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ARMENIA RENEWABLE RESOURCES AND ENERGY EFFICIENCY FUND

FASEP - Floating PV in Armenia

Tripartite meeting #1

October 2021

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Introduction

by the Economic Service for Georgia and Armenia of the French Embassy

The project ambition

- Draw up **an inventory of the constraints and opportunities of Armenia** for the development of floating photovoltaics, in order to allow the emergence of the sector.
- Present the Armenian context in order to **open Armenian market to energy companies** specialized in floating photovoltaics.
- Attract investors to **increase the renewable energy production capacity of the Republic of Armenia** and allow the structuring of projects around the **French technologies**' partners of the FASEP.

3 phases :

National potential study

Analysis of the national regulatory framework
Constraints and opportunities on a macroscopic scale
Calculation of national FPV potential

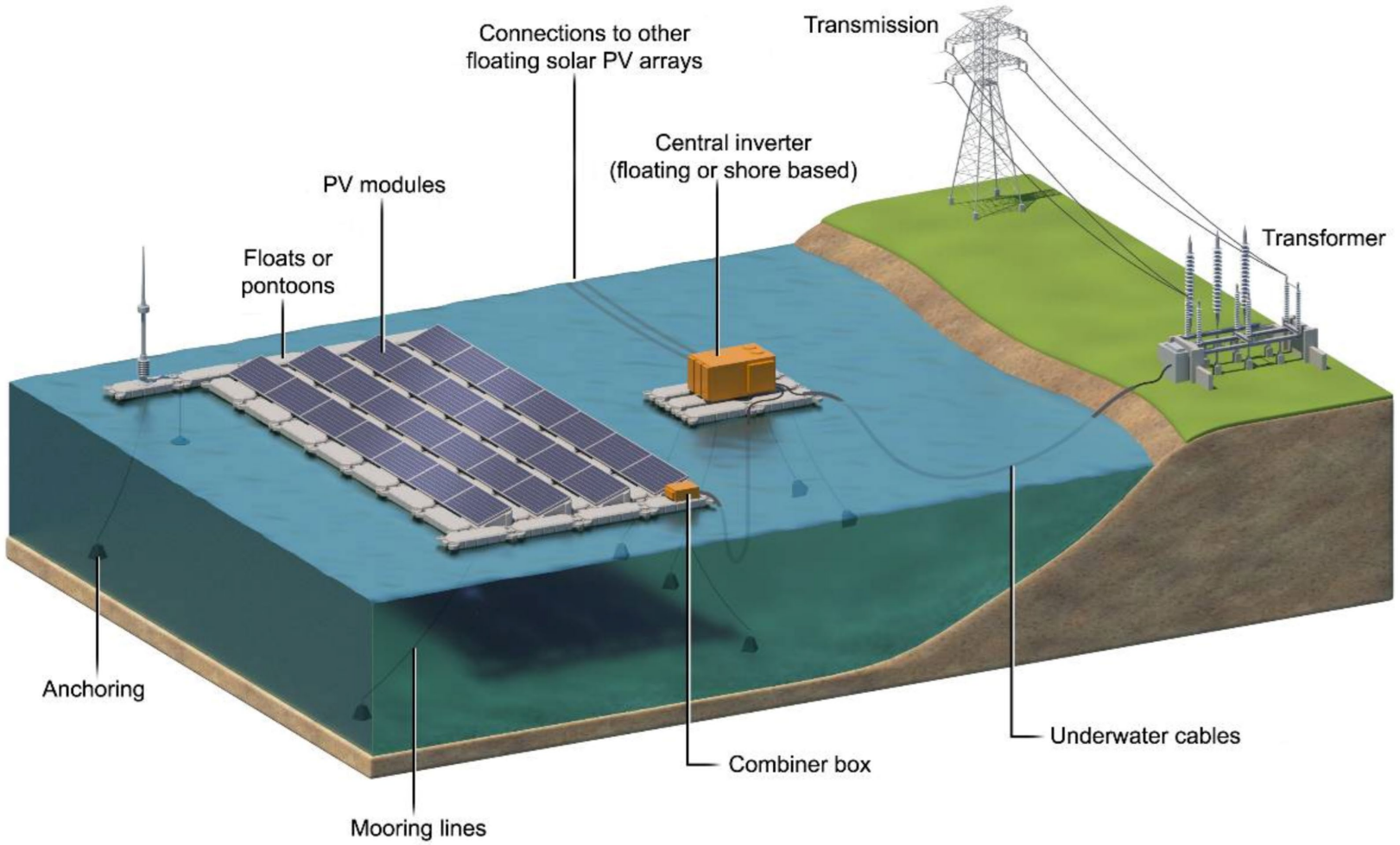
Feasibility studies

Selection of 3 representative sites
Analysis of local constraints
Completion of 3 feasibility studies

Conception and construction of a pilot power plant

Technical design of the demonstrator
Selection of equipment and construction companies
Training of construction and maintenance teams
Construction and commissioning

The floating solar PV technology



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National potential study

Methodology

Analysis of the regulation framework of Armenia
- Armenian Energy Law
- Water Code
- Environmental legal framework

Analysis of Armenian resources for FPV
- Solar resources
- Hydro resources

Analysis of constraints and opportunities of Armenian territory for FPV
- Grid infrastructures
- Accessibility
- Natural constraints

Definition of an analytical grid to determine issue levels

Characterization of sites through a GIS mapping analysis

Calculation of the potential capacity and production

Analysis of the constraints

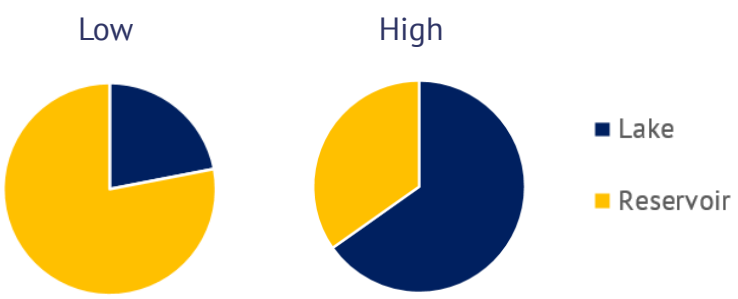
Level	Climat	Accessibility	Natural protected areas	Grid	Water Level Variation	General
Low	82	130	160	65	38	71
Medium	58	4	-	20	8	38
High	46	52	26	-	2	77
Unknown	-	-	-	111	NA	-

