Water Resources Engineering and Management

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

5 ETCS, Master course

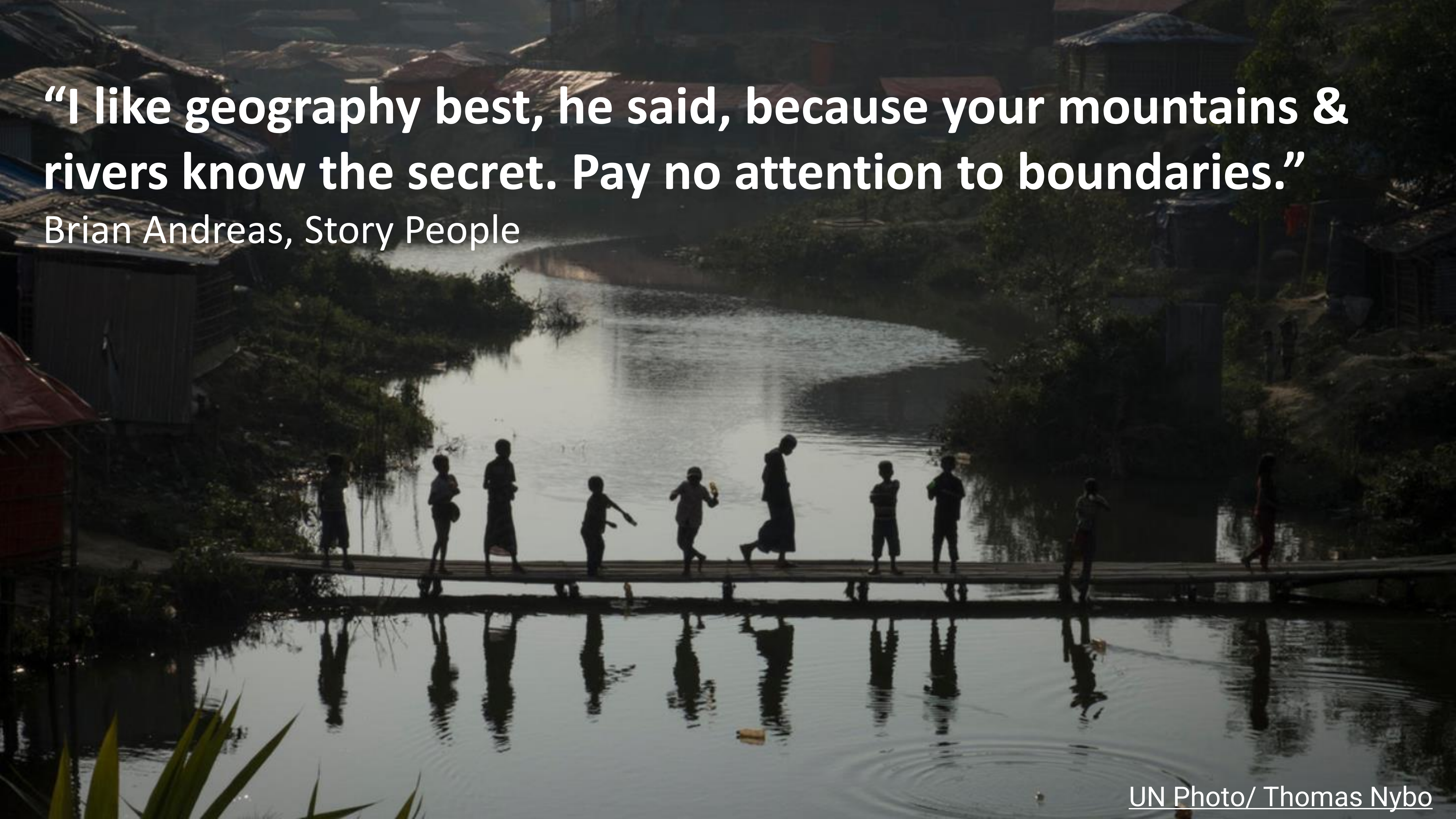
Marcelo Leite Ribeiro

gruner

Lecture L9.2 - Water Management: conflict of interest & International river basins

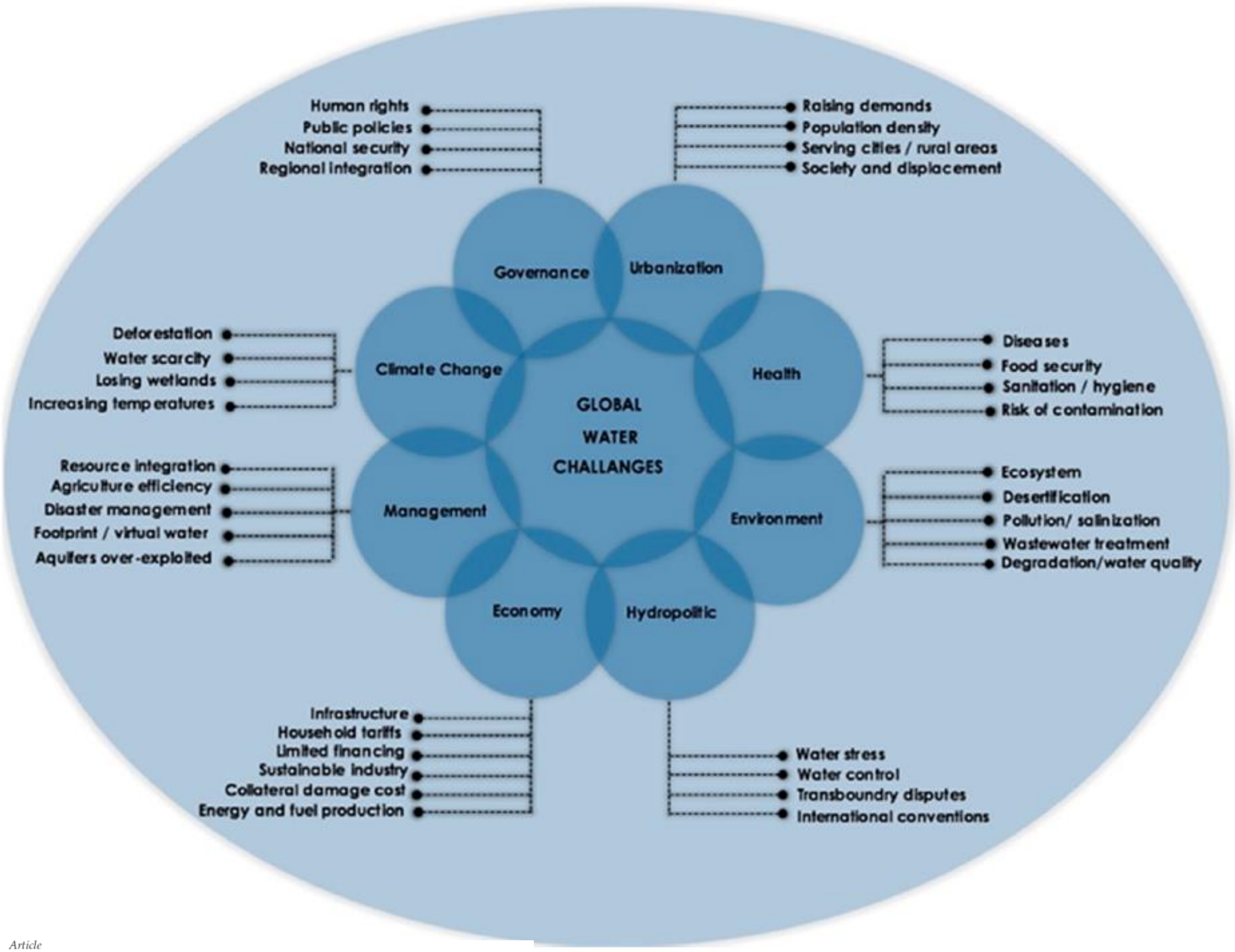
“I like geography best, he said, because your mountains & rivers know the secret. Pay no attention to boundaries.”

Brian Andreas, Story People



UN Photo/ Thomas Nybo

Conflicts of interest



Article

Developing Strategy for Water Conflict Management and Transformation at Euphrates–Tigris Basin

Sameh W. H. Al-Muqdadi

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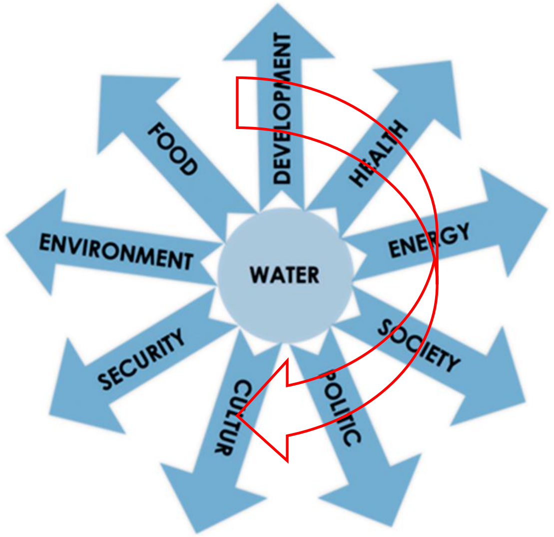
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- Problem with many dimensions

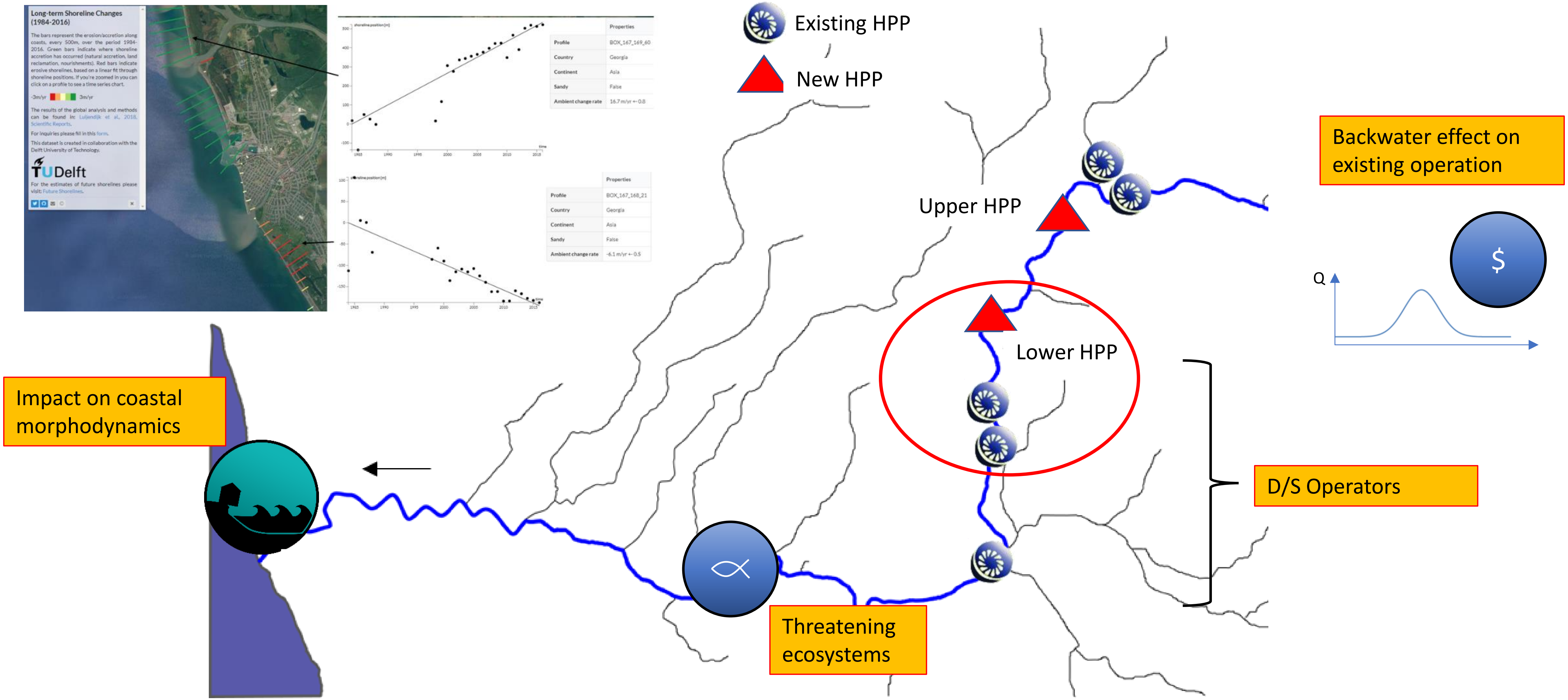


- And stakeholders
  - Regulators and government
  - Industry
  - Landowners, farmers and members of the general public
  - Members of the scientific community
  - Investors & Development banks

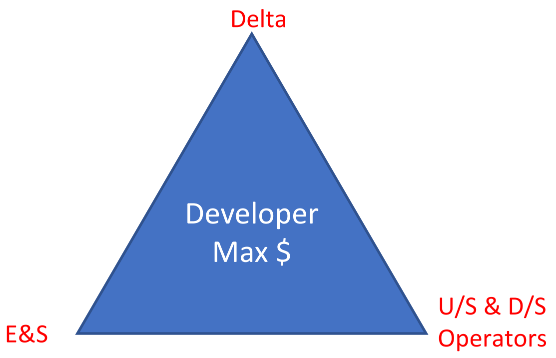
Conflicts of interest

https://www.linkedin.com/posts/alexpassini_water-resources-engineering-ugcPost-7304859997694308353-Nw_p?utm_source=share&utm_medium=member_ios&rcm=ACoAAAicPAoBFH9YYmAIZJv8vn6MrEfr3bvYCio

Case study - Hydropower cascade under development

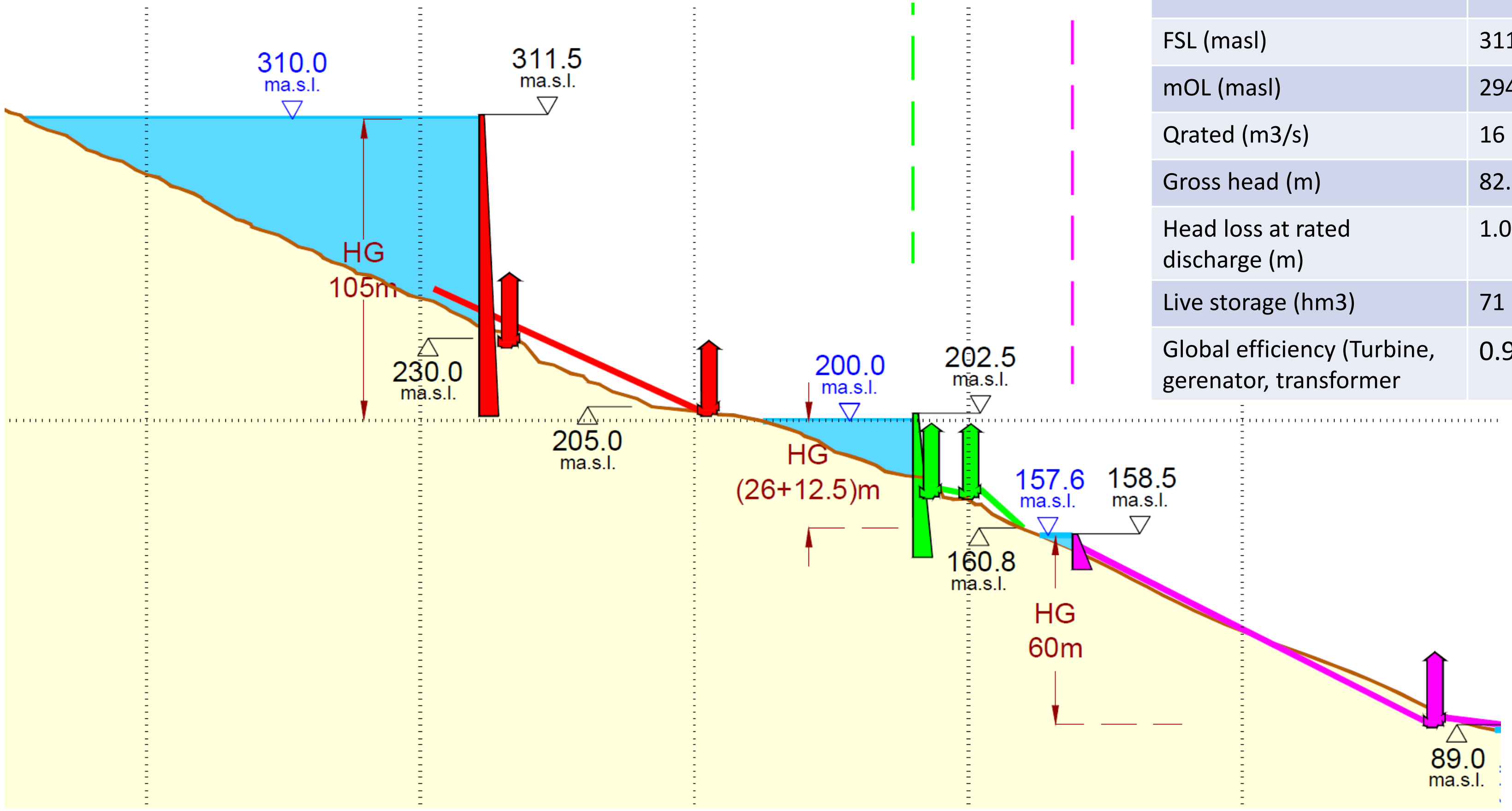


Project features



- **How to operate Lower HPP in order to:**
  - Maximize revenue for the developer
    - Operating mode
    - Sediment management (Flushing / Sluicing?, recurrence?)
  - Reduce impact on upstream and downstream operators (loss of head, loss of revenue during peak operation, integrated sediment management plan, etc…)
  - Reduce downstream E&S impacts (safety, sturgeon, reduction of sediment load → bank/bed erosion, etc)
  - Reduce costal impacts (erosion, possible mitigation measures?, definition of responsibilities or better saying who pays for the mitigation measures?)

