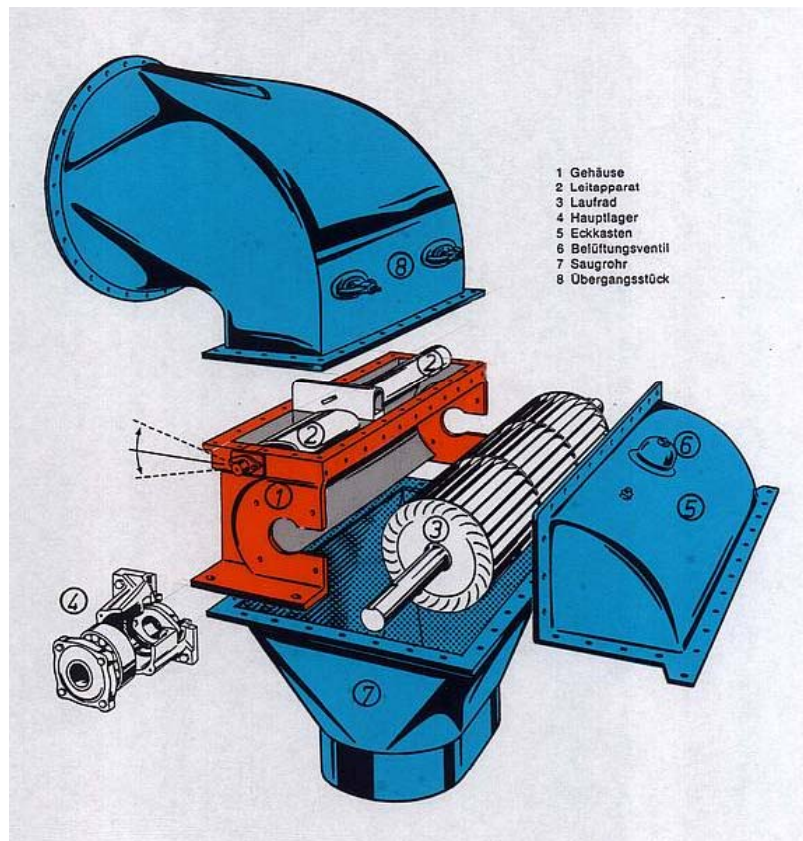
Pelton



Turgo

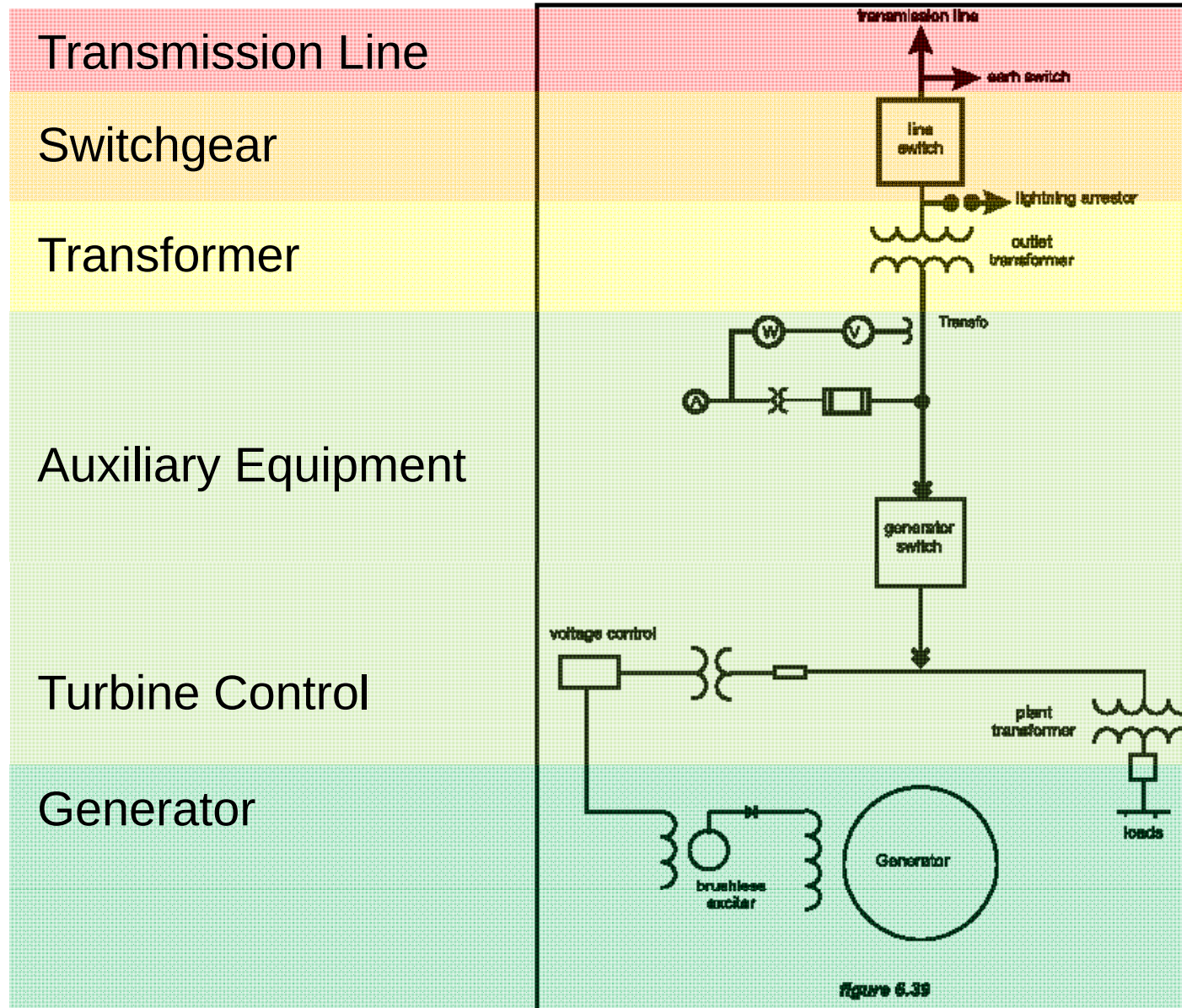
Hydropower Structures - Hydromechanical Equipment

Cross-Flow (Ossberger, Banki-Michell)