Altitude
Mean Temperature
Climate description

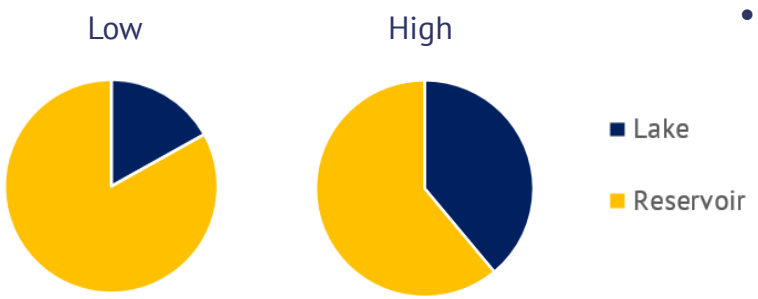
Altitude
Distance to the road

Distance to the grid
Line voltage
Capacity

Climate constraints



General constraints



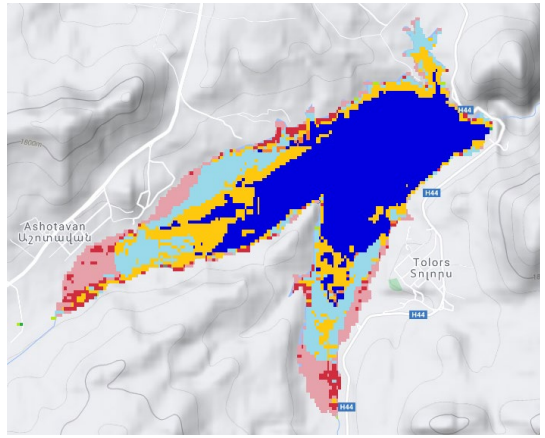
- Lakes are less favorable for FPV projects than reservoirs, mainly due to climate constraints.
- Exclusion criteria associated with climate and accessibility constraints often apply to the same sites.
- 38% of lakes and reservoirs are associated with low constraints.
- 41% were excluded due to high level of constraints.

Caracterisation of the water body

Water level variation

- Measure of the permanent and seasonal water surface,
- Estimation of the water level variation.

Water level variations > 20 m is poorly compatible with a FPV project.

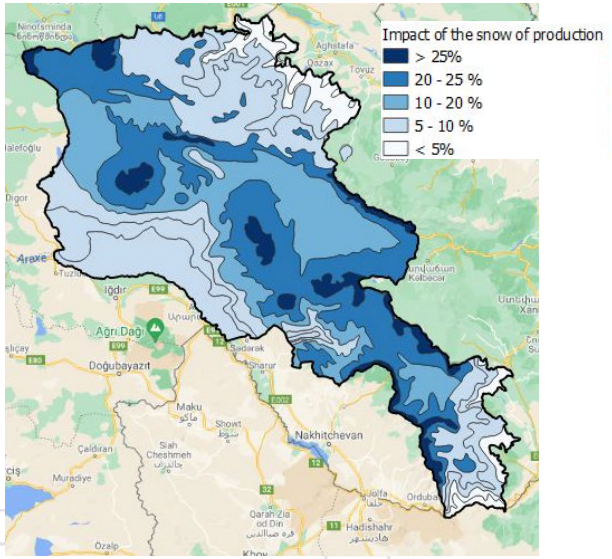


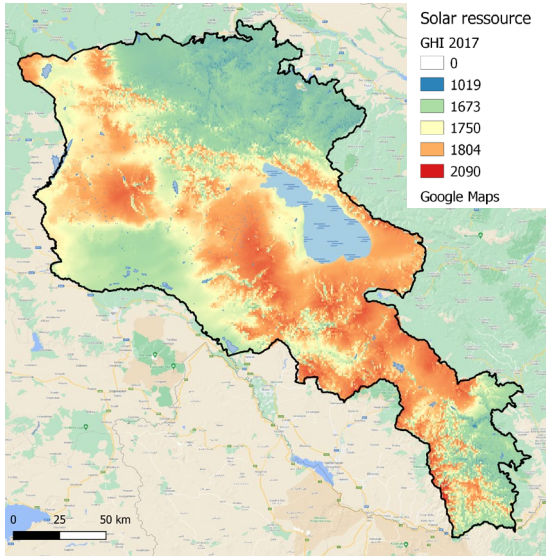
FPV project can occur in seasonal dry zones with adequate float technology.

From capacity to production

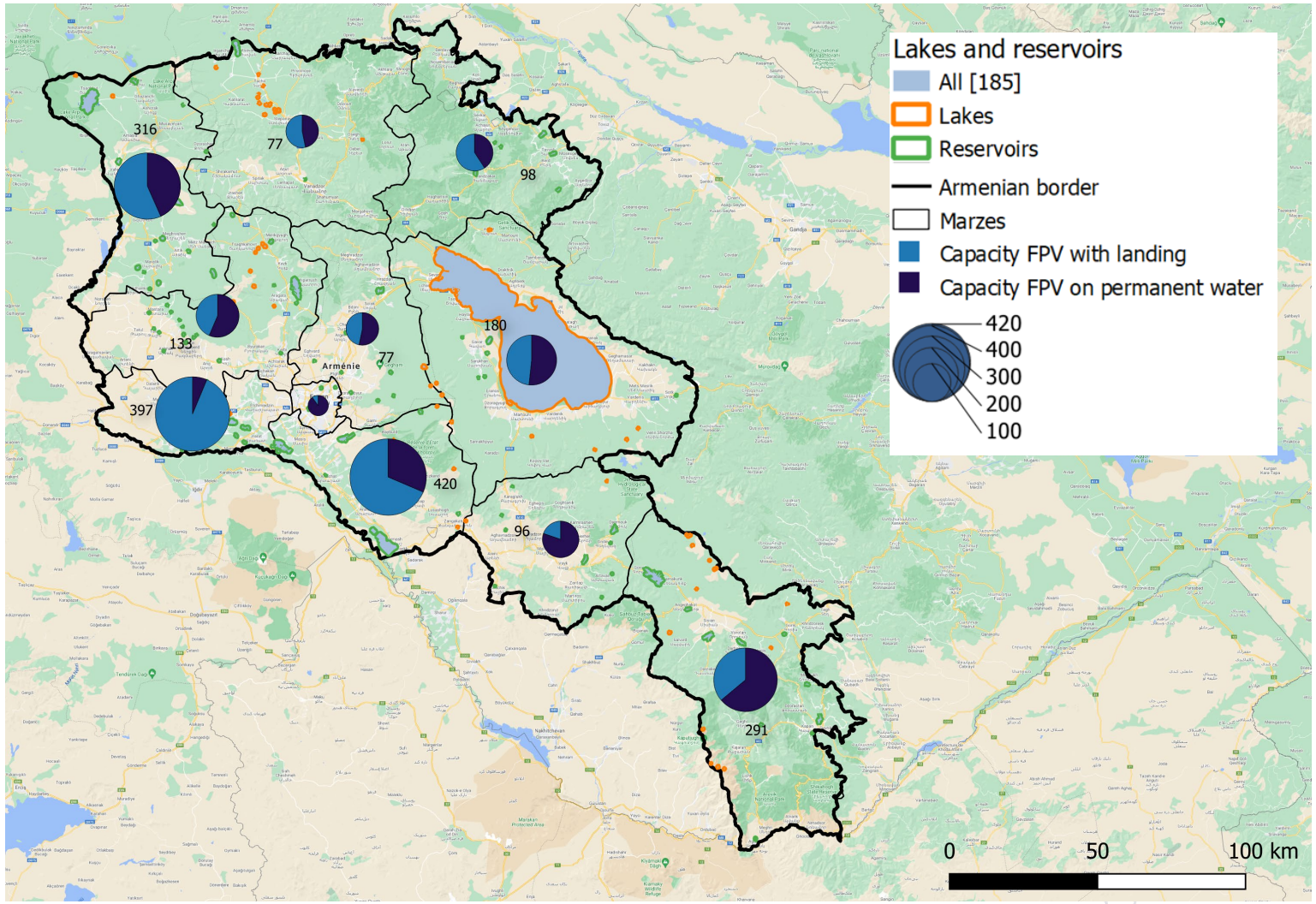
- Water body > 2ha,
- Power plant on 50% of the water body,
- Potential capacity of 1MWp/ha,
- Minimum capacity : 1 MWp,
- Maximum capacity : 50 MWp.