Project features



	Scheme			
Parameters	Lower SHPP	Lower HPP	Existing HPP **U/S**	Existing HPP **D/S**
FSL (masl)	311.5	311.5	198.2	158.0
mOL (masl)	294.5	294.5	196.0	157.0
Qrated (m3/s)	16	334	214	75
Gross head (m)	82.5	105.9	26+12.5=38.8	60
Head loss at rated discharge (m)	1.0	10.0	0.9	Not considered
Live storage (hm3)	71	71	1.2	0
Global efficiency (Turbine, gerenator, transformer	0.92	Variable	0.90	0.90

Project features

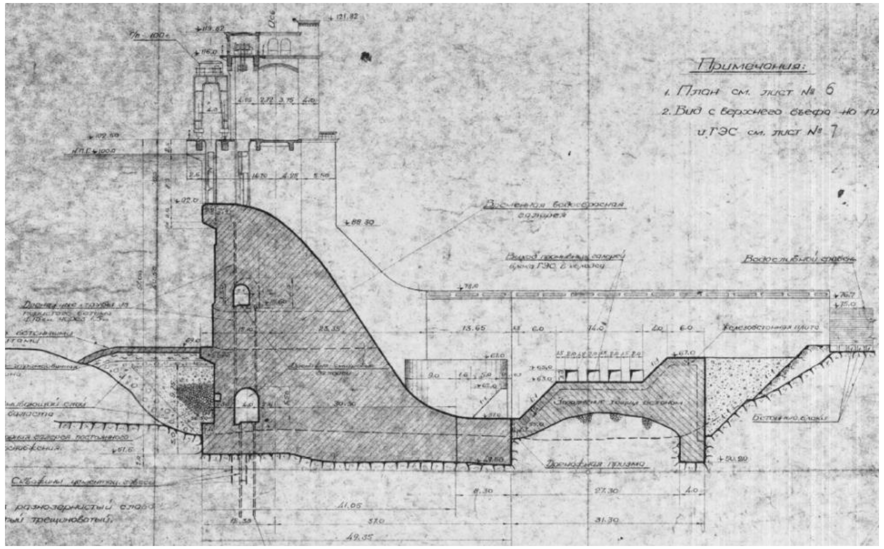
➢ New HPP

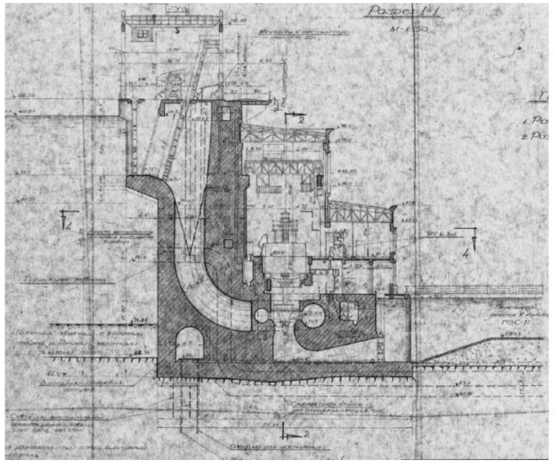
Project features

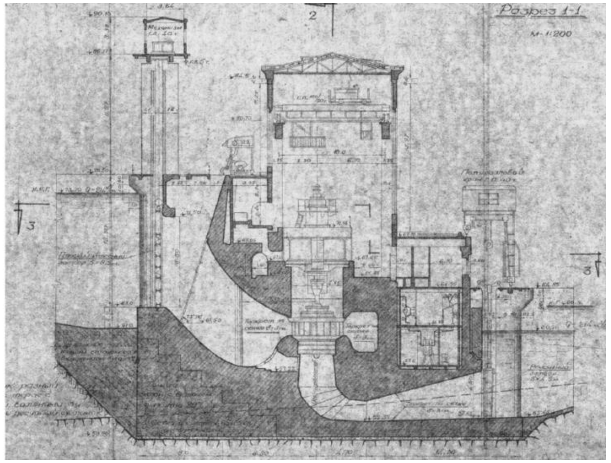
- New HPP

Project features

- Existing U/S HPP

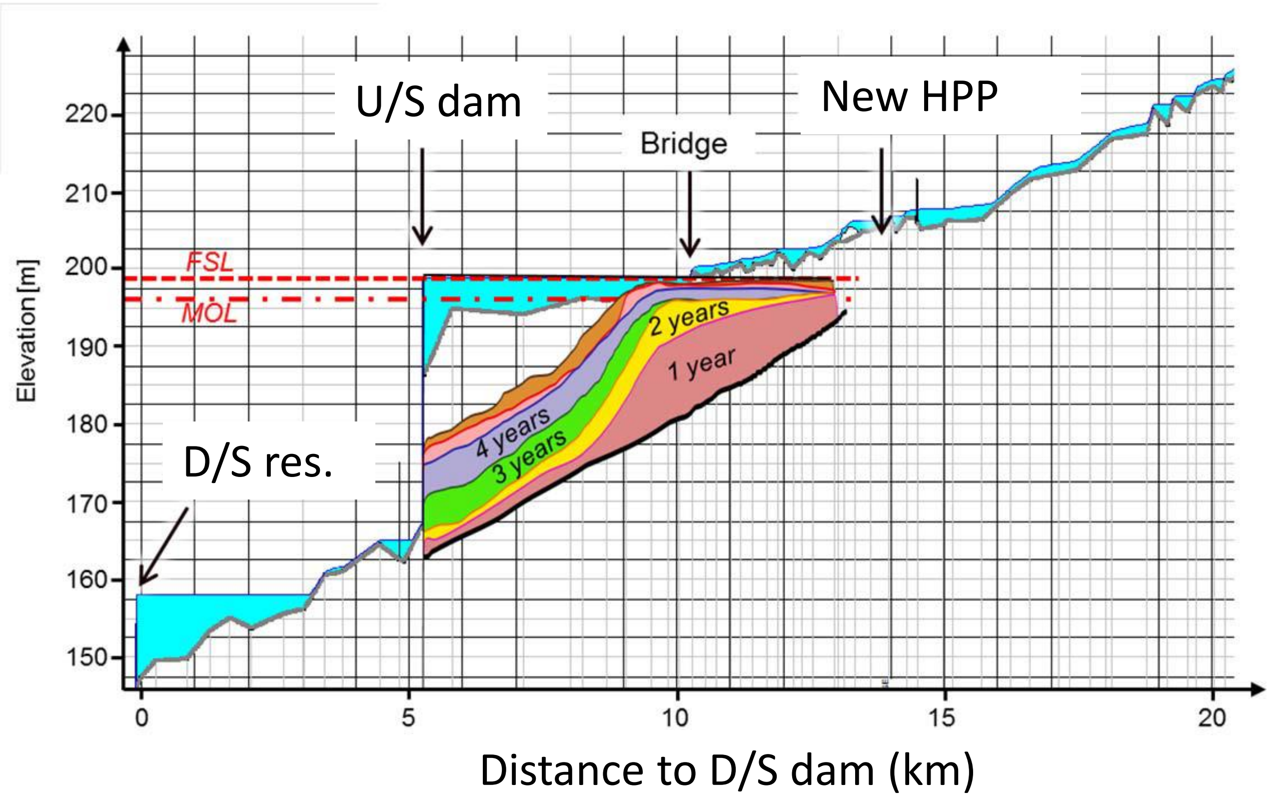






Project features

➢Existing U/S HPP



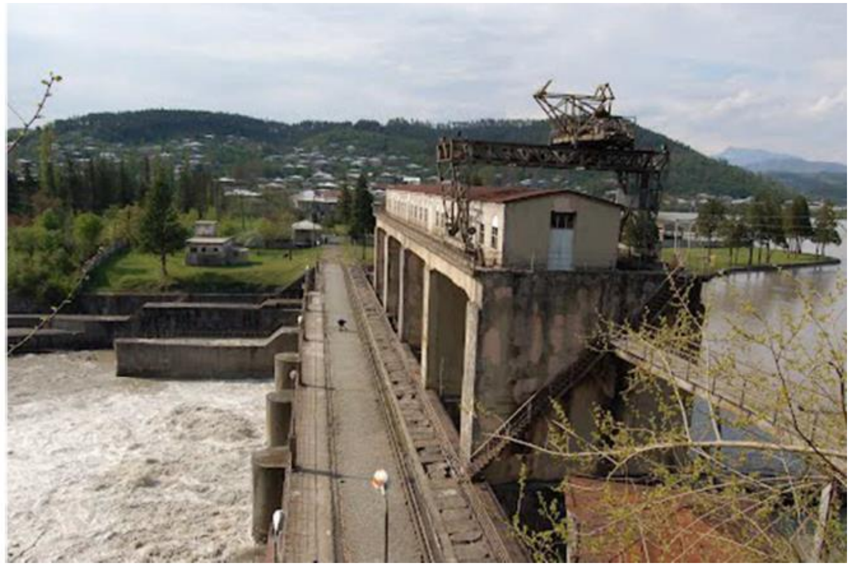
➢Limited available volume (1,2 hm^3)

➢No bottom outlet at the dam

➢Active sediment management → impossible

Project features

- Existing D/S HPP

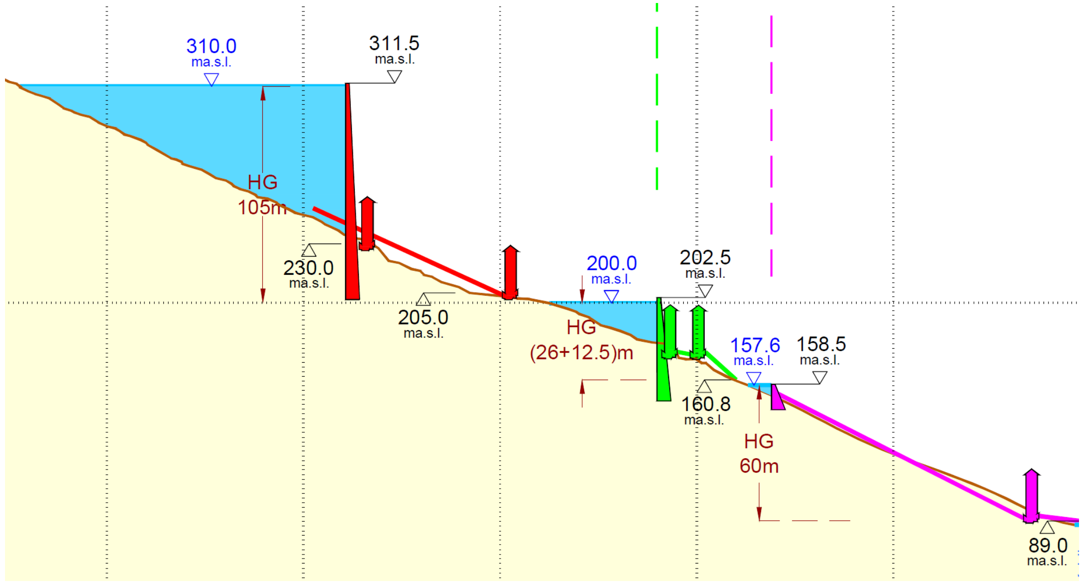


Energy production

- Inflow at Lower HPP:
  - Daily streamflow discharges from 1938 to 2013
  - Forecast based on the BD series with an horizon of 7 days
- Outflow at Lower HPP
  - Lower SHPP: 16 m^3/s (constant)
  - Lower HPP: depends on scenario
- Outflow at Existing HPP 1
  - Existing HPP
    - 2 conditions:
      - Qout max = 214 m^3/s if
        - WL > 198.7 masl or
        - Qin> 214 m^3/s

      Or

        - Qout = 0.95 * Qin (= reservoir filling)
- Outflow at Existing HPP 2
  - Qout=Qin (max = 75 m^3/s)



Energy production

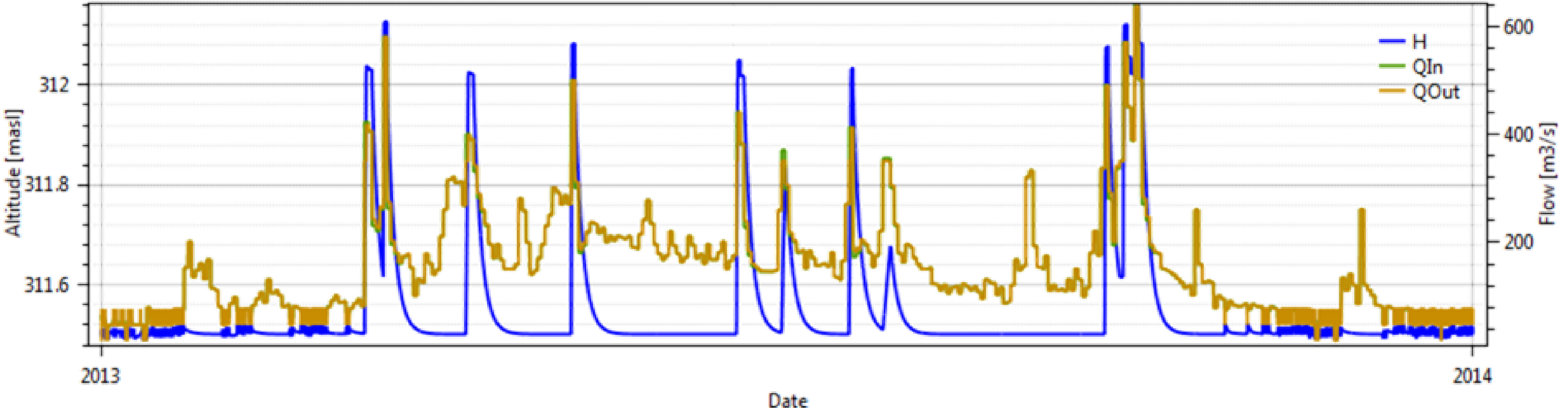
- Current situation: the current situation is run (i.e. without cascade).

  This sets the reference production of existing HPP.
- Three main scenarios are then considered for the outflow of Lower HPP:
  - RoR:
    - Run-off-the-river operation where the volume is kept as high as possible.
    - (Optionally) preventive turbining takes place in order to minimize spillage with a forecast horizon of 1 week.
  - Free:
    - Operation following the criteria of peak (8 hours/day during weekdays) and base (16 hours/day during weekdays and the whole weekend). The volume of the next days and the targets on the water level imposed are taken into account for the determination of the values of peak and base discharges
  - RoR+FREE
    - RoR operation during the months covered by the PPA (January to April and September to December)
    - Free operation during the remaining months (May to August)

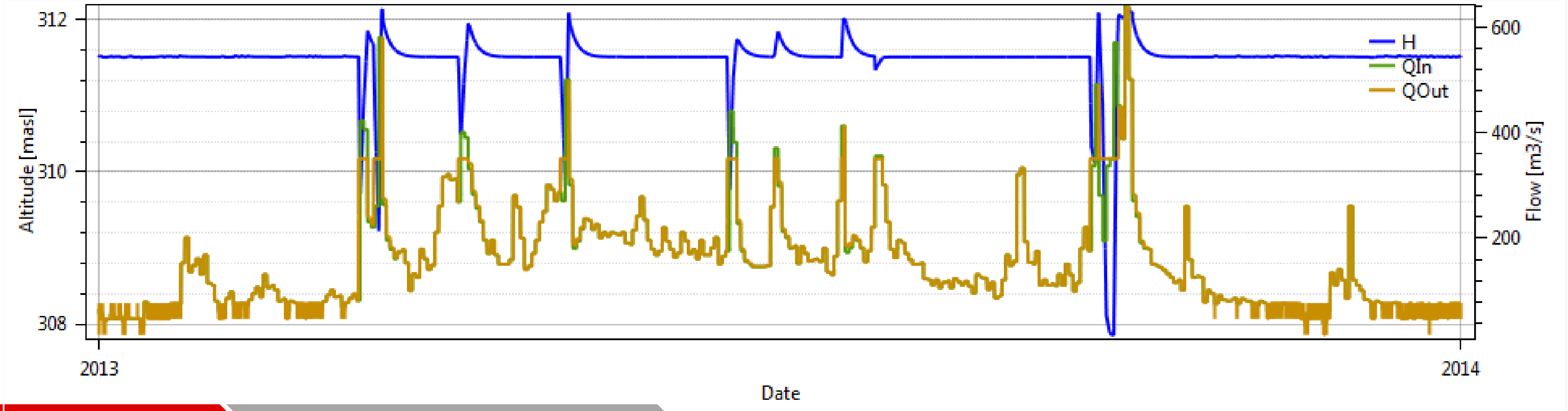
Energy production

- RoR Operation

Pure RoR – negligible gain at existing HPPs(<0.1 %)