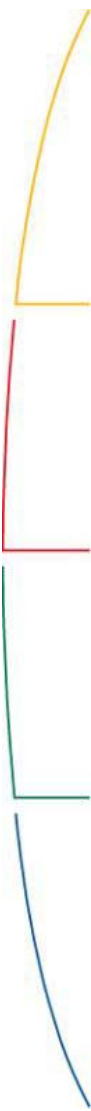
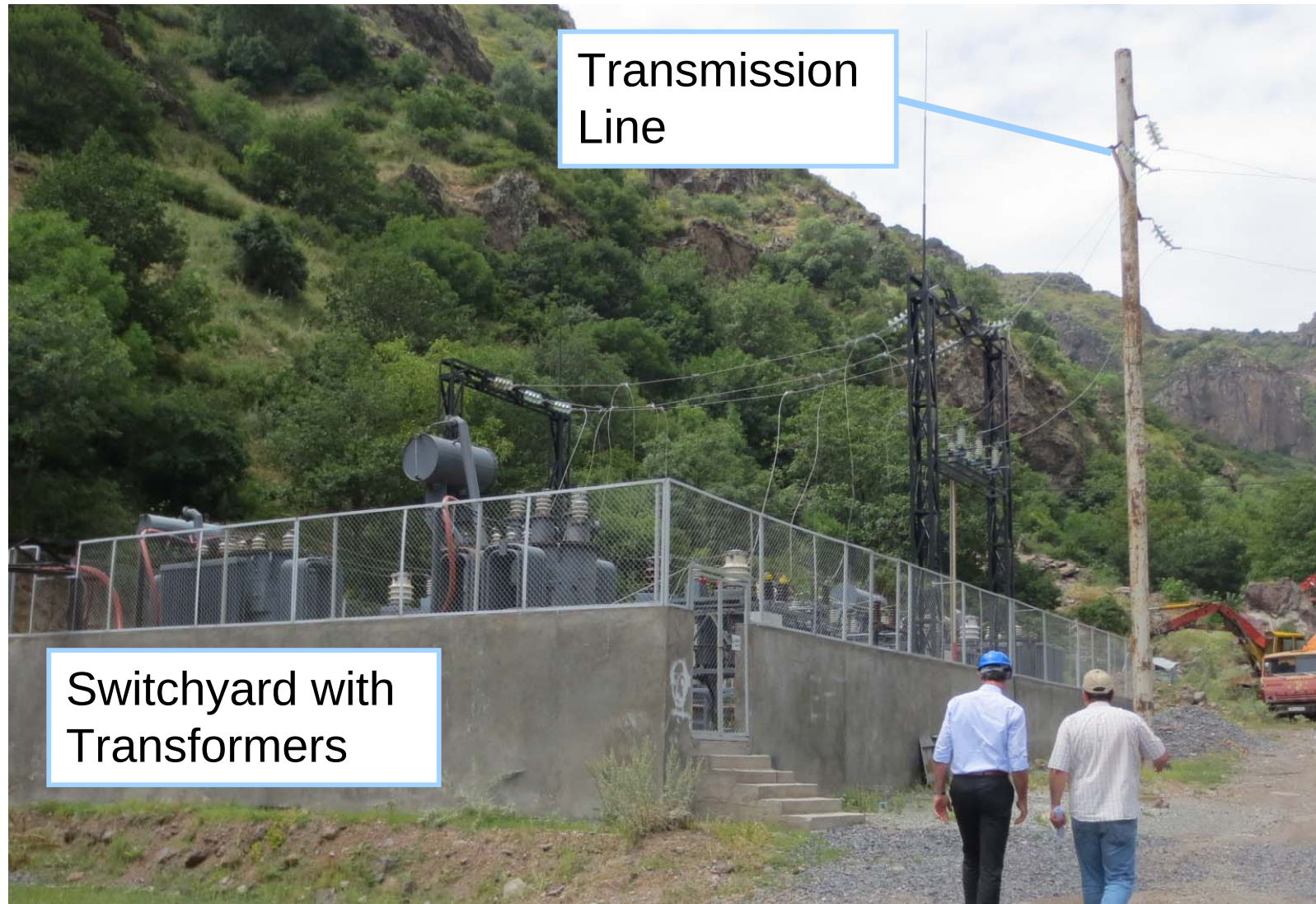


Source: water21.org.uk

Hydropower Structures - Electrical Equipment



Hydropower Structures - Electrical Equipment



Stages of Development

Identification

- Masterplan
- Definition of potential sites

Pre-Feasibility Study

- Scheme Development (Hydroproject)
- Depth of Investigation

Feasibility Study

- Reliable Data Base (Field Works and Field/Laboratory Tests)
- Screening of Layout Alternatives
- Detailed Determination of Quantities and Costs
- Financial Analysis

