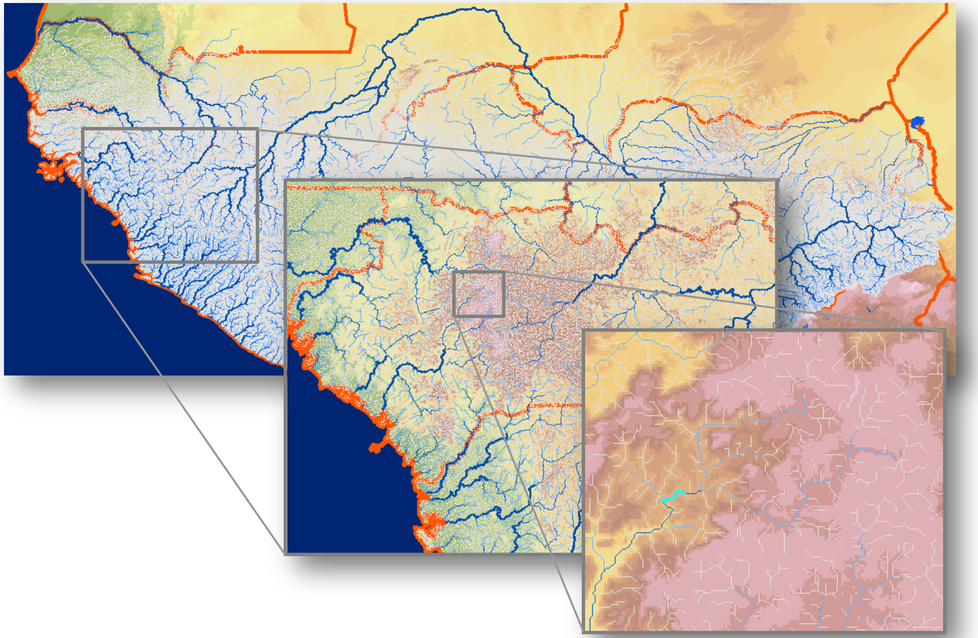
GIS Hydropower Resources Mapping for ECOWAS Region

Session 6: Hydropower plant size & Power generation



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Hydropower plant size & power generation

Overview

- Theory
  - Theoretical hydropower potential
  - Installed capacity
  - Power generation

- Group work
  - Select a river section
  - Calculate power generation
  - Test different design scenarios of installed capacity

Hydropower theory

Definitions

- Theoretical hydropower potential [MW]
  - Computed in this study
  - Hydropower generation if all natural water flows would be utilized. Includes rough consideration of turbine efficiency.

- Installed capacity [MW]
  - Key design decision (costs!)
  - Closely related to rated discharge of turbine

- Power generation [MW]
  - Power output during operation of HPP
  - Depends on:
    - Inflow time-series
    - Limited by installed capacity and rated discharge
    - Depends on hydraulic head, hydraulic losses, efficiency (turbine, generator, transformer)
  - Energy [MWh] = Power [MW] x Time [h]