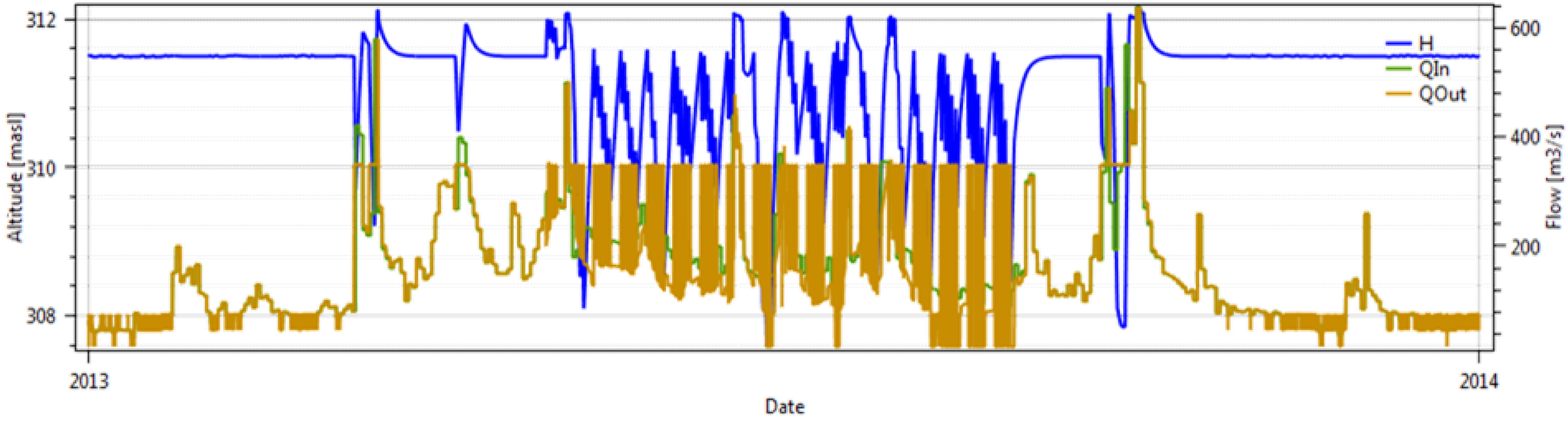
RoR with preventive turbining – minor gain at existing HPPs (~0.2%)
minor gain at Lower HPP (~0.9%)



Energy production

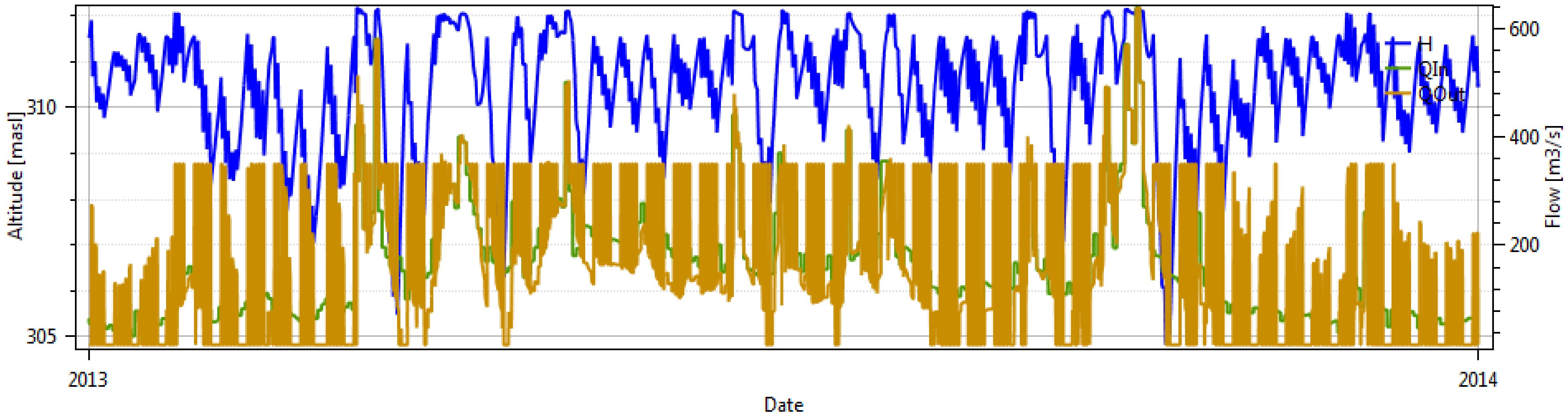
- RoR + Free operation (one daily peak)
  - Results with residual optimization of the Existing HPP reservoir (the role played by the reservoir is very limited and its full live storage is not mobilized).
  - During the free operation season (May to August), a continuous peak of 8hr was considered.

loss at Existing HPPs (3.9%)



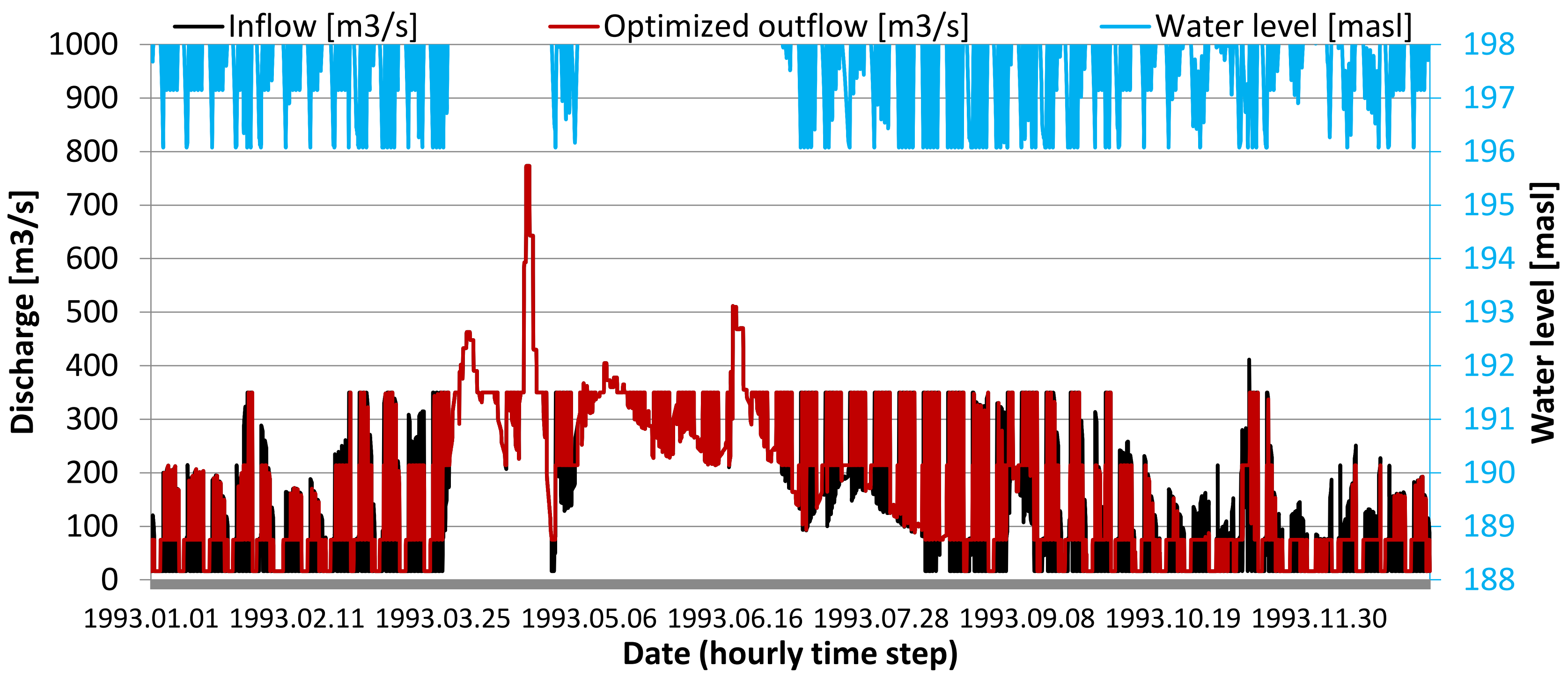
Energy production

- Free operation (one daily peak)
  - Results with residual optimization of the **existing D/S HPP** reservoir (the role played by the **existing D/S HPP** reservoir is very limited and its full live storage is not mobilized).
  - A continuous peak of 8hr was considered for all working days.

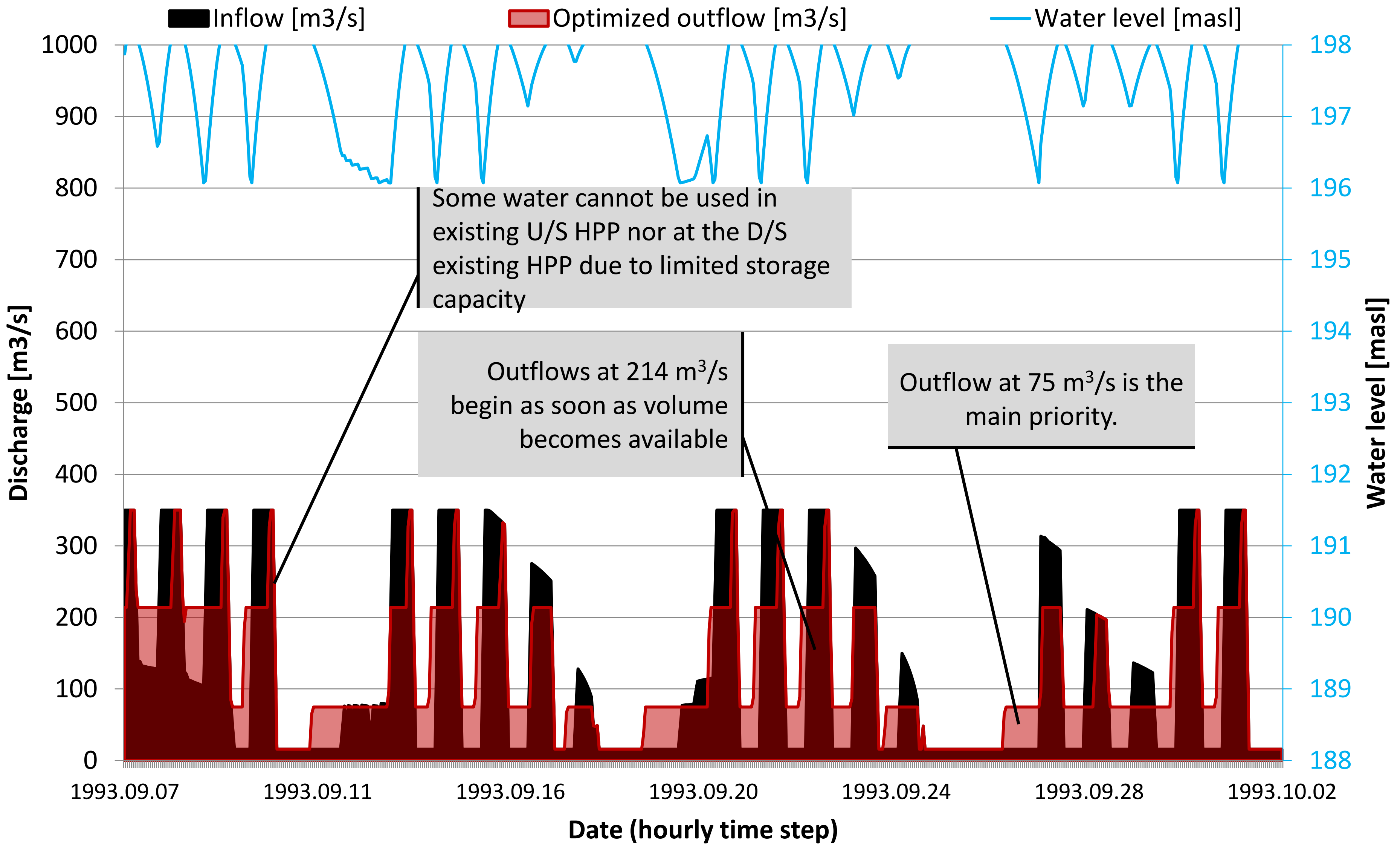


Energy production

- The volume at the **existing U/S HPP** can be used to laminate part of the peaks from the **lower HPP**.
  - Two goals to the preventive turbining: provide a stable 75 m^3/s for **existing D/S HPP** and release the remaining water at a maximum of 214 m^3/s to the largest extent possible.
  - The preventive turbining may be limited by 1) time and 2) volume of the reservoir.
  - The only adverse effect the operation may have is decreased water level at **Existing U/S HPP**.



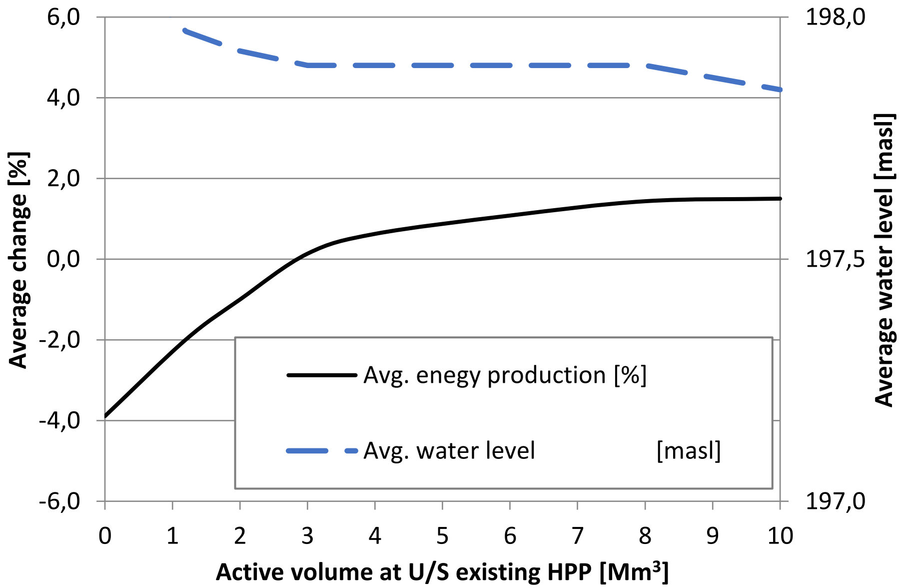
Energy production



Low inflows (example)

Energy production

- Effects of the increased volume at U/S existing Reservoir
  - "RoR+Free" operation:
    - The current live storage (1.2 hm3) can be used to reduce the potential lost at the U/S and D/S existing HPP's and due to the Lower HPP operation to about 2%.
    - With the increase of the available volume at the U/S existing reservoir, a preventive operation of the HPP can help the increase of energy production at both the U/S and D/S existing reservoirs.
    - An increase of the U/s existing live storage up to about 3 hm^3 would lead to full mitigation of the impacts of the peak production at the Lower HPP between May and August.
    - This volume is approximately the volume needed to cover the peak production at Lower HPP, i.e. V= 8hours * (334 m^3/s +16 m^3/s - 214 m3/s) * 3600s ~ 4 hm^3