- Calculation of the production from solar irradiation local data and impact of snow on energy generation.





Main results

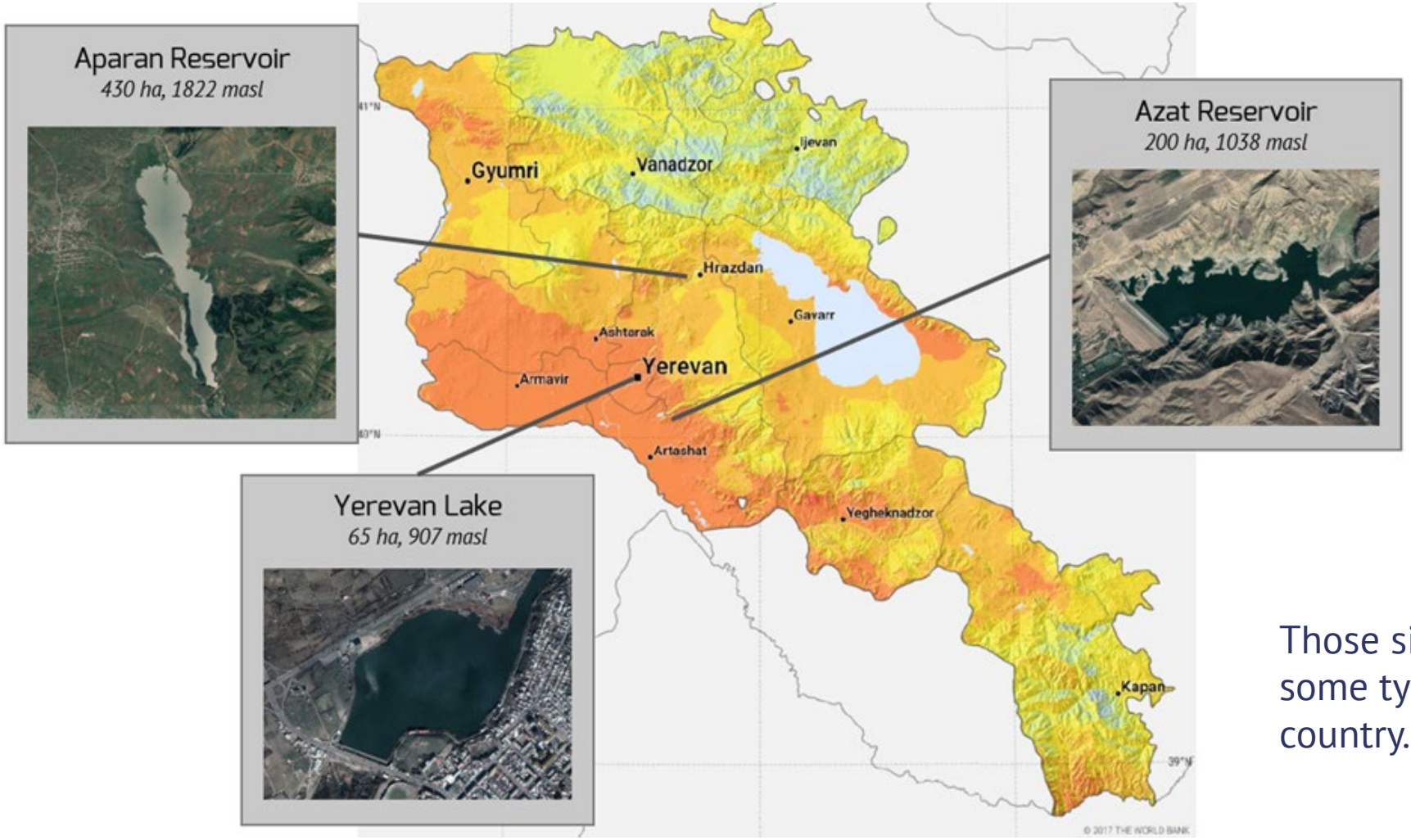


On permanent water bodies			
	Sites	Capacity (MWp)	Annual production (GWh/year)
In non-protected areas	36	520	691
Including protected areas	45	721	967

With landing			
	Sites	Capacity (MWp)	Annual production (GWh/year)
In non-protected areas	109	1429	1969
Including protected areas	124	1728	2373

- 64 % of the potential capacity requires a floating technology that allows landing.
- 72 % of the potential capacity is located in non-protected areas.
- The potential on permanent water bodies in non–protected areas could increase Armenian electricity production by 9%.

3 sites selected for pre-feasibility studies



3 sites have been chosen for feasibility studies :

- Yerevan Lake : an urban reservoir,
- Azat reservoir : located in a mountainous region,
- Aparan reservoir : an altitude lake with important water surface variation.

Those sites allow to study more in detail some typical constraints found in the country.

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Feasibility study – Yerevan

Description of the site

- Artificial reservoir on Hazdan River,
- 650 000 m² (65 ha),
- Dam started operations in 1967,
- Reservoir uses :
  - River flow regulation,
  - Irrigation,
  - Hydroelectricity generation (1M HPP).