Hydropower theory

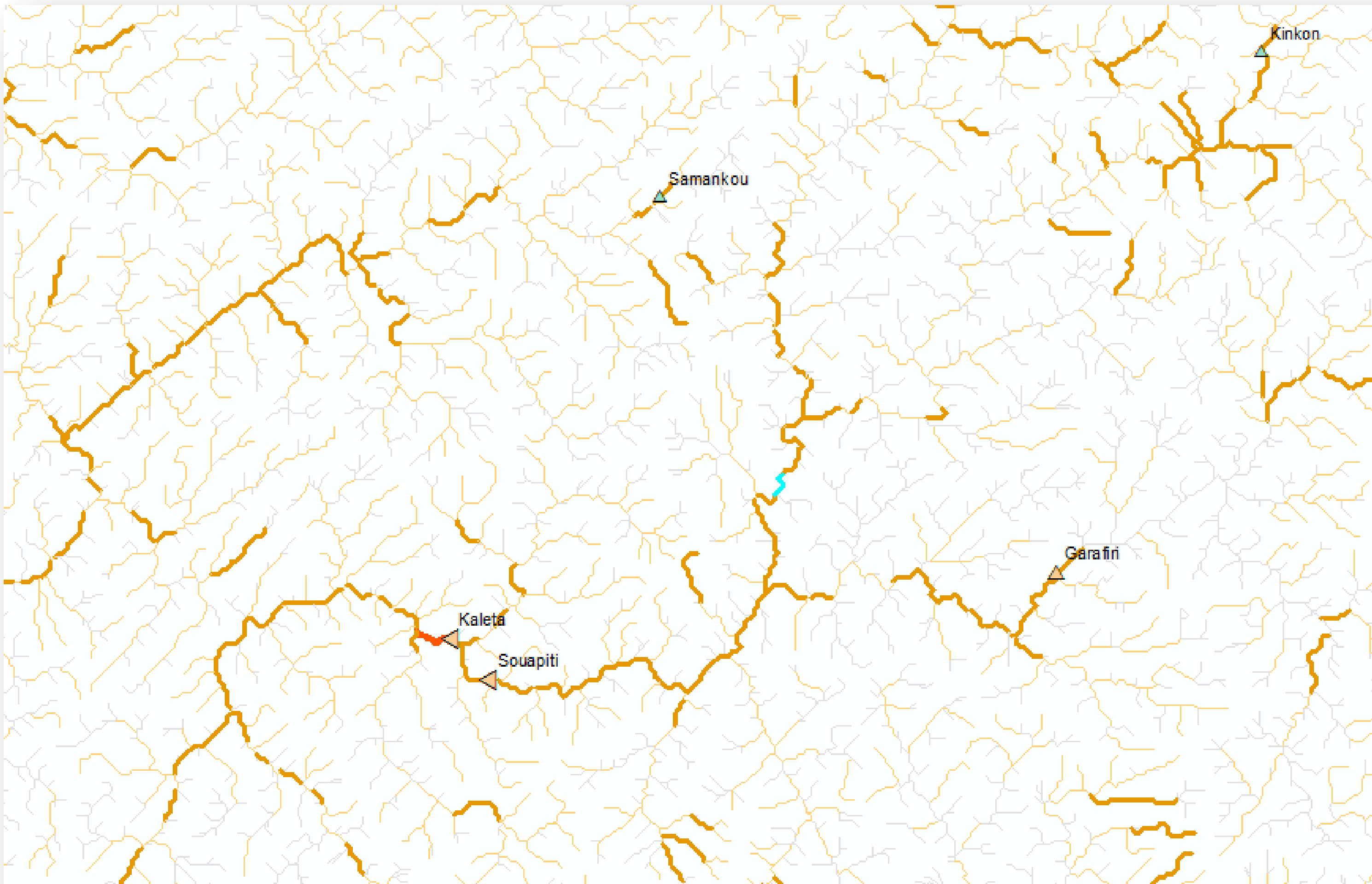
Theoretical hydropower potential of a river reach

$$\textbf{\textit{Power}}\ [\text{MW}] = \textbf{\textit{Flow}}\ [\text{m}^3/\text{s}] * \textbf{\textit{Height}}\ [\text{m}] * \textbf{\textit{c}}$$

Power	Theoretical hydropower potential [MW]
Flow	Mean annual discharge in reach [m^3/s]
Height	Elevation difference from start to end of river reach [m]
c	Constant, typically $c = 8.5/1000$

Theoretical hydropower potential

Example for Guinea



Field	Value
ARCID	693004
TOARCID	693899
FROMARCID	690929
NB	310
RIVER	Kakrima
RIVER_FREN	Kakirima
COUNTRY_1	GIN
COUNTRY_2	
AREA	5701.17
LENGTH	3.09
EXRIVER	1
ELEV_US	215.4
ELEV_DS	212.8
ELEV_DIFF	2.6
SLOPE	0.00086
POWER	2.494
POWER_SPEC	0.808
Q_YEAR	111.25
Q_JAN	21.34
Q_FEB	18.97
Q_MAR	26.09
Q_APR	47.43
Q_MAY	118.56
Q_JUN	237.12
Q_JUL	308.27
Q_AUG	284.55
Q_SEP	142.28
Q_OCT	71.14
Q_NOV	35.57
Q_DEC	23.71
Q_2035_P25	-5.4
Q_2035_P50	-0.9
Q_2035_P75	4.3
Q_2055_P25	-6.3
Q_2055_P50	0.9
Q_2055_P75	4
PLANT_SIZE	3

POWER [MW]