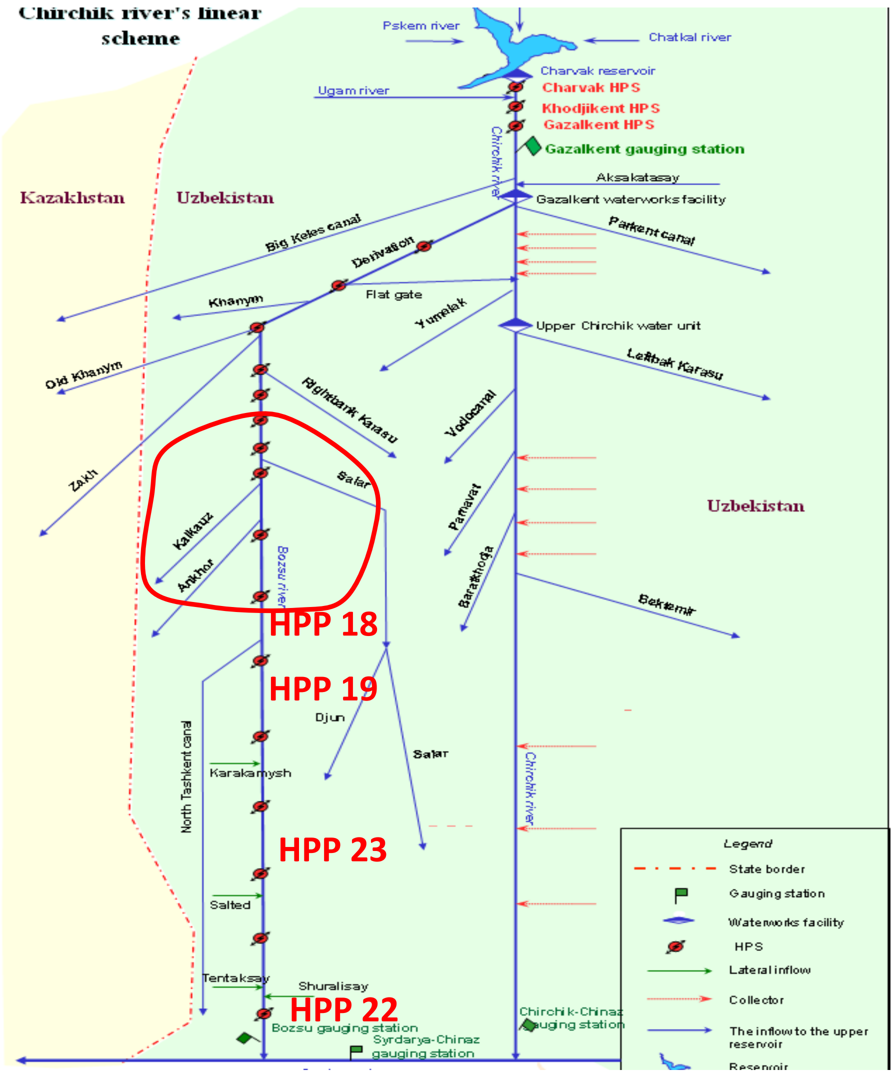


Conclusions

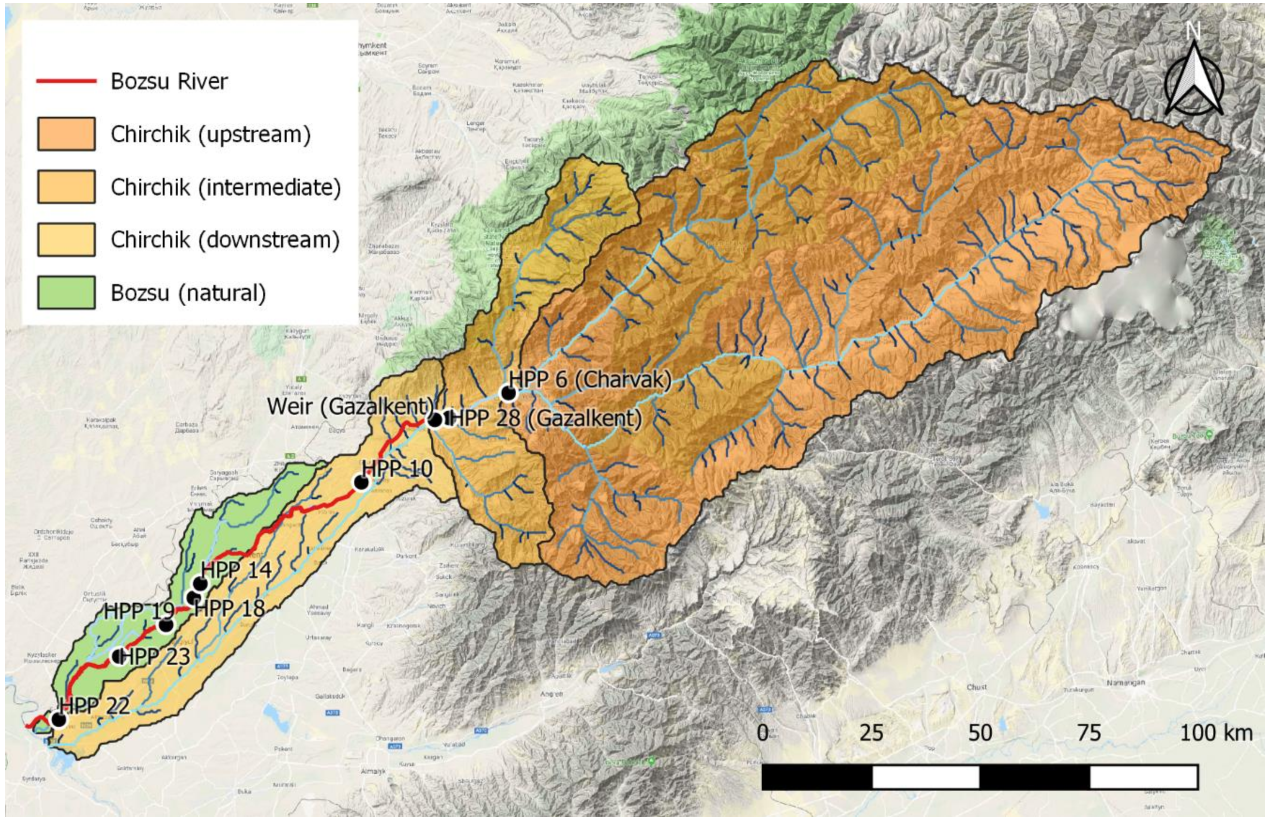
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- Need for an integrated water management program for the catchment
  → driven by the government.
- Interest between all (or at least the main) stakeholders shall be taken into account.
- E&S aspects shall be integrated into the design from the very early stages of a project → it cannot be underestimated.

Case study - Hydropower cascade in Uzbekistan



- Rehabilitation of existing HPPs
- Lender: European Bank for Development and Reconstruction (EBRD)
- Beneficiary: UzbekHydroenergo



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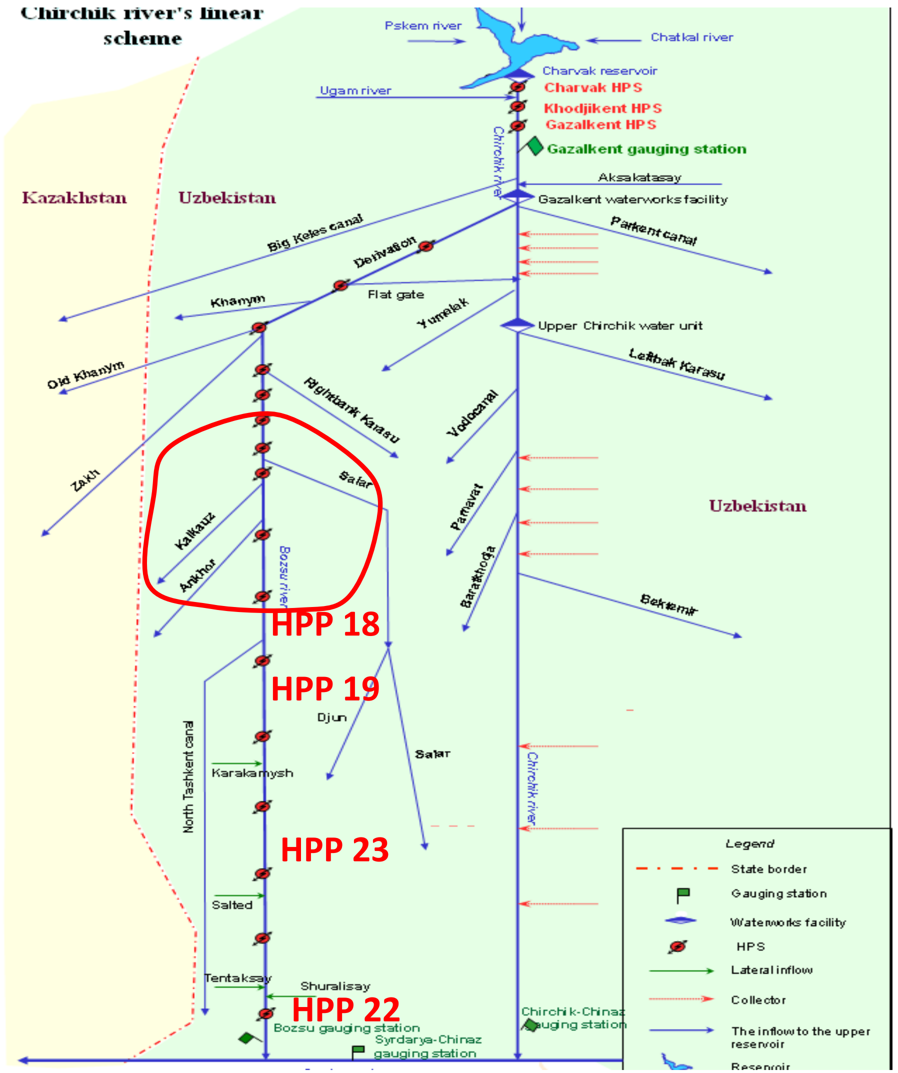
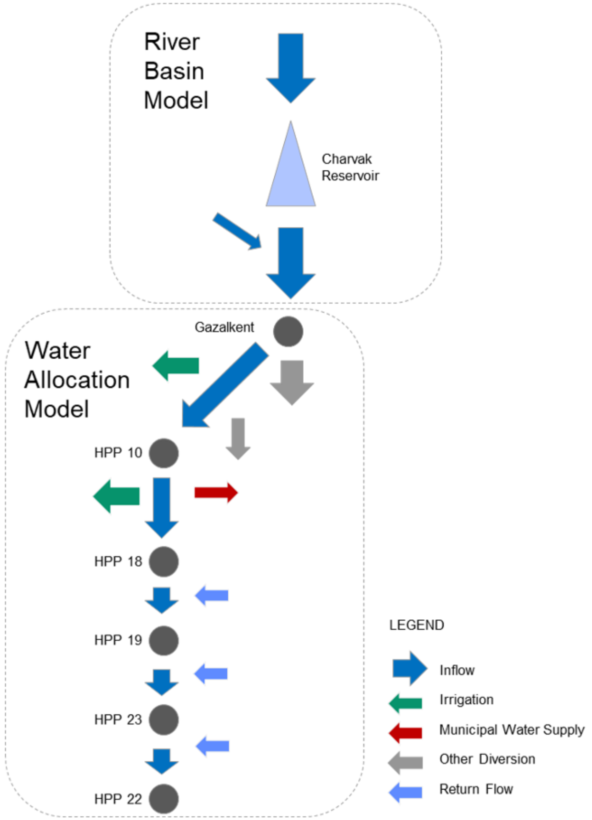
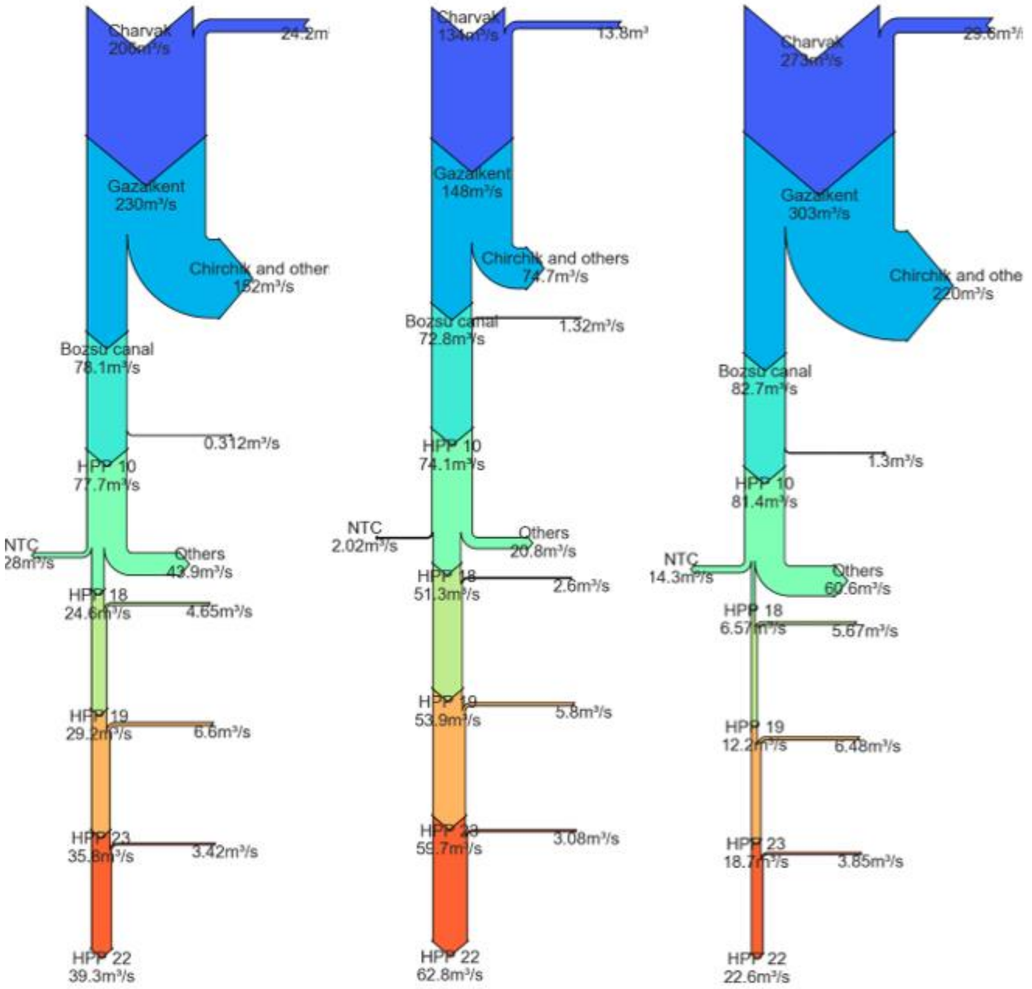


- Chirchik - River Basin Model
  - Precipitation-Runoff Model
  - Charvak Reservoir Operation Model
- Boszu - Water Allocation Model
  - Water allocation model Gazalkent
  - Diversions Gazalkent - HPP10
  - Diversions HPP10 - HPP18
  - Return flows HPP18 – HPP22



Main features



Whole year — Winter (December – March) — Summer (May – October)

- During summer, only about 6.5% of the water entering the Bozsu River reaches HPP 18.

Table 1: Summary data for the lower Bozsu HPP cascade.

	HPP 18	HPP 19	HPP 23	HPP 22
Q_{rated} [m³/s]	75	74	60	50
H_{rated} [m]	11.5	17.6	35.8	11
Turbines [-]	3	2	2	2
$Power_{rated}$ [MW]	7.0	11.2	17.6	4.4
Efficiency (theoretical) [-]	~0.83	~0.86	~0.85	~0.82
Energy production target 2018 [GWh]	13.84	12.90	73.57	19.47
Energy production 2018 [GWh]	12.00	7.65	77.36	25.22

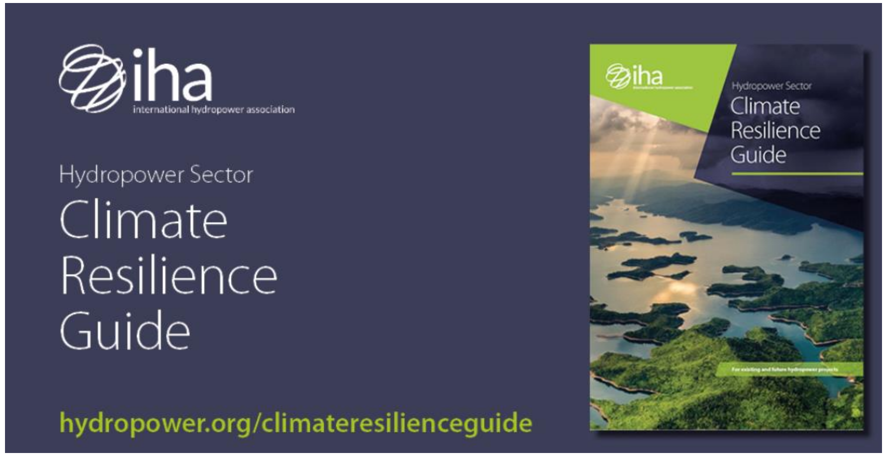
Impact of Climate Change

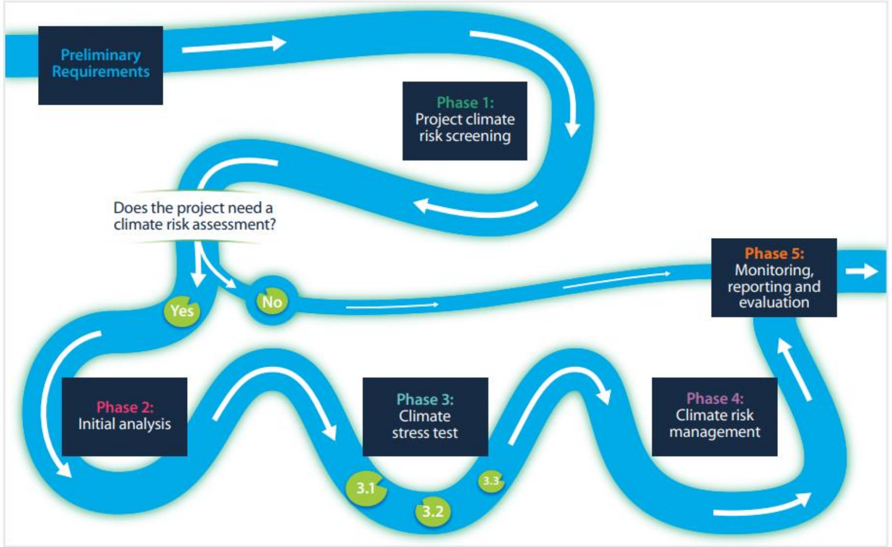
- The Bozsu crosses Tashkent and other growing urban areas, which should keep significant water consumptions also during winter months.
- With a rise in such consumptions, there may be associated a decreased of the energy produced in the lower Bozsu cascade.