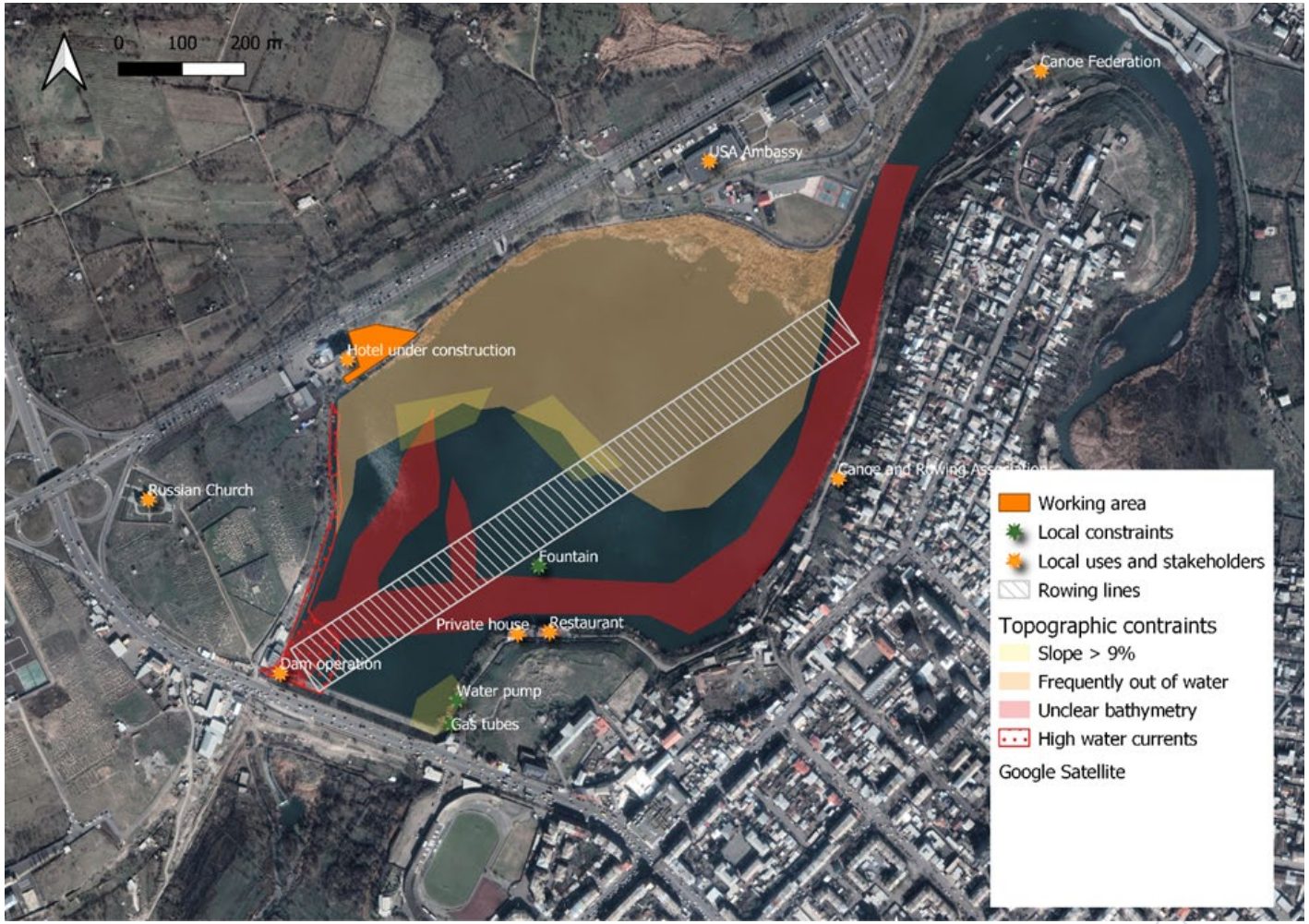
Why is Yerevan Lake a good location for a pilot project ?

- Easily accessible,
- Good visibility,
- No major environmental and technical concerns.

Maximum water level : 907 m

Minimum water level : 888 m

Contraints



What are the constraints limiting the installation of a FPV power plant ?

- **Dam operation constraints**: proximity to the gates and spillway, flushing, water level management …
- **Water current and level variation:** frequently out of water zones, high water current zones…
- **Reservoir bottom:** important slope and unclear bathymetry impeding anchoring and landing.
- **Human uses**: recreative uses, fishing, touristic activities…

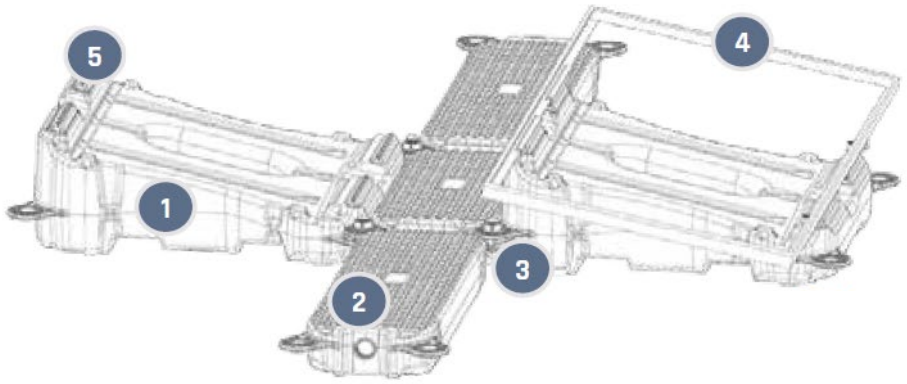
Synthesis of the constraints

The location of the demonstrator has been chosen by combining technical constraints and human activities constraints.

Armenian regulation for grid connection of PV power plants requires a minimum of 151 kWc, or about 1 600 m².

Layout

1. Main float
2. Secondary float
3. Connection pin
4. PV module
5. Fixing system



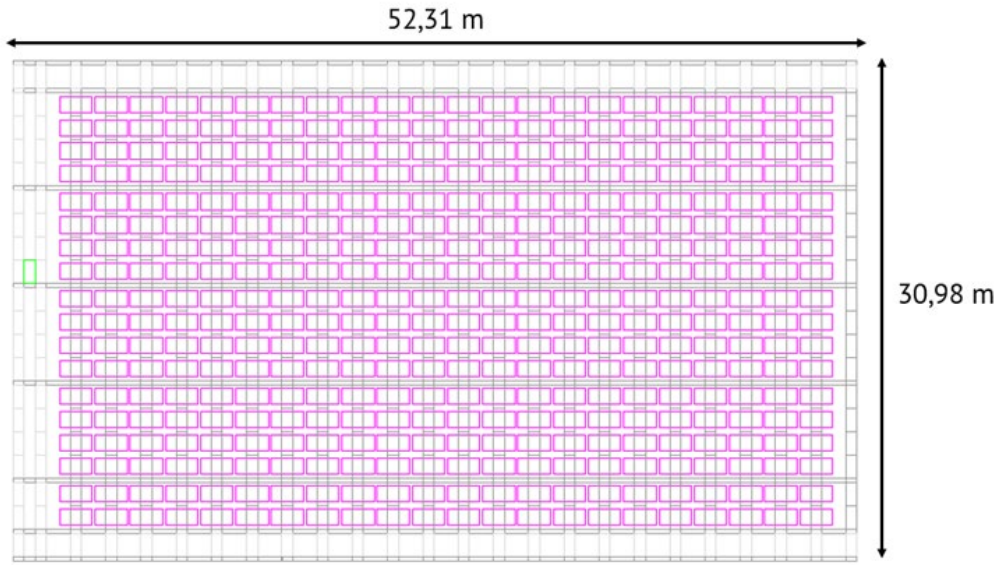
The floating island will use the Hydrelio floats, from the French manufacturer Ciel&Terre.