- 0.0 - 0.1
- 0.2 - 1.0
- 1.1 - 30.0
- 30.1 - 100.0
- 100.1 - 568.0

Theoretical hydropower potential

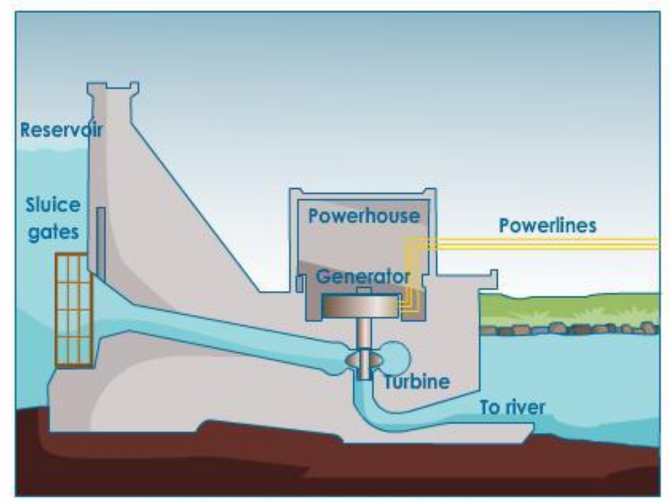
Zoom in to reach
Switch between Q_YEAR and POWER view
Click on reach and show attributes
Show existing HPP layer
Explain sum of POWER for several reaches
POWER depends on plant layout:
- Run-of-river with diversion
- Storage

switch to GIS presentation...

Hydropower theory

Power generation

POW = Qturb * eff * (RWL – TWL – HL) * 9.81 / 1000



A schematic view of a hydro power plant

POW	power output [MW]
Qturb	turbined discharge [m³/s]
eff	efficiency (turbine, generator, transformer) [/]
RWL	reservoir water level [m]
TWL	tailwater level [m]
HL	hydraulic losses (penstock, etc.) [m]

Constraints:

POW limited by installed capacity [MW]

Qturb limited by turbine capacity [m³/s]

Key design parameters!

Qturb also limited by environmental flow requirements!

Energy:

E [MWh] = POW [MW] * time [h]

Hydropower theory

Theoretical hydropower potential of a river reach

$$POW = Qturb * (RWL - TWL - HL) * eff * g / 1000$$

$$P = Q * H * c / 1000$$

Power generation (POW) and hydropower potential (P) are related!

P	theoretical hydropower potential [MW]
Q	mean annual discharge in reach [m^3/s]
H	elevation difference from start to end of reach [m]
c	constant, typically $c = 8.5$

Group work

Plant size and energy generation

- We will use GIS to select a river section as practice example

- Decision about plant layout
  - Run-of-River scheme without diversion
  - Run-of-River scheme with diversion
  - Storage scheme: balancing of flow variability, more complicated, not covered in training

- Query key data from the river network

- In Excel:
  - Rough energy calculation
  - Test different design scenarios for installed capacity

Group work

Plant size and energy generation

Energy simulation using rough simplifications

Data from GIS layer river network

variable	value	units
river	Boa	
ARCID us	890979	
ARCID ds	891899	
elev us	341.7	m
elev ds	325	m
height	16.7	m
eff	0.9	/

	User specified scenarios for installed capacity									
Pinst [MW]	1	2	3	4	5	6	7	8	9	10
Qrated [m³/s]	6.8	13.6	20.3	27.1	33.9	40.7	47.5	54.3	61.0	67.8
Mean power output [MW]	0.9	1.5	1.9	2.3	2.6	2.8	3.1	3.3	3.4	3.5
Load factor [%]	90.1	72.5	62.9	57.0	51.3	46.9	43.8	40.8	38.0	34.8
nnual energy generation [MWh]	7895.8	12709.1	16522.2	19957.1	22473.3	24663.3	26853.3	28613.0	29994.5	30457.3
	Calculated energy for design scenarios									

	[m³/s]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]
month	Q monthly	Power	Power out	Power out	Power out	Power out	Power out	Power out	Power out	Power out	Power out	Power outp
1	4.52	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
2	4.02	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
3	5.53	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
4	10.05	1.5	1.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
5	25.13	3.7	1.0	2.0	3.0	3.7	3.7	3.7	3.7	3.7	3.7	3.7
6	50.26	7.4	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.4	7.4	7.4
7	65.34	9.6	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	9.6
8	60.31	8.9	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	8.9	8.9
9	30.16	4.4	1.0	2.0	3.0	4.0	4.4	4.4	4.4	4.4	4.4	4.4
10	15.08	2.2	1.0	2.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
11	7.54	1.1	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
12	5.03	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Group work

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Plant size and energy generation