Impact of Climate Change

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- Climate Risk Assessment (CRA) for the Boszu River Cascade was conducted based on the approach described in the Climate Resilience Guide (CRG) of the International Hydropower Association
- Outcomes indicate that climate change may have a significant impact on the project, with the following major risks identified:
  - Reduced inflow to the Chirchik-Boszu River system due to changes in the temperature and precipitation regime of the natural river basin.
  - Increased water abstraction from Boszu River, due to temperature-driven increase of evapotranspiration and irrigation demand
  - Changes in the demand for irrigation and municipal water supply due to technological development and population growth





Impact of Climate Change

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

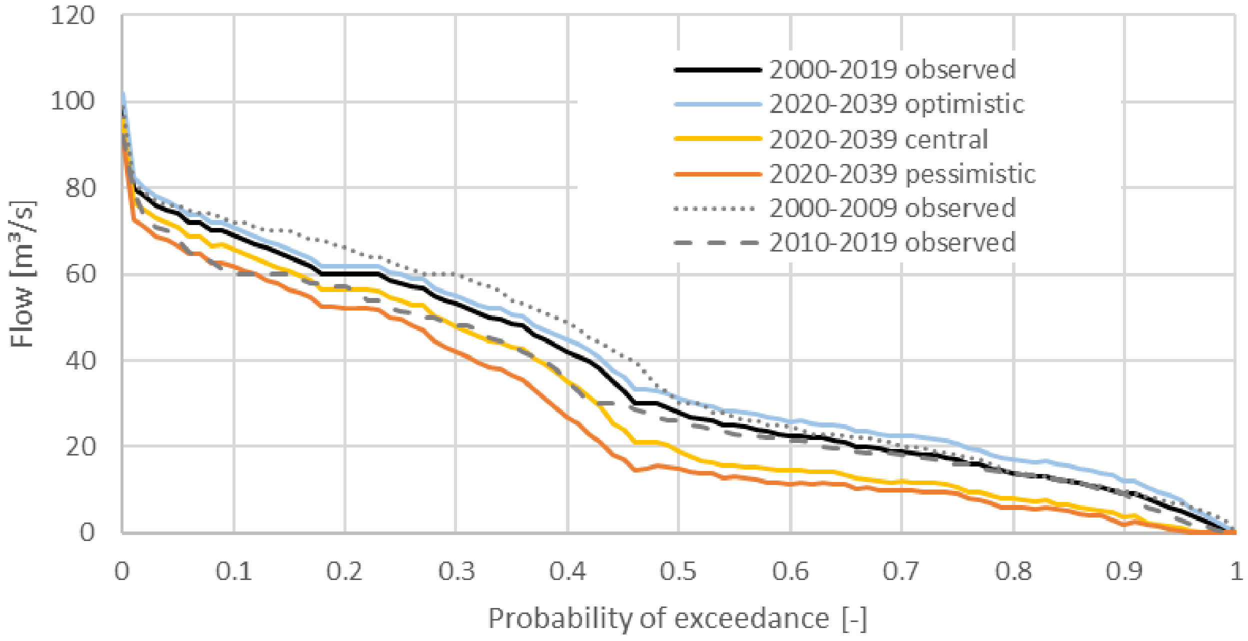
- A model was set up and calibrated based on observed data
- The model was run for different scenarios of climate change and water extraction for irrigation and municipal water supply.
- The time horizons of the scenarios cover the near-term future (2020-2039) as well as the mid-term future (2040-2059).

- Climate Change Scenarios
  - Near-term future
  - Mid-term future
- Irrigation & Municipal Demand Scenarios
  - Near-term future
  - Mid-term future

	OPTIMISTIC RCP 4.5 (10% quant.)	CENTRAL Avg of Optim & Pessim	PESSIMISTIC RCP 8.5 (90% quant.)
Temperature increase	+ 0.2°C	+ 0.75 °C	+ 1.3°C
Precipitation Change	+ 6 %	+ 2 %	- 2 %

	OPTIMISTIC ~VodaProjekt 2010	CENTRAL	PESSIMISTIC
Changes in municipal water demand due to growth	+ 15 %	+ 25 %	+ 35 %
Changes in irrigation demand due to agricult.developm	- 15 %	0 %	+ 15 %

Impact of Climate Change



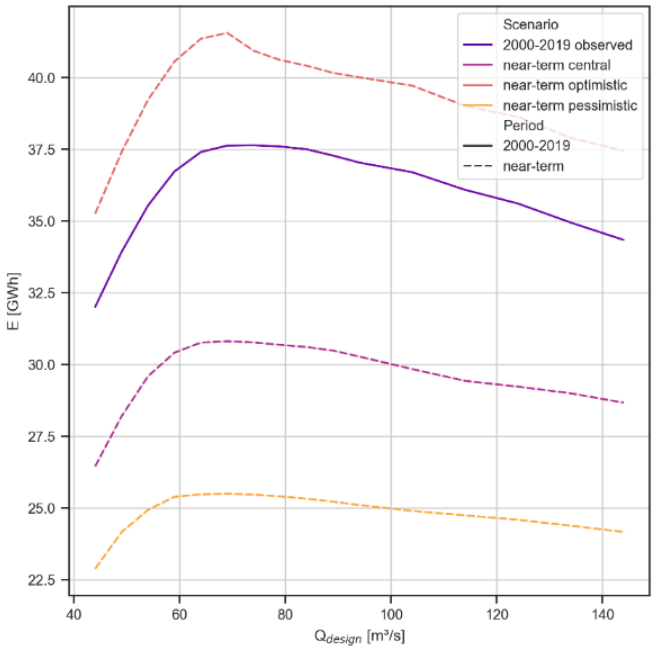
- Flow duration curves simulated for the different scenarios
- Central and pessimistic scenarios entail significant reduction of the discharge in along the cascade.
- The bulk of these changes is motivated by municipal water demand and is, therefore, well distributed throughout the year.

Impact of Climate Change

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- Analysis of annual Energy (GWh/year) vs Installed capacity (MW)

HPP 19



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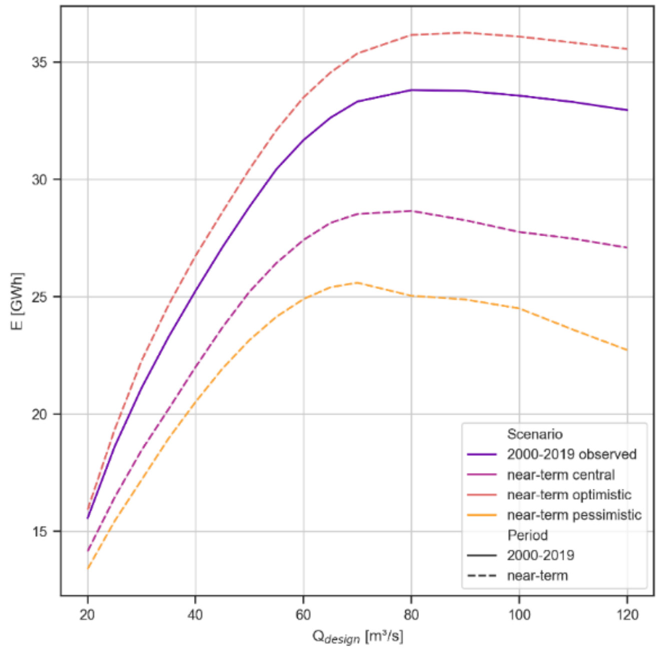
HPP 22



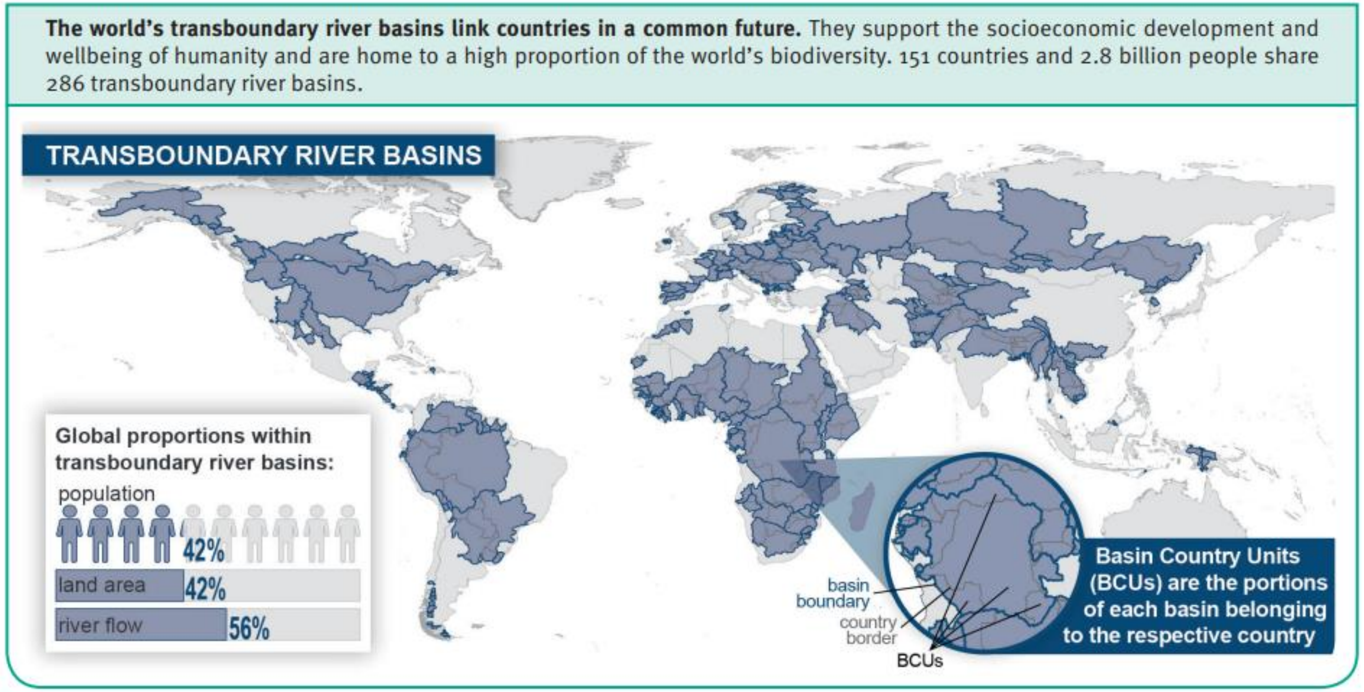
Conclusions

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- Climate change aspects shall be considered during the design phase.
- In some cases, current issues (losses, inefficiency of the system, bad utilization) have a significant impact on the design of the project.

Transboundary river systems

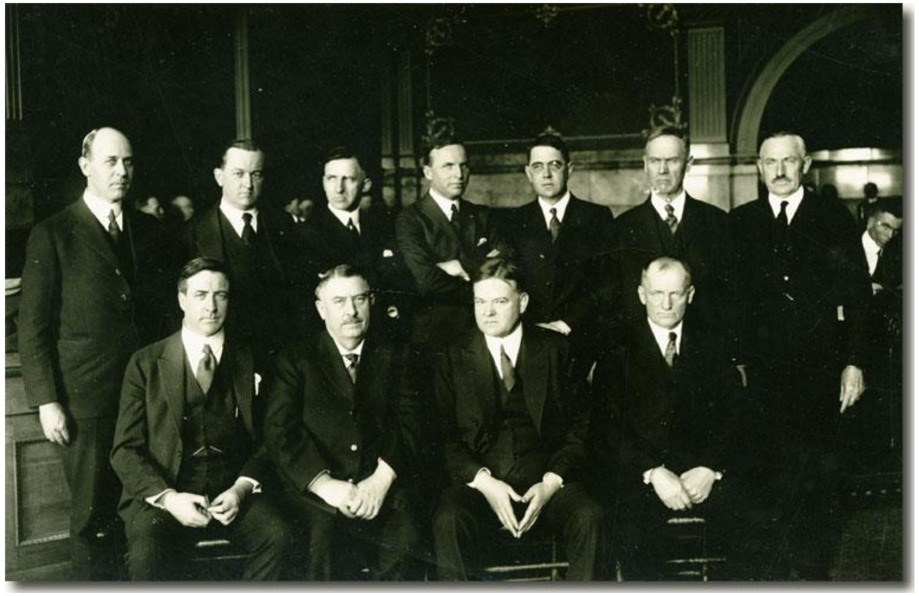
- There are over 286 transboundary river basins in the world, covering more than 60% of the Earth's surface.
- This highlights the importance of effective management and cooperation between countries that share these rivers to ensure **equitable** and **sustainable** use of the shared resources.
- River commissions play a key role in the management of some transboundary river systems



Transboundary river systems

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- A river commission is an **organization** responsible for **managing** and **regulating** a particular river or river system.
- It is typically composed of representatives from various government agencies, non-profit organizations, and private stakeholders.
- River commissions may be responsible for issues such as **water allocation**, **dam construction**, and **flood control measures**.
- They may also be involved in monitoring water quality, flow rates, and other factors that may affect the health of the river ecosystem.
- The **ultimate goal** is to ensure that **water resources** are used in a **sustainable, equitable, and efficient manner**.



https://coloradoencyclopedia.org/image/colorado-river-commission-1922

Transboundary river systems

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

> River commissions play an important role in the management of transboundary river systems

International Commission for the Protection of the Oder against pollution	Czech Republic, Germany, Poland, European Community	http://www.mkoo.pl/
International Commission for the Protection of the Elbe	Czech Republic, Germany, European Community	http://www.ikse-mkol.org/
International Commission for the Protection of Lake Geneva	France, Switzerland	http://www.cipel.org/
International Commission for the Protection of Lake Constance	Austria, Germany (Baden-Wurttemberg, Bavaria), Switzerland	http://www.igkb.de/
International Commission for the Meuse/Maas	Belgium (Brussels-Capital region, Flemish region, Walloon region), France, Germany, Luxembourg, Netherlands	http://www.meuse-maas.be/
International Commission for the Scheldt	Belgium (Brussels-Capital region, Flemish region, Walloon region), France, Netherlands	http://www.isc-cie.com/
Joint Finnish-Russian Commission on the Utilization of Frontier Waters	Finland, Russian Federation	http://www.rajavesikomissio.fi/
International Commissions for the Protection of Mosel and	For Mosel: France, Germany, Luxembourg For Saar: France, Germany	http://www.iksms-cipms.org
International Commission for the Protection of the Rhine	France, Germany, Luxembourg, Netherlands, Switzerland, European Community	http://www.iksr.org/
International Commission for the Protection of the Danube River	Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Montenegro, Republic of Moldova, Romania,	http://www.icpdr.org/
International Sava River Basin Commission	Bosnia and Herzegovina, Croatia, Serbia, Slovenia	http://www.savacommission.org/
International Commission for the Protection of Italo-Swiss	Italy, Switzerland	http://www.cipais.org/
Interstate Commission for Water Coordination of Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan	http://www.icwc-aral.uz/

Commission on the Use of Water Management Facilities of Intergovernmental Status on the Rivers Chu and Talas	Kazakhstan, Kyrgyzstan	http://www.talaschu.kz/
Mekong River Commission	Cambodia, Lao People's Democratic Republic, Thailand, Viet Nam	http://www.mrcmekong.org/
Amazon Cooperation Treaty Organization	Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, Venezuela	http://www.otca.info/
Intergovernmental Coordinating Committee of La Plata Basin	Argentina, Bolivia, Brazil, Paraguay, Uruguay	http://www.cicplata.org/
Mixed Technical Commission of Salto Grande	Argentina, Uruguay	http://www.saltogrande.org/
Administrative Commission of the River Uruguay	Argentina, Uruguay	http://www.caru.org.uy/
International Boundary and Water Commission	Mexico, United States	http://www.ibwc.state.gov/
International Joint Commission	Canada, United States,	http://www.ijc.org/
Great Lakes Commission	Eight States of the United States. Associate members: Ontario and Quebec	http://www.glc.org/
Niger Basin Authority	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria	http://www.abn.ne/
Permanent Okavango River Basin Water Commission	Angola, Botswana, Namibia	http://www.okacom.org/
Organization for the Development of the Senegal River	Mali, Mauritania, Senegal	http://www.omvs.org

Capacity for Water Cooperation in Eastern Europe, Caucasus and Central Asia

RIVER BASIN COMMISSIONS AND OTHER INSTITUTIONS FOR TRANSBOUNDARY WATER COOPERATION

UNITED NATIONS
New York and Geneva, 2009

Transboundary river systems

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Trump Threatens Mexico With Tariffs Over 1944 Water Treaty

By WSJ Staff

President Trump threatened to impose tariffs and even sanctions on Mexico for alleged violations of a 1944 water treaty, which outlines sharing water between the two countries. "Mexico OWES Texas 1.3 million acre-feet of water under the 1944 Water Treaty, but Mexico is unfortunately violating their Treaty obligation," Trump said on Truth Social Thursday night.

Trump said Texas farmers are being hurt because Mexico "has been stealing the water."