- 396 PV modules of 395 Wp each,
- Walkaway for an easier access to the modules for maintenance,
- PV inverter on the island to ensure public safety.

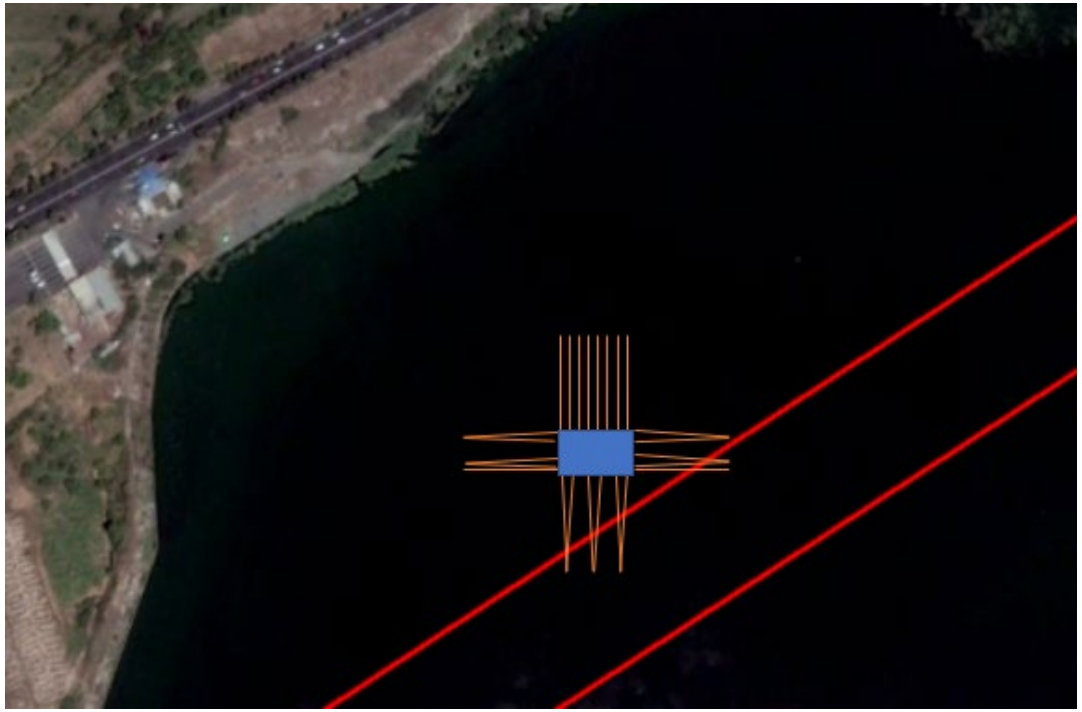
String inverters

PV panels (colored per junction box)

Floats HYDRELIO

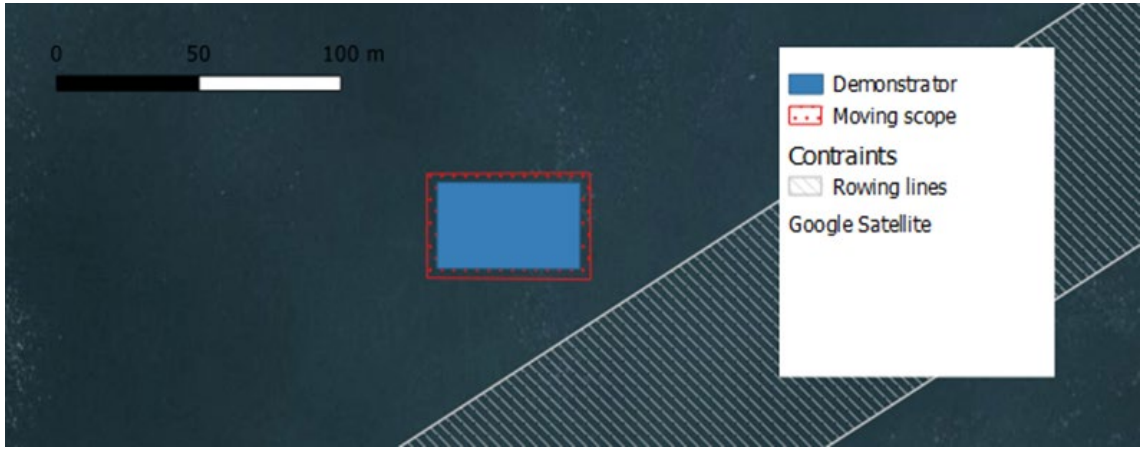


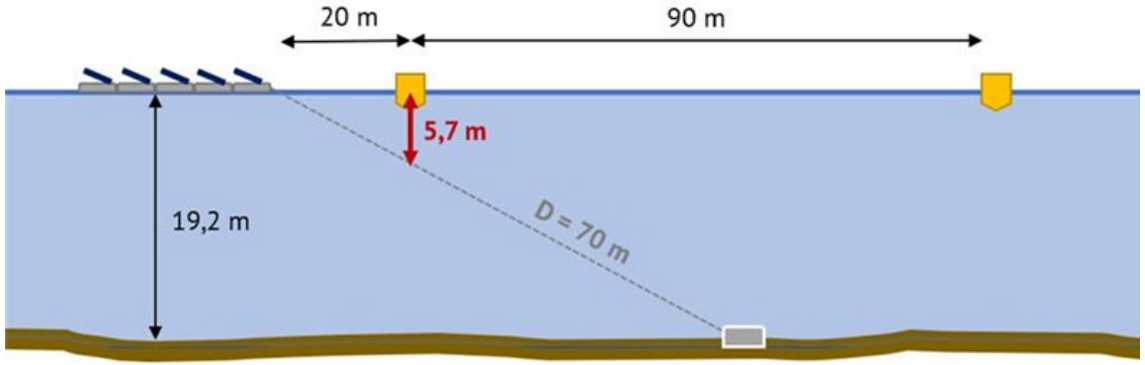
Anchoring



- 24 mooring lines of 70 m each,
- Bottom-anchored to 17 concrete anchors.

Mooring-lines are placed not to interfere with the rowing lines.





Construction platform

The launching area identified is the property of Yerevan Municipality.

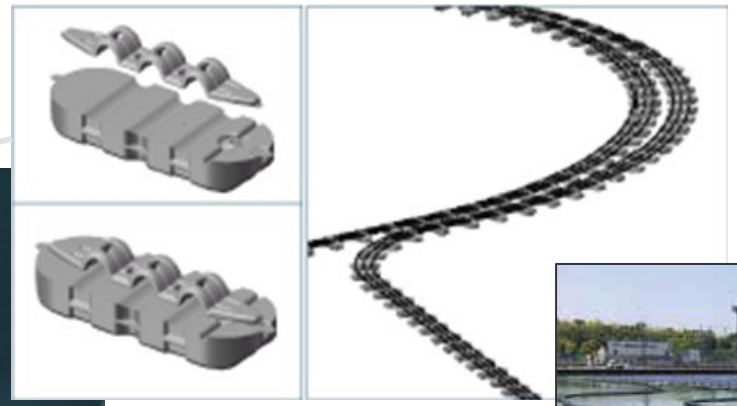
1

Floats are assembled on ground. A suitable launching area with a gentle slope has been identified near the hotel in construction

2

Anchors will be preliminary installed.
The floating island is then towed to its final location by motorboats and will be connected to the anchors.