Financing Arrangements

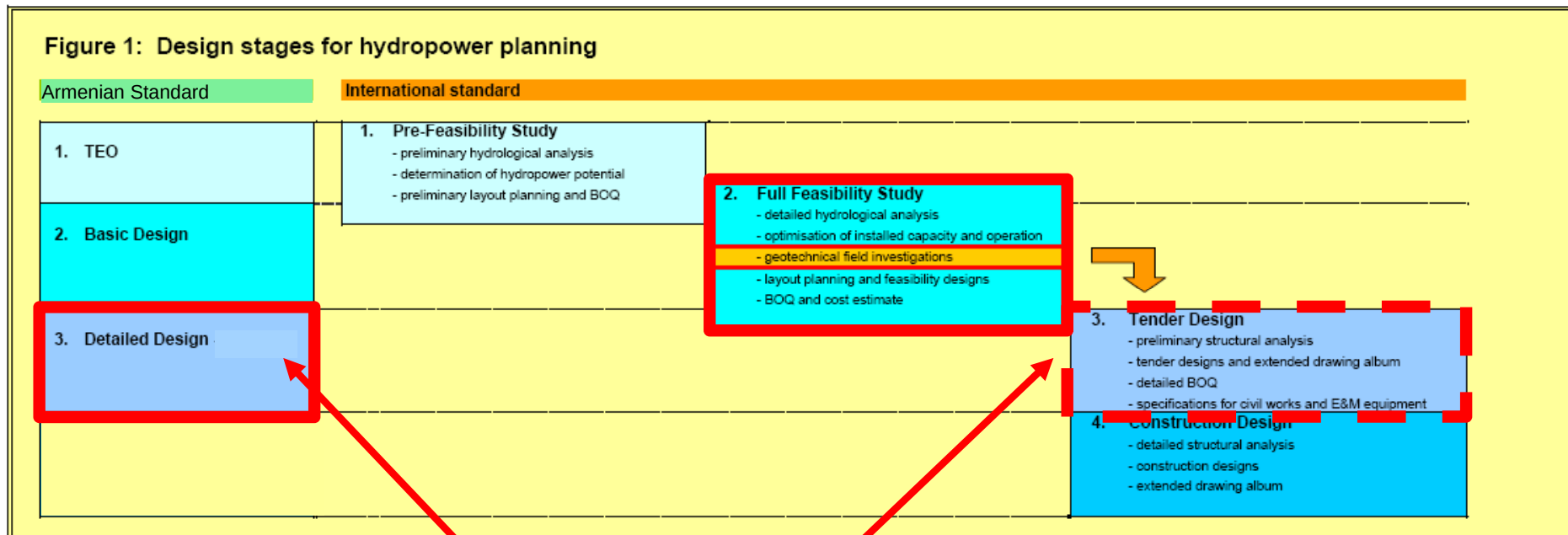
Detailed Design and Tender

- Design of Structures, Technical Specifications

Construction

Commissioning

Stages of Development



Required Level for Assessment within GAF-RE Programme

Feasibility Studies

Data Basis

- Topography → Head H
- Hydrology → Discharge Q (Water Supply, Irrigation, Demand Forecast)
- Geology/Seismicity

Environmental Impact Assessment

- Baseline Conditions, Impacts, Mitigation Measures, Minimum Ecological Flow

Layout Alternatives

Technical Drawings

Optimization of Design

- Economic Considerations

Power and Energy

Quantities and Costs

→ Input Financial Analysis

Construction Planning

→ Input Financial Analysis

Financial Analysis

Cost Estimation

Physical Contingencies,
Engineering and
Supervision,
Client's Costs and
Miscellaneous Items
must be specified based
on the specific boundary
conditions of each Project
(5% - 20%).

Exchange Rate: 550 Dram=1 US\$, Price Index July 2004				
		LOCAL	FOREIGN	TOTAL
ITEM	DESCRIPTION	[US\$]	[US\$]	[US\$]
I	Environmental Mitigation Costs	133,400	0	133,400
II	Preliminary and General	171,769	0	171,769
III	Civil Works	1,088,425	0	1,088,425
	Subtotal I - III	1,393,594	0	1,393,594
IV	Hydraulic Steel Structures	849,917	0	849,917
V	Hydromechanical Equipment	0	1,857,689	1,857,689
VI	Electrical Equipment	382,626	0	382,626
VII	Transmission Line	20,000	0	20,000
	Subtotal I-VII	2,646,137	1,857,689	4,503,826
VIII	Physical Contingencies			
	5 % of Preliminary Works	8,588	0	8,588
	5 % of Civil Works	54,421	0	54,421
	5 % of Hydraulic Steel Structures	42,496	0	42,496
	5 % of Hydromechanical Equipment	0	92,884	92,884
	5 % of Electrical Equipment	19,131	0	19,131
	5 % of Transmission Line	1,000	0	1,000
	Subtotal VIII	125,637	92,884	218,521
IX	Engineering & Supervision			
	% of Invest. Cost (Subtotal III-VII)	150,000	0	150,000
X	Client's Costs			
	% of Invest. Cost (Subtotal III-VII)	0	0	0
XI	Miscellaneous			
	unknown	0	0	0
	Subtotal IX-XI	150,000	0	150,000
XII	Total Base Cost	2,921,774	1,950,574	4,872,347
XIII	Duties			
	10 % on Imported Goods	195,057	0	195,057
XIV	Total Project Cost	3,116,831	1,950,574	5,067,405

Thank you for your Attention!