THE WALL STREET JOURNAL.

https://www.wsj.com/livecoverage/stock-market-trump-tariffs-trade-war-04-11-25/card/trump-threatens-mexico-with-tariffs-over-1944-water-treaty-9TnRHIA6Fkt4fhXMacgB

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SOUTH ASIA

China's plan for world's biggest dam a mega-disaster for India

Brahmaputra dam will generate huge amounts of power for C... , stability and influence

By SARA SHEIKH

APRIL 5, 2025

https://asiatimes.com/2025/04/chinas-plan-for-worlds-biggest-dam-a-mega-disaster-for-india/#

WORLD NEWS

Nile basin nations say water-sharing accord has come into force without Egypt's backing

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FILE - A fisherman's boat sails along the River Nile in Cairo, Egypt, Saturday, Sept. 3, 2011. (AP Photo/Amr Nabil, File)

BY RODNEY MUHUMUZA

Updated 2:43 AM UTC+2, October 15, 2024

https://apnews.com/article/nile-river-accord-egypt-ethiopia-water-sharing-e245661a016bb75d9337d3e45a7753f7

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

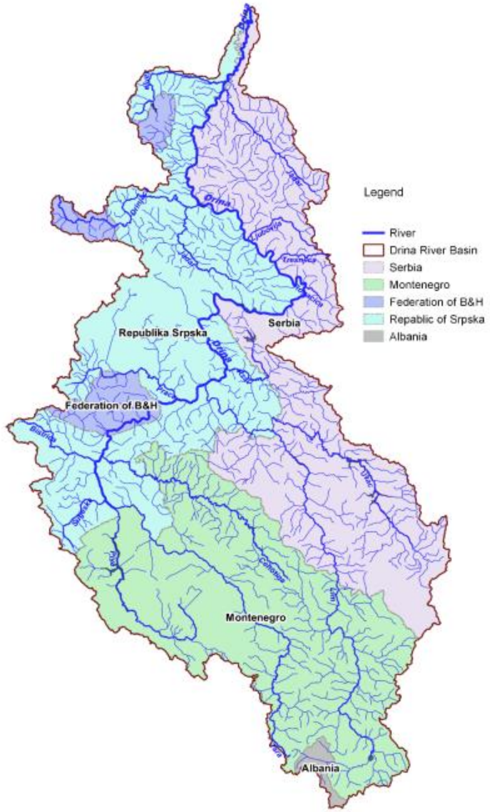
EPFL

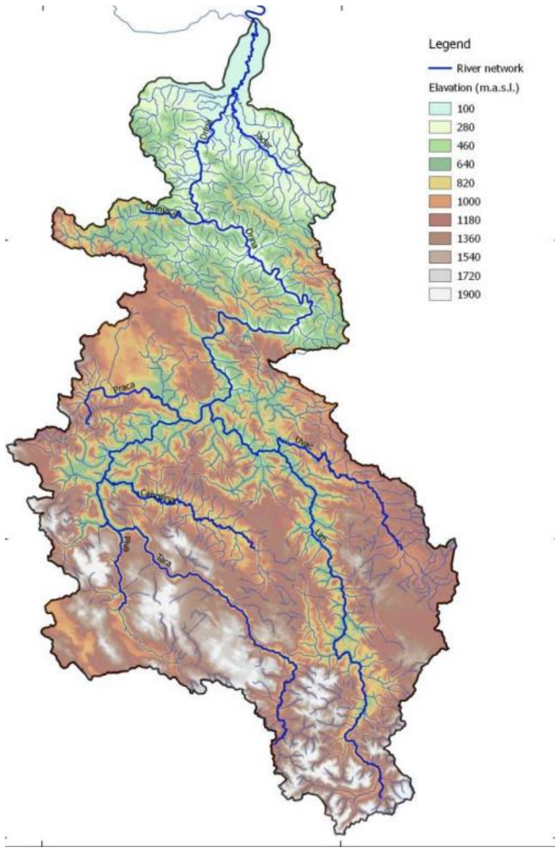
Case study - Drina River management

- The World Bank is supporting more effective water resources management in Drina River Basin, taking into consideration flood and drought mitigation, sustainable water use and environmental management
- The main aim of this Project is to define all important parameters of the basin and water resources in order to define a regional strategy for water resources management, with the development and rationalization of water management and use.
- Strengthen the mechanisms for cooperation among Bosnia and Herzegovina, Montenegro, and Serbia regarding this shared resource.
- Deal with climate change-related extreme weather events, given that in recent years, disastrous floods and seasonal droughts have become more frequent and have caused severe damage in the region.

Drina River management

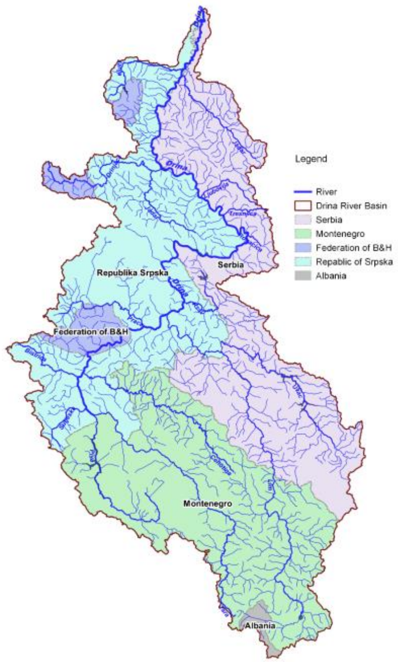
- The Drina River is formed by the junction between the Tara and Piva rivers
- 346 km in length with catchment area of 19’680 km2
- Catchment covers the territory of four countries: Serbia, BiH, Montenegro and Albania
- Mountainous and flat low land characteristics
- Features 9 reservoirs used for electricity generation, flood protection, irrigation and water supply
- Large dams and runoff the river HPPs

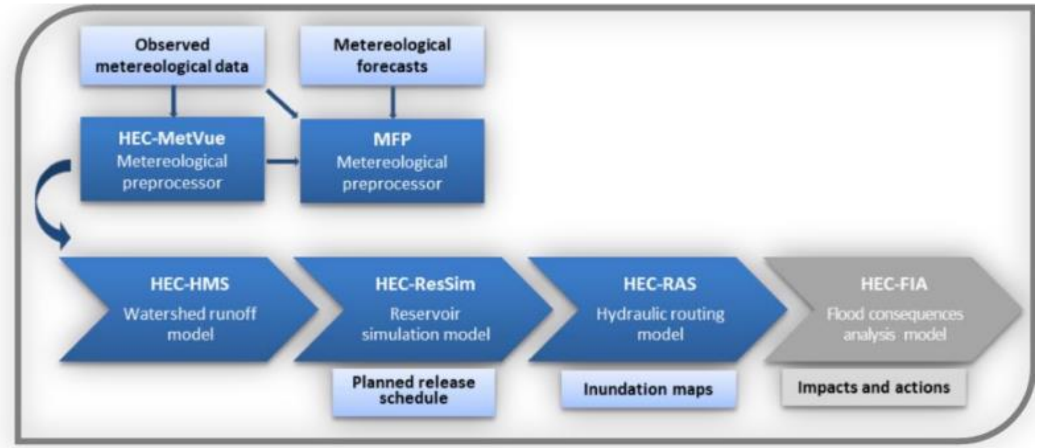




Scope

- ➢ Preparation of the DRB Water Resources and Basin Study with the following components:
  - ➢ hydrological study,
  - ➢ ecological/guaranteed flow study,
  - ➢ river morphology and sediment study with investigation works,
  - ➢ water temperature study, and
  - ➢ torrential flow database
- ➢ Preparation of hydrological and hydraulic models (Hydraulic and Hydrologic Modelling for the DRB Including Reservoir Operation)
- ➢ Establishment of a GIS database to support decision-making.





Project Structure

- **Lender:**
  - World Bank
- **Clients:**
  - Ministry of Foreign Trade and Economic Relation of Bosnia and Herzegovina
  - Directorate for Water Management within the Ministry of Agriculture and Rural Development of Montenegro
  - Water Directorate within the Ministry of Agriculture, Forestry and Water Management of Republic of Serbia

Consultants - Joint venture

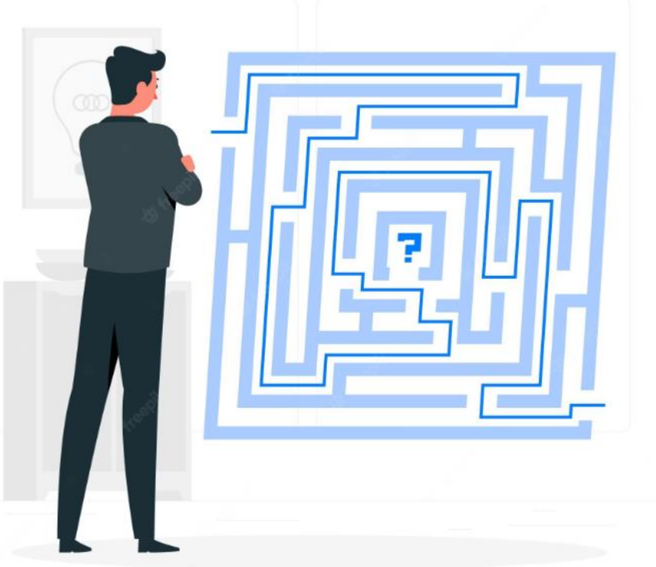
Project Structure

- **Beneficiaries :**
  - Sava River Watershed Agency, Sarajevo
  - Public Institution Vode Srpske, Bijeljina
  - Republic Hydrometeorological Institute of Republika Srpska, Banja Luka
  - Federal Hydrometeorological Institute of Bosnia and Herzegovina, Sarajevo
  - Institute for Hydrometeorology and Seismology of Montenegro, Podgorica
  - Water Administration of Montenegro, Podgorica
  - Republic Hydrometeorological Service of Serbia, Belgrade
  - Public water management company Srbijavode, Belgrade.

Input Data

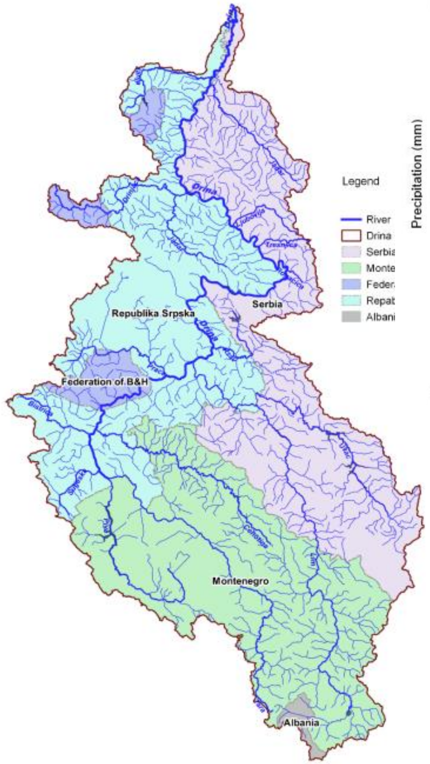
➢ Challenges

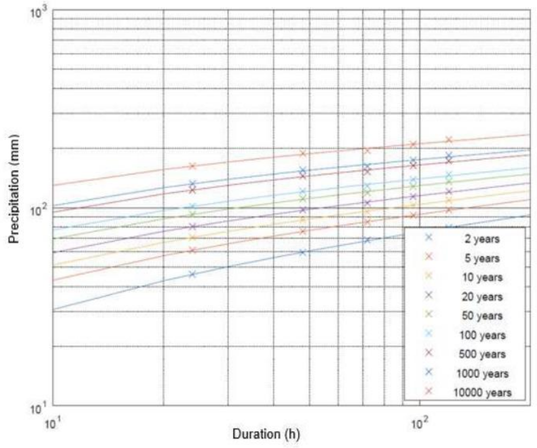
- ➢ Development of the DRB water resources and basin study heavily relies on the input data → Meteorological, Hydrological, Morphological, Topographical, Bathymetrical, Land Cover, Infrastructure etc…..
- ➢ **GIGO principle** (Garbage In → Garbage Out)
- ➢ Several countries with complex history and geopolitical situation
- ➢ Large number of different agencies involved in management of the river basin
- ➢ Data availability, format and willingness to share
- ➢ Questions about data sensitivity and ownership

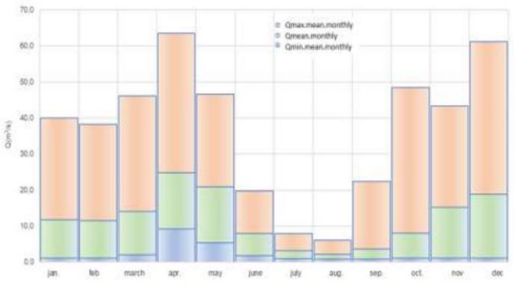


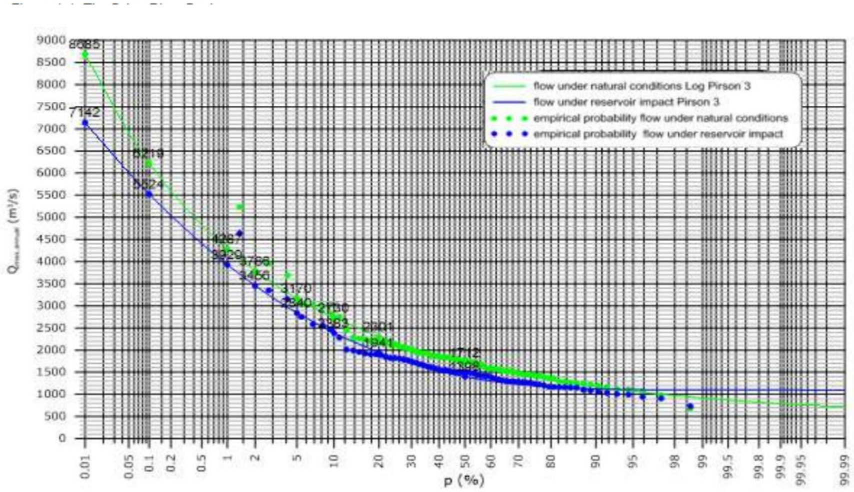
Hydrological Study

- ➢ Flow regime analysis for Drina river and tributaries
- ➢ Precipitation analysis in form of IDF curves for main meteorological station in the Drina River Basin
- ➢ **Challenges** → availability of sufficiently long historical series on the entire Drina River Basin
- ➢ Flows in the basin analysed in:
    - ➢ Unregulated regime → assuming no hydraulic structures exist
    - ➢ Regulated regime → with all hydraulic structures allowing impact assessment
- ➢ Extreme precipitation and flood analysis --> DDF curves and flow duration curves at various representative locations → GIS based tools developed to support decision making



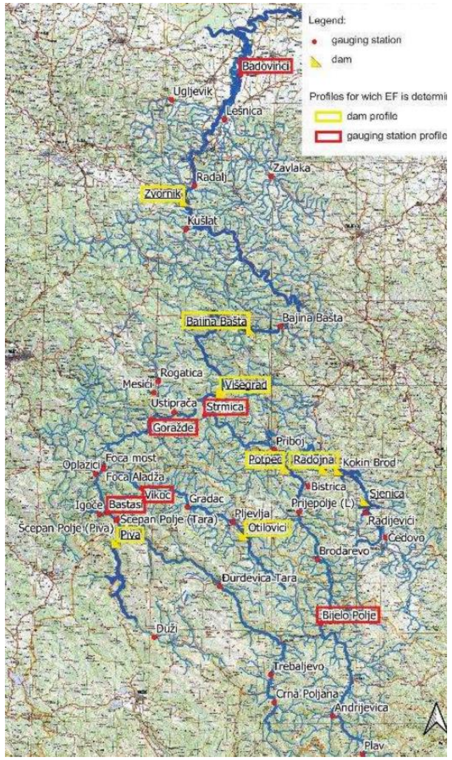


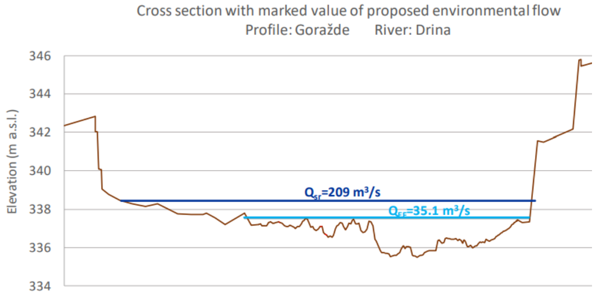




Environmental flow study

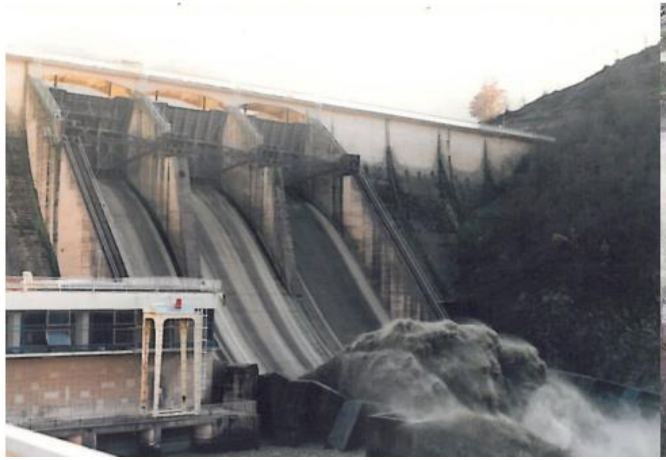
- Analysis and definition of the environmental flows values in the Drina River Basin.
- Environmental flow is important for the management of reservoirs
- Analysis performed considering:
  - Methodologies defined by the legislation of the countries in the Drina river basin,
  - Flow currently discharged downstream of the hydraulic structures,
  - Methodologies most commonly used in other countries worldwide.
- Allowed comparison with EF being released
- Recommendations for EF releases

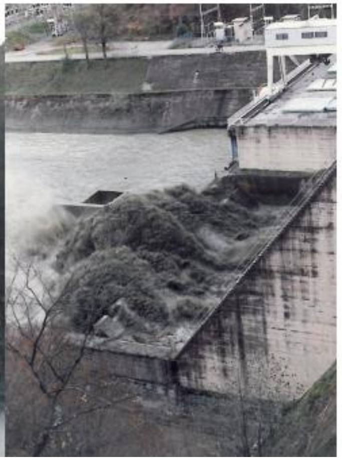


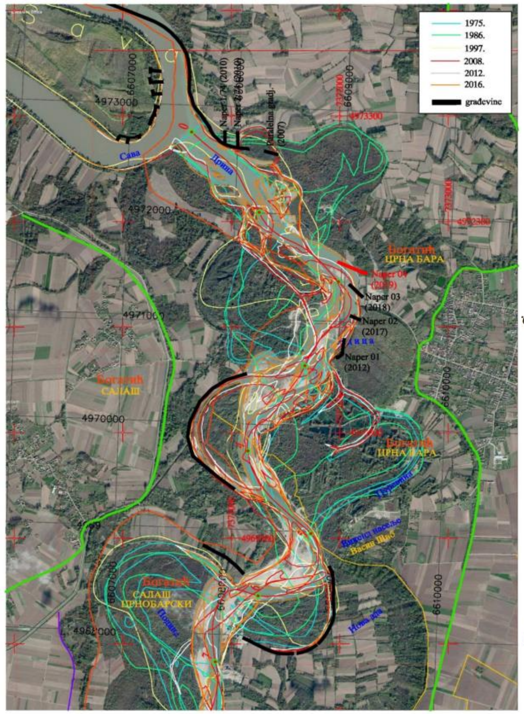


River morphology and sediment study with field campaign

- ➢ Sediment regime analysis
- ➢ Analysis of river morphology on the alluvial lower course of the Drina → GIS using historical satellite imagery data
- ➢ Field investigations performed sampling suspended sediments, bedload etc.
- ➢ Analysis of sediments deposited in the reservoirs
- ➢ Methodology and locations for sediment monitoring development in the DRB proposed.
- ➢ First steps towards formulation of **Sediment Management Plan** with current and future developments in the DRB/







...e A3 -1 : Velocity measurement with ADCP device

Figure A3 -2 : Placing the winch on the bridg...