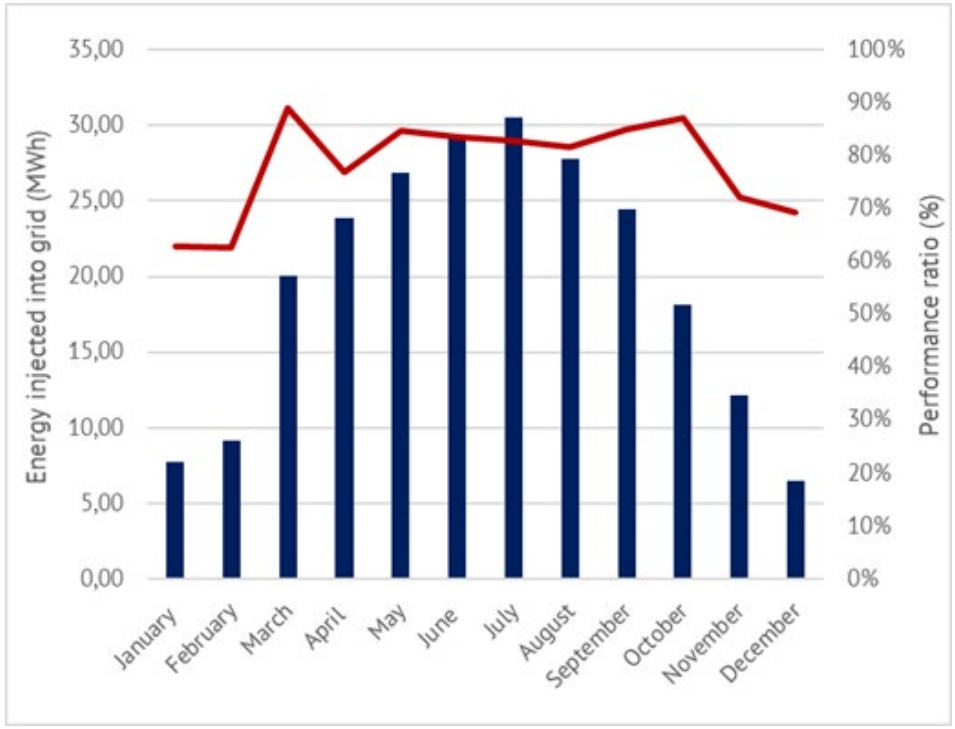
Cable management and grid connection



Alternative current (AC) wires will circulate on the surface of the lake, and then along the spillway, to the grid connection point : the dam private substation.

Energy yield analysis

Month	E injected into grid	PR
January	7,76	63%
February	9,21	63%
March	20,05	89%
April	20,47	77%
May	26,08	85%
June	28,40	84%
July	29,62	83%
August	26,98	82%
September	23,80	85%
October	17,67	87%
November	10,49	72%
December	6,30	69%
Year	**226,83 MWh**	**78%**



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- Low shadings.
- Water cooling effect improves electricity generation.

-

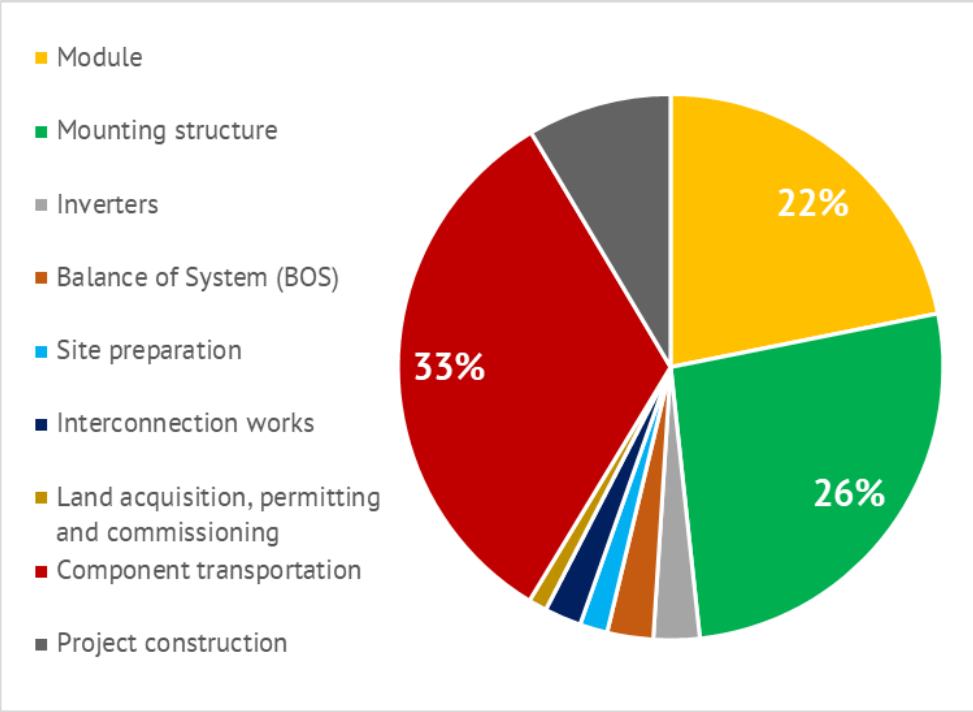
- Loss of irradiance due to :
  - Snow,
  - Bird dropping.

The pilot power plant will produce about 227 MWh of renewable electricity a year.

This equals to a reduction of 53 tons of carbon dioxide emissions per year.

Economical analysis

Total provisional cost : 276 600 US$ (238 000 €)



LCOE : 98,85 $/MWh
Considering a lifetime OPEX of 53 220$.

Tariff from the PSRC (July 2021 to July 2022) : 26,204 AMD/kWh (around **53,5$/MWh**)

- 33% of the CAPEX is transportation. Transportation costs between Europe and Asia have raised in 2021 and are expected to continue raising.
- The demonstrator is not economically profitable, due to important transportation costs and its small size.