Figure A3 -3 : Connecting torpedoes

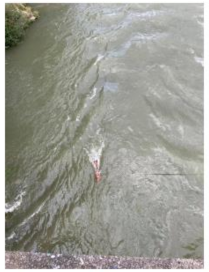
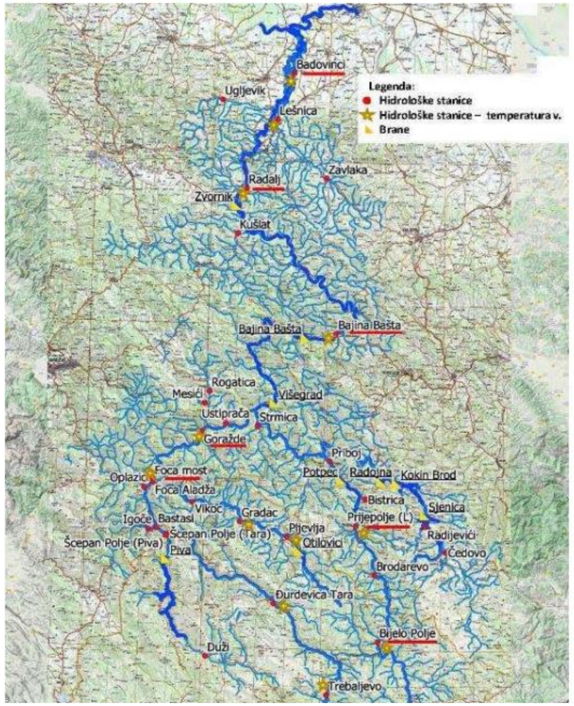
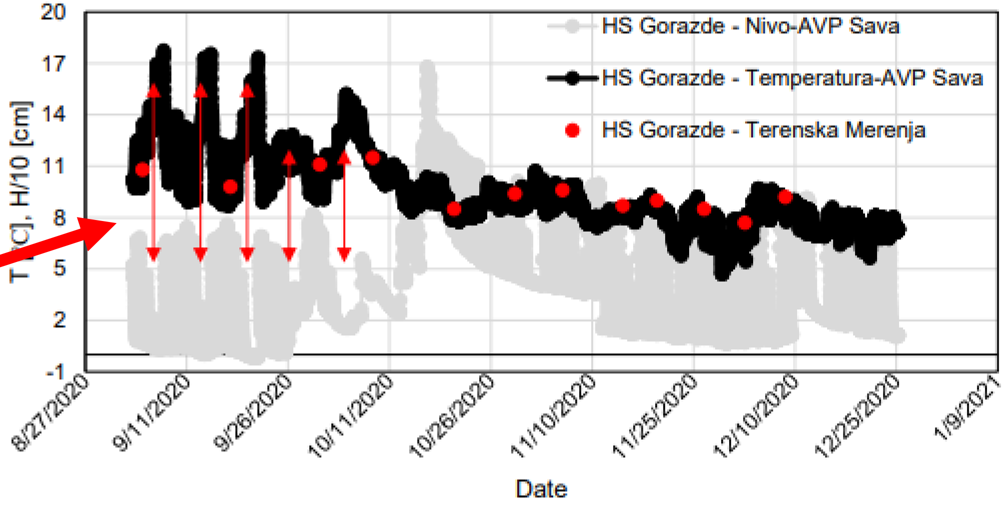


Figure A3 -4 : Sampling of suspended sediment

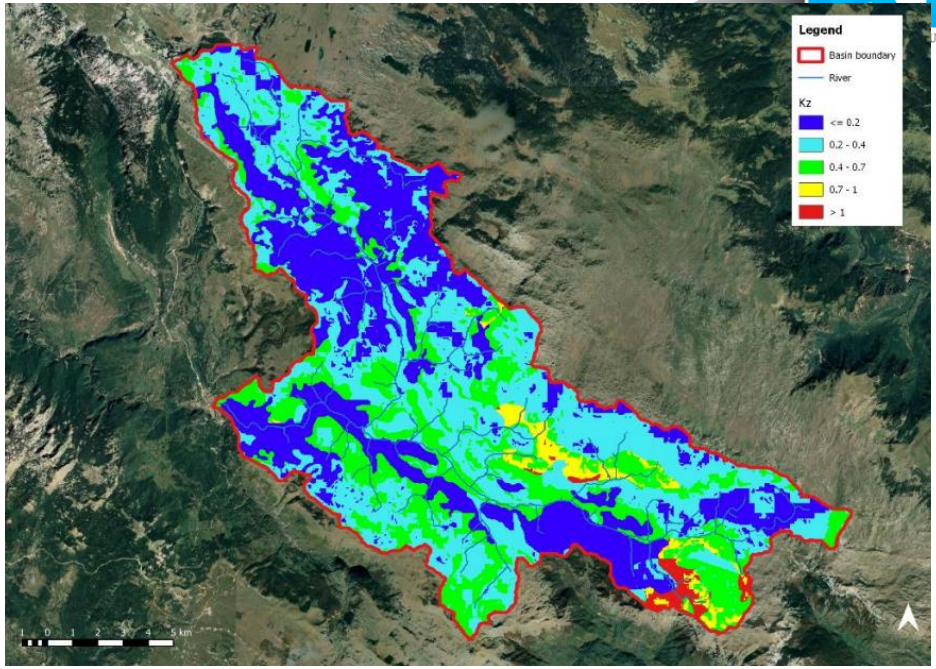
Water temperature study

- Temperature is one of the most significant physical parameters for monitoring surface water quality
- Establish the basis for further research of ecological and biological conditions in the Drina River Basin
- Analysis of historical data regarding surface water temperatures and air temperatures performed at various relevant locations:
- Extensive field campaign performed.
- Water temperatures strongly governed by HPP releases, especially during summer months.





Torrential streams database

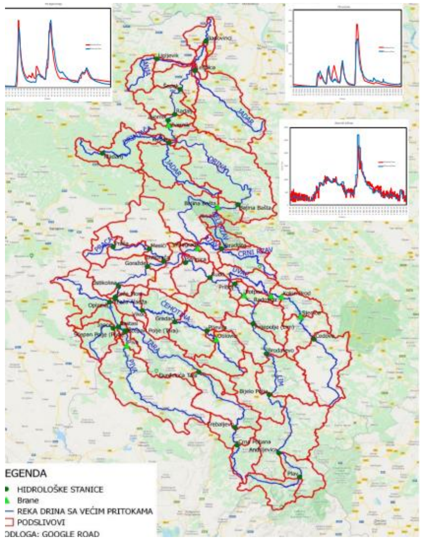


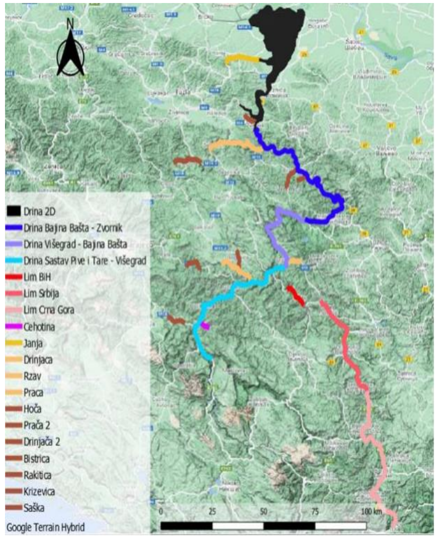
- The uncontrolled erosion phenomenon induced by torrential streams (flash floods) in a river basin can cause significant morphodynamic variations as well as significant economic and social damage.
- **Aim** → Preparation of a database on the torrential streams serving as a guide for water resources development planning, providing a quick assessment of water protection and use potential.
- Erosion Model Tool developed on potential soil loss evaluation developed and implemented on four pilot reaches.
- GIS based database formed supporting decision making in the Drina Basin River.

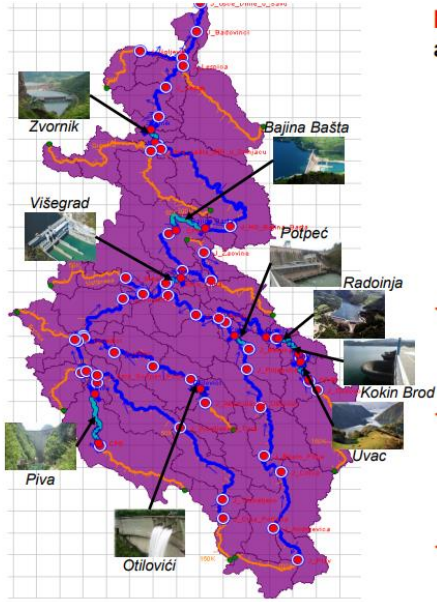
Numerical Modelling

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- To support Drina River Basin Management decision making, several numerical models were developed:
  - Hydrological Model
  - Hydraulic Model
  - Reservoir Operation Model
  - Sediment Transport Model
  - Water Temperature Model
- Hydrological, Hydraulic and Reservoir Operation Models were coupled under an "Umbrella" model providing a **Real-Time** integrated tool for Drina River Basin management.



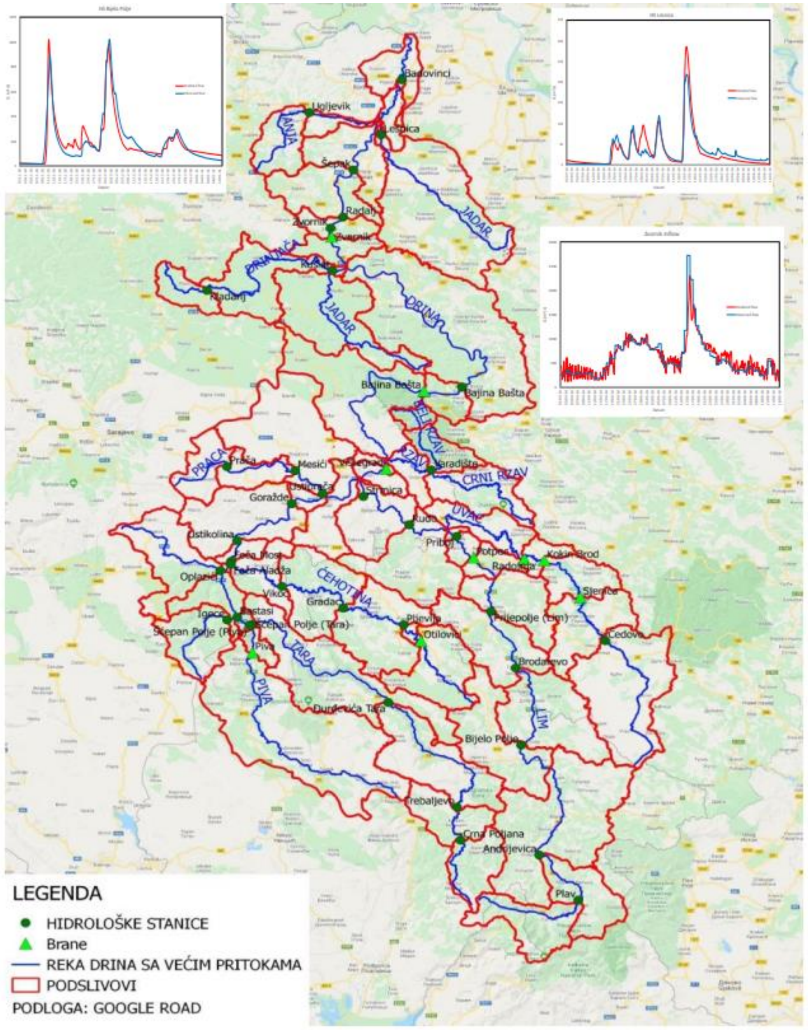




Numerical Modelling

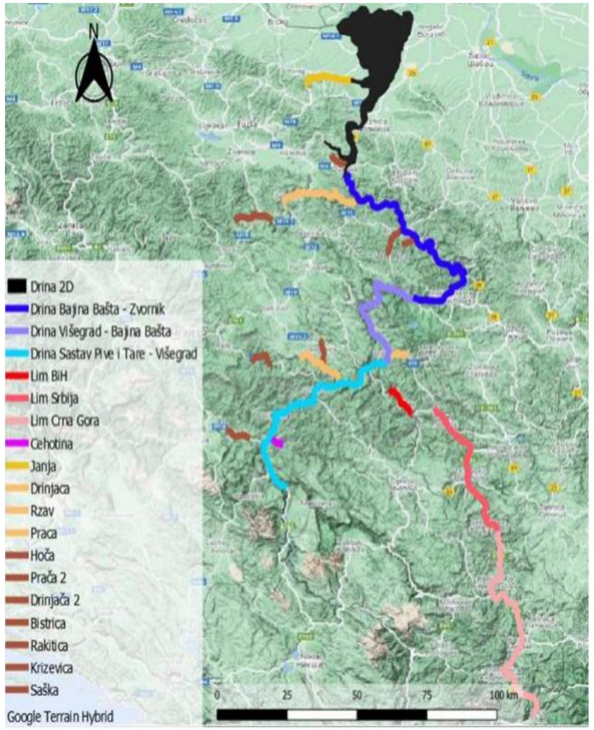
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

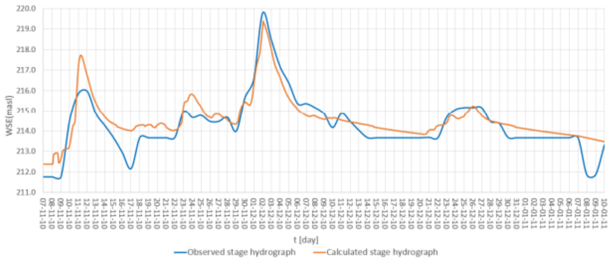
- Hydrological Model
  - Developed using HEC-HMS
  - Featuring entire DRB area subdivided into 62 sub-catchments, 59 river reaches and 73 node
  - Extensive calibration and verification performed considering extreme flood events that occurred in 2010 and 2014.
  - Using the model, flow hydrographs for large return period floods developed.
  - The developed model was integrated in the “Umbrella” model providing real-time support in decision-making.



Numerical Modelling

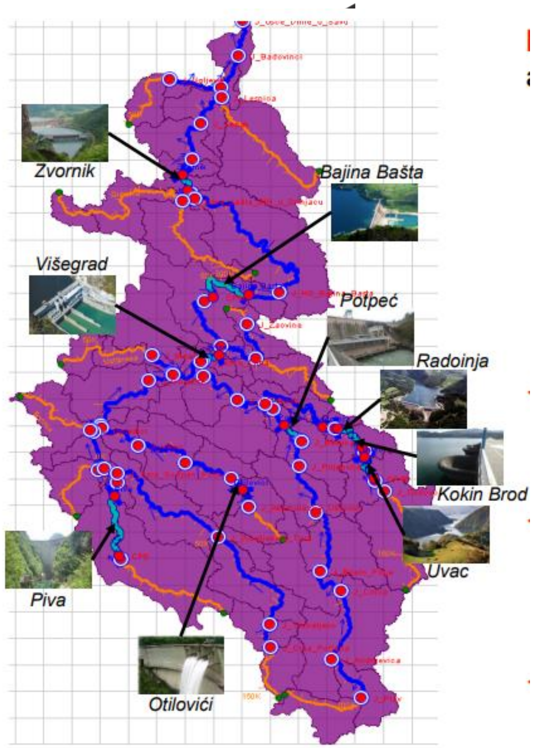
- Hydraulic Model
  - Developed using HEC-RAS
  - Featuring entirety of the Drina river reach and its 13 tributaries.
  - 1D-2D modelling approach was apported featuring over 14’000 cross-sections, 159 bridges and 9 dam structures. 2D model provided in the lowlands.
  - Extensive calibration and verification performed considering extreme flood events that occurred in 2010 and 2014.
  - Flood mapping performed for extreme events
  - The developed model was integrated in the “Umbrella” model providing real-time support in decision making.

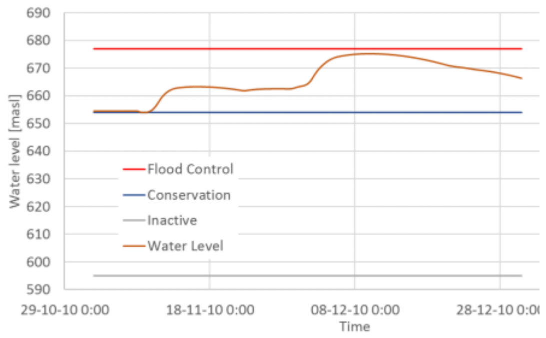


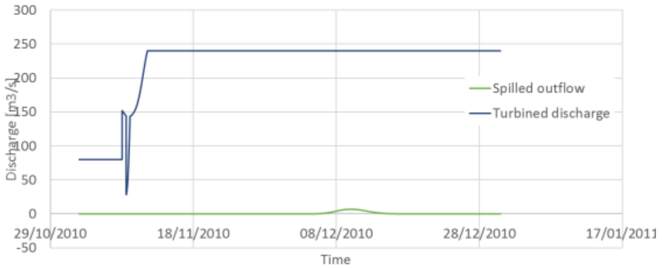


Numerical Modelling

- **Reservoir Operation Model**
  - Developed using HEC-ResSim
  - Featuring 9 existing reservoir and all river courses.
  - Model reflected the dam characteristics and current operating rules
  - Extensive study on the operating rules performed and showed to be not optimal → new operating rules proposed
  - Challenges: The latter study showed that improved reservoir operation could have mitigated impacts of 2010 and 2014 flood events in the upper Drina reach, currently under dispute.
  - The developed model was integrated in the "Umbrella" model providing real-time support in decision making.