Next steps

Year	2021													2022																													
Month	October				November					December				January				February					March				April					May				June				July				
	4-Oct	11-Oct	18-Oct	25-Oct	1-Nov	8-Nov	15-Nov	22-Nov	29-Nov	6-Dec	13-Dec	20-Dec	27-Dec	2-Jan	9-Jan	16-Jan	23-Jan	30-Jan	6-Feb	13-Feb	20-Feb	27-Feb	6-Mar	13-Mar	20-Mar	27-Mar	3-Apr	10-Apr	17-Apr	24-Apr	1-May	8-May	15-May	22-May	29-May	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul	24-Jul	31-Jul
Phase 2.1 - FPV demonstrator development and design																																												
In-depth technical design		■	■	■	■	■	■	■	■																																			
ESIA	■	■	■	■																																								
Financial modelling			■	■	■																																							
Legal and financial structure			■	■	■	■	■	■	■	■	■	■	■																															
Permitting					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																						
Construction work companies selection							■	■	■	■	■	■	■																															
Phase 2.2 - FPV demonstrator construction and comissioning																																												
Execution studies																																												
Equipements order							■	■	■	■	■	■	■																															
Transportation														■	■	■	■	■	■	■	■	■	■	■	■	■																		
Local actors FPV training session for anchoring and construction																											■																	
Construction of the demonstrator																											■	■	■	■	■	■												
FPV demonstrator works completion																																■												
FPV demonstrator commissioning																																		■										
FPV follow-up procedure and tools																																			■	■	■	■						
Phase 2.3 - Training and communication																																												
Local actors FPV module training session (technical aspect for O&M mainly)																																			■	■	■	■						
Grand opening																																							■					
End of the project																																								■				

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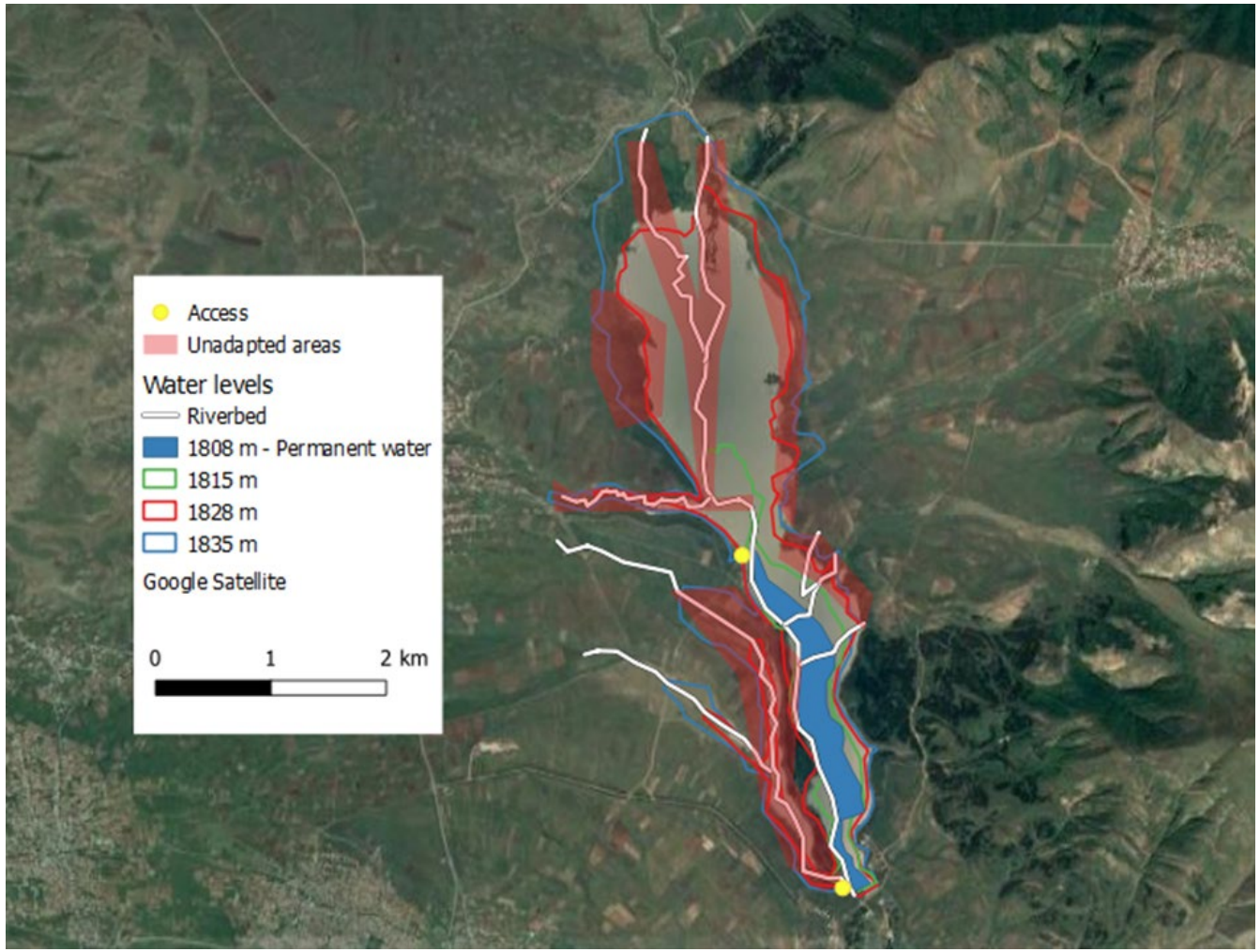
Ongoing feasibility studies
Azat and Aparan reservoirs

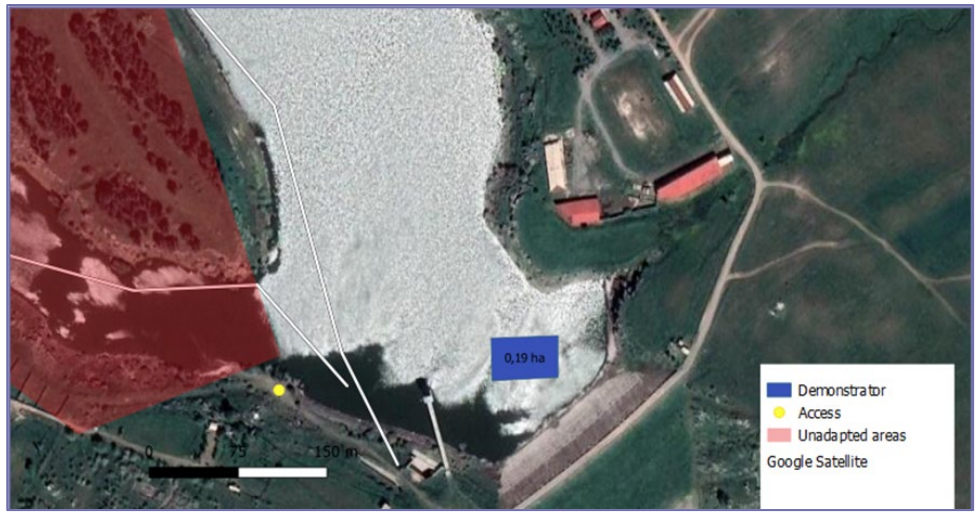
Aparan



- Artificial reservoir on Kasakh River,
- 7,3 km², 8,5km long and 2,5 km wide,
- Largest artificial reservoir in Armenia,
- Dam started operations in 1968,
- Reservoir uses :
  - Drinking water supply for Yerevan,
  - Irrigation,
  - Hydroelectricity generation.
- Operated by the Water Committee.