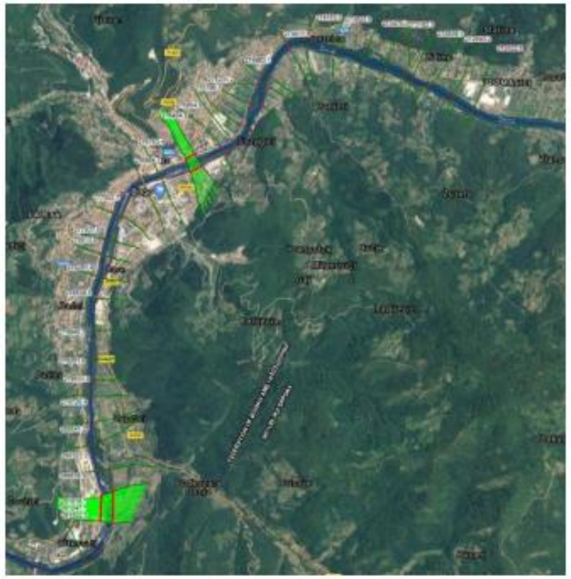


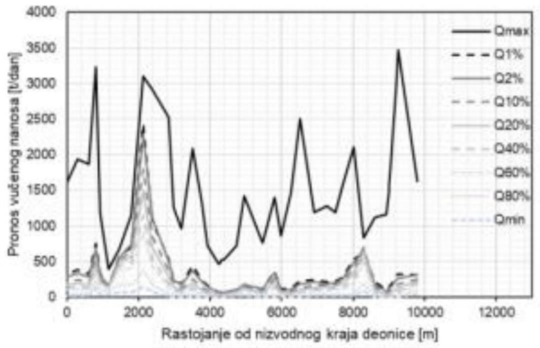
Numerical Modelling

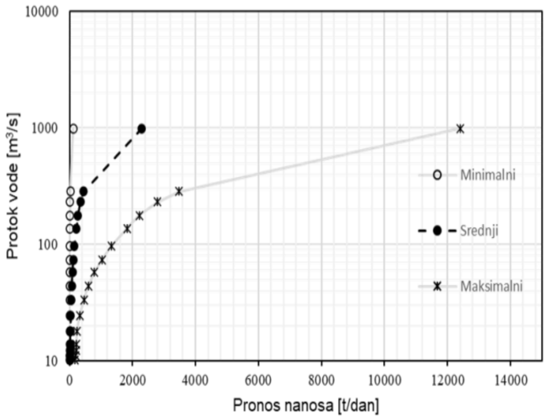
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

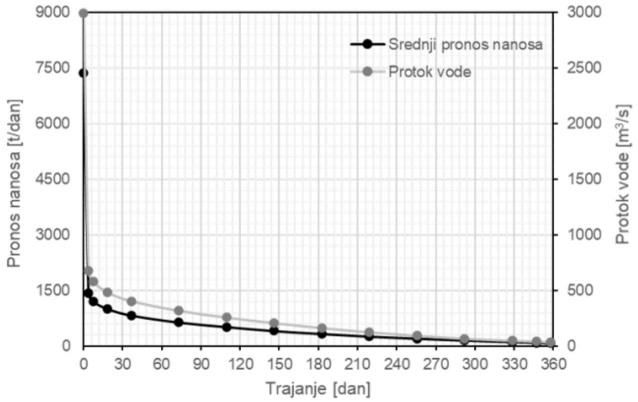
➢ Sediment model

- ➢ Developed using HEC-RAS
- ➢ Featuring 6 pilot reaches
- ➢ 1D sediment model developed
- ➢ Based on the findings of the sediment study and field campaign
- ➢ Allowed assessing the sediment transport capacities for large span of discharges
- ➢ Will be used in the definition of the **Sediment Management Plan** as well as assessing impacts of future developments in the River Drina Basin





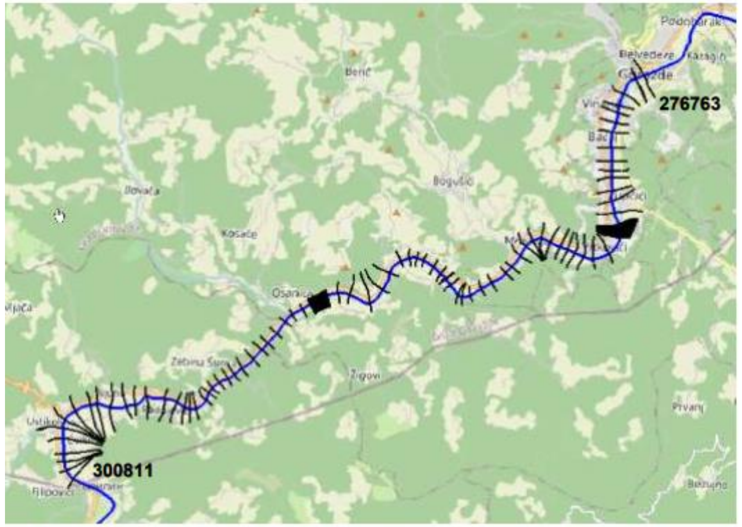




Numerical Modelling

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- **Temperature model**
  - Developed using HEC-RAS
  - 1D model featuring 3 pilot reaches
  - Extensive calibration and validation based on the findings of the temperature study and field campaign
  - Allowed assessing the spatial and temporal distribution of temperatures on the relevant Drina river reaches
  - Serves as a basis for Environmental Impact Assessments including future developments on the Drina River Basin



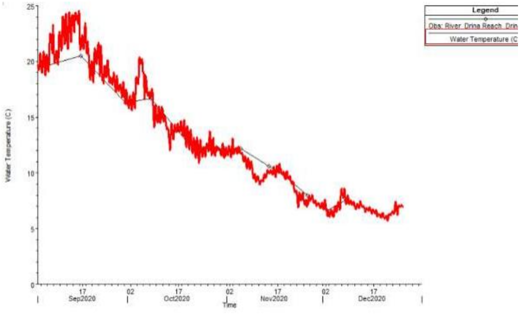
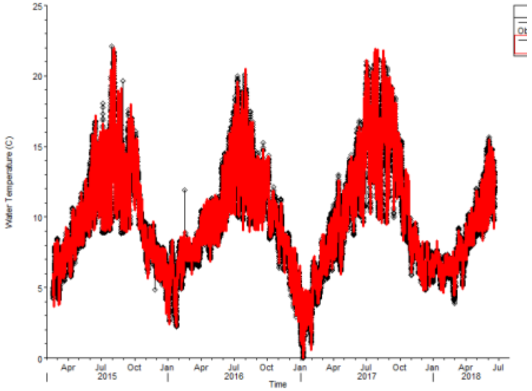


Figure 7-45: Badovinci: comparison between computed and measured temperature at last downstream section



Numerical Modelling

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

“Umbrella ” Real-Time Management Model

- Developed using HEC-RTS
- Integrates:
  - HEC-HMS hydrological model
  - HEC-RESSim reservoir operation mode
  - HEC-RAS hydraulic model
- Included development of proprietary acquisition model for harvesting required input data (Meteorological and Hydrological)
- The acquired input data are processed and fed to the:
  - Hydrological model providing expected runoff across DRB
  - Reservoir operation model which also processes hydrological analysis output providing releasing and reservoir levels
  - Hydraulic model which based on hydrological and reservoir operation model outputs routes releases downstream of dams across DRB.

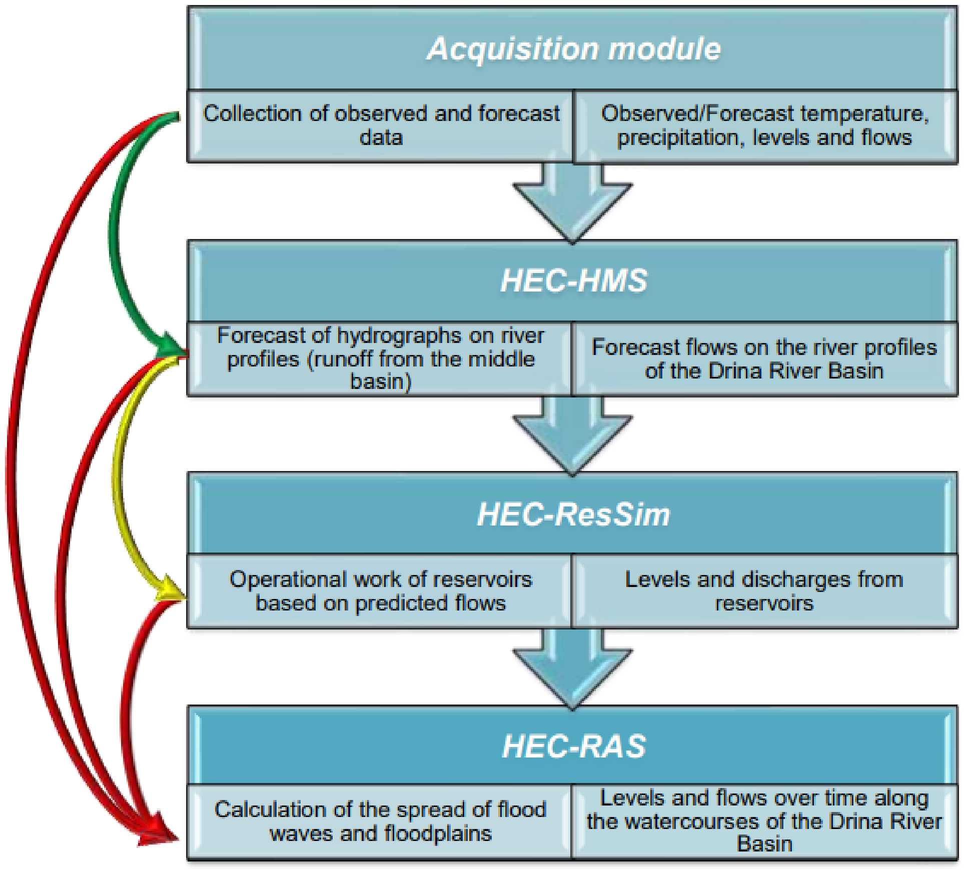
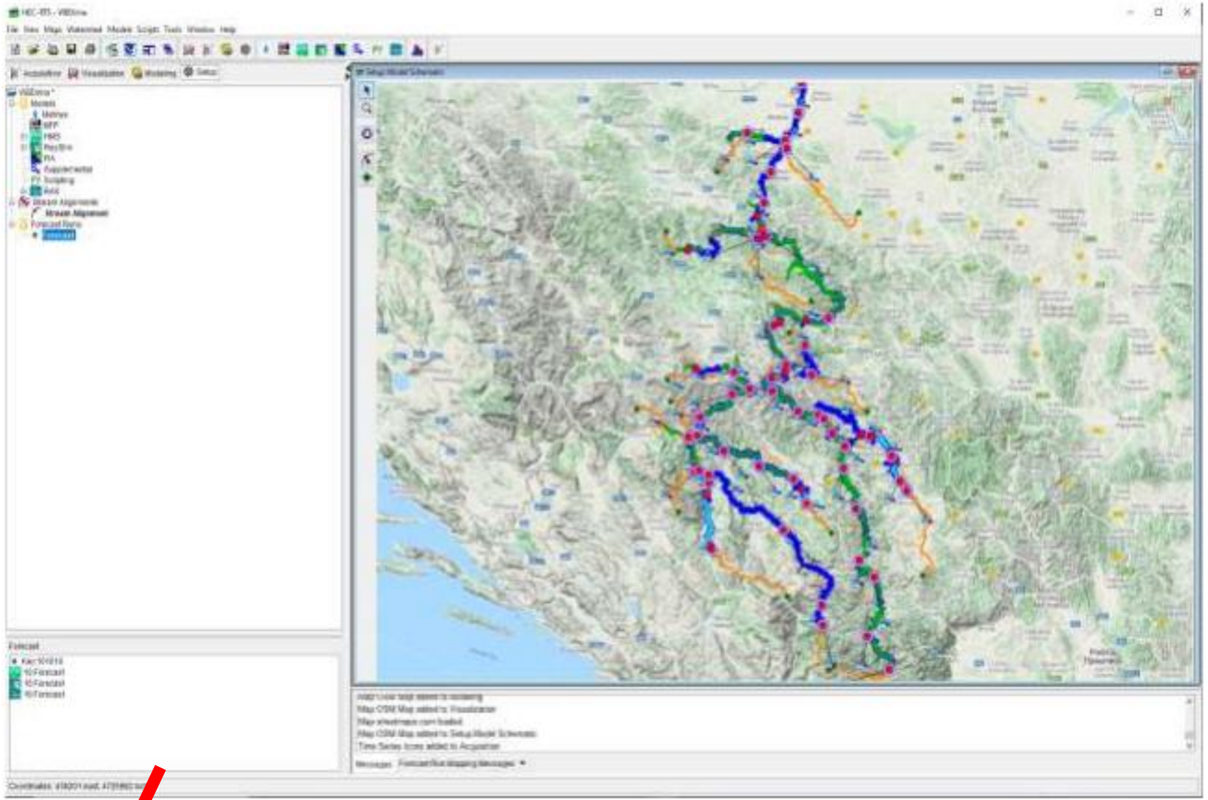


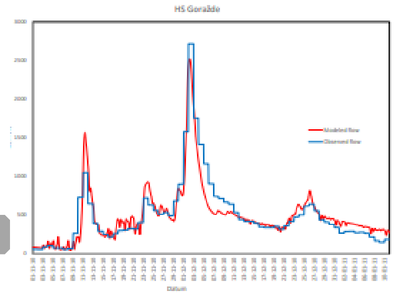
Figure 2-1 Basic operating principle of the integrated model of the Drina Basin.

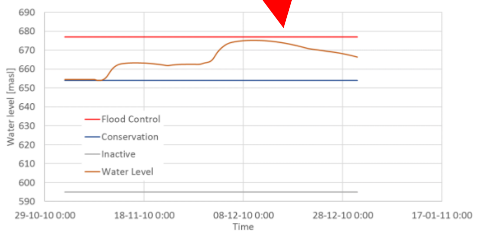
Numerical Modelling

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- **“Umbrella ” Real-Time River Basin Management Model**
  - Such a developed model provides a **Real-Time** decision-making tool:
    - To plan flood mitigation measures based on meteorological forecasts
    - Identify areas that may be at risk of flooding and therefore take appropriate measures
    - Optimize energy production based on the meteorological forecasts
    - Optimize water use and thus river basin management







Conclusions

- Project successfully concluded in 2021
- Willighness to share data and work together was a positive point driving the success of the project
- Operational “umbrella model” provided to beneficiaries
- Online training workshop
  - User manual for developed models
  - Protocol on the exchange of hydrological and meteorological data in the Drina River basin
  - More than 60 participants from the different beneficiaries

The Vakhsh River (Amu-Darya catchment)

Vakhsh river cascade includes:

- Rogun → 330 m high rockfill dam under construction
- Nurek → 300 m high embankment dam
- Baipaza → 59 m high concrete-faced rockfill dam
- Sangtuda I→ 75 m high embankment dam
- Sangtuda II → 31.5 m high earth fill dam
- Golovnaya → 32 m high embankment dam
- Two small HPP located on Main Vakhsh Canal.

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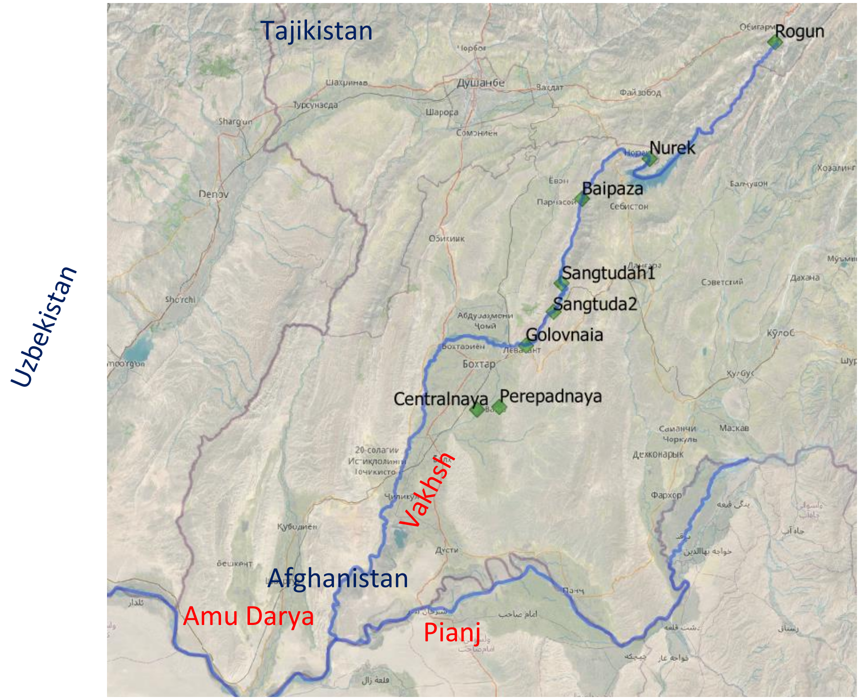