Aparan

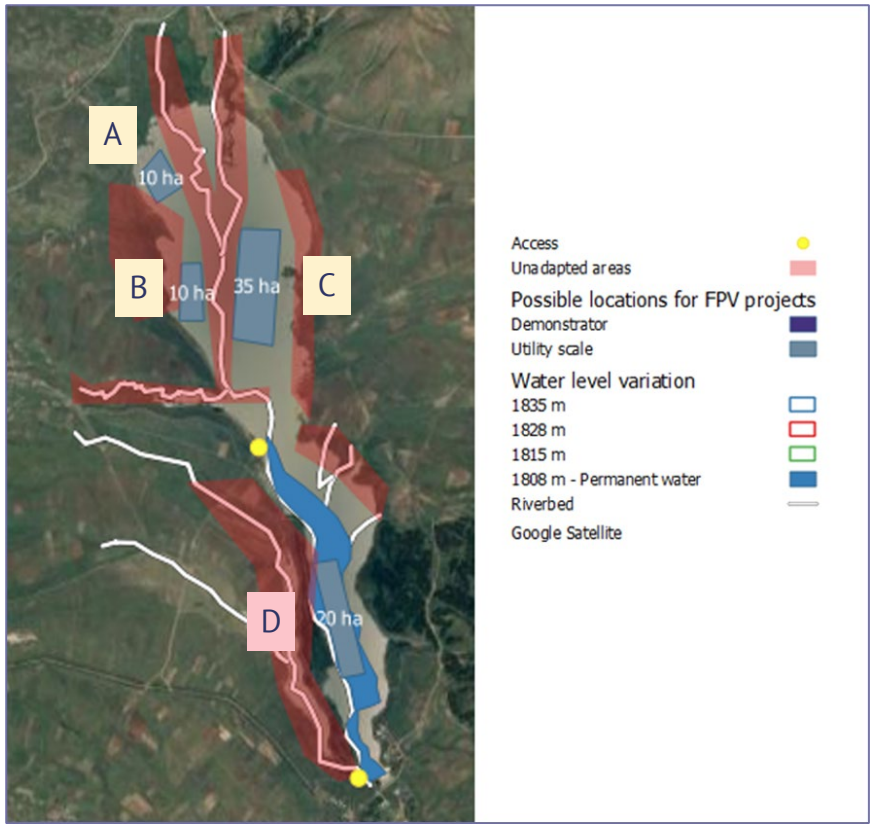
Demonstrator



- Important level variation (up to 27 m) : anchoring impossible,
- Strong mechanics constraints on the floats due to ice movements.

Not feasible

Utility scale project

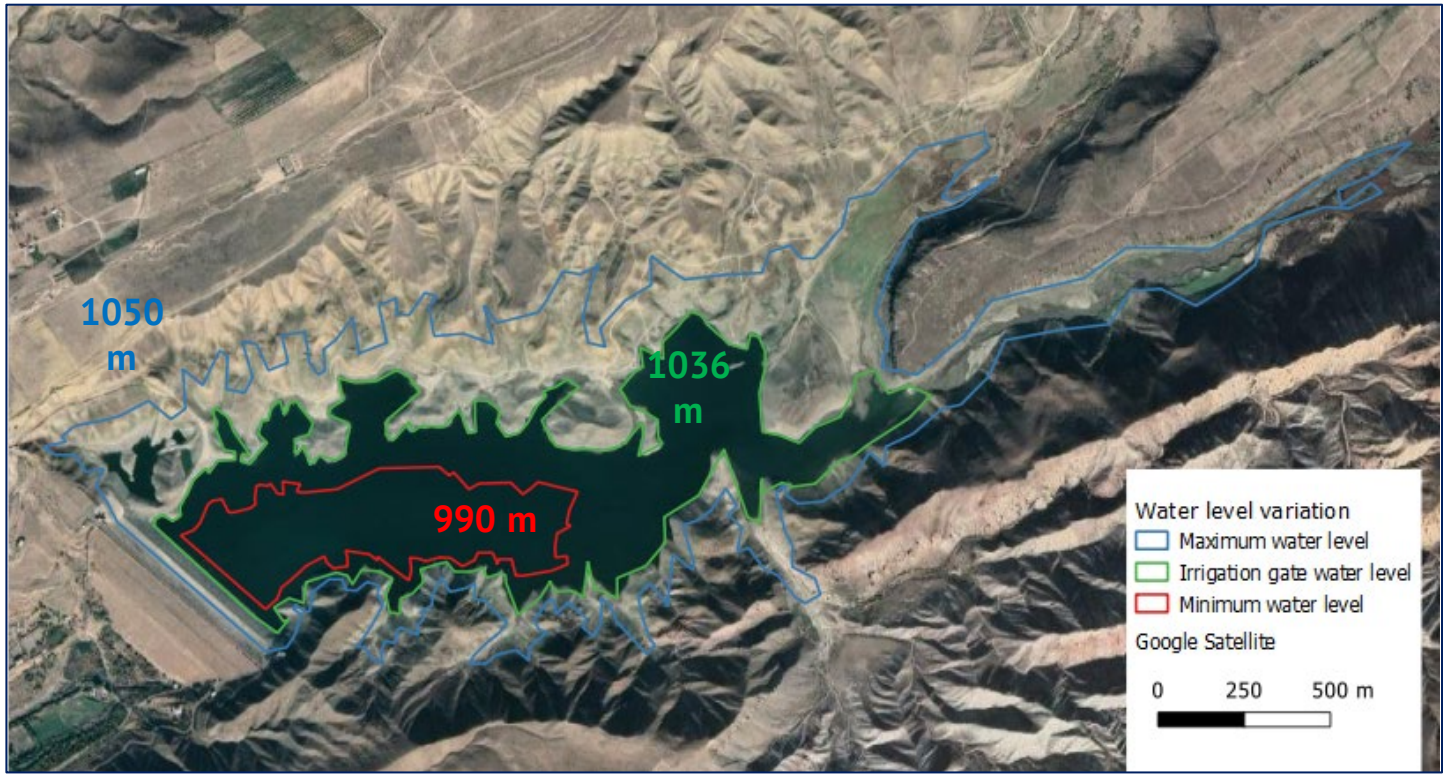


- 4 areas totalizing 75 ha.
- 3 areas are not on permanent water : floating system must land.
- Strong ice constraints on D area.
- Areas A, B and C are accessible by foot when low water level : human use conflicts and security issues.

Area D : not feasible

Areas A, B and C : feasibility under study

Azat



- Artificial reservoir on Azat River,
- 200 ha, 2,5km long,
- Dam started operations in 1975,
- Reservoir uses :
  - Irrigation of the Ararat valley,
  - Hydroelectricity generation.
- Operated by the Water Committee.

Very important level variation : 60 m

Anchoring impossible

Not feasible

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Thank you for your attention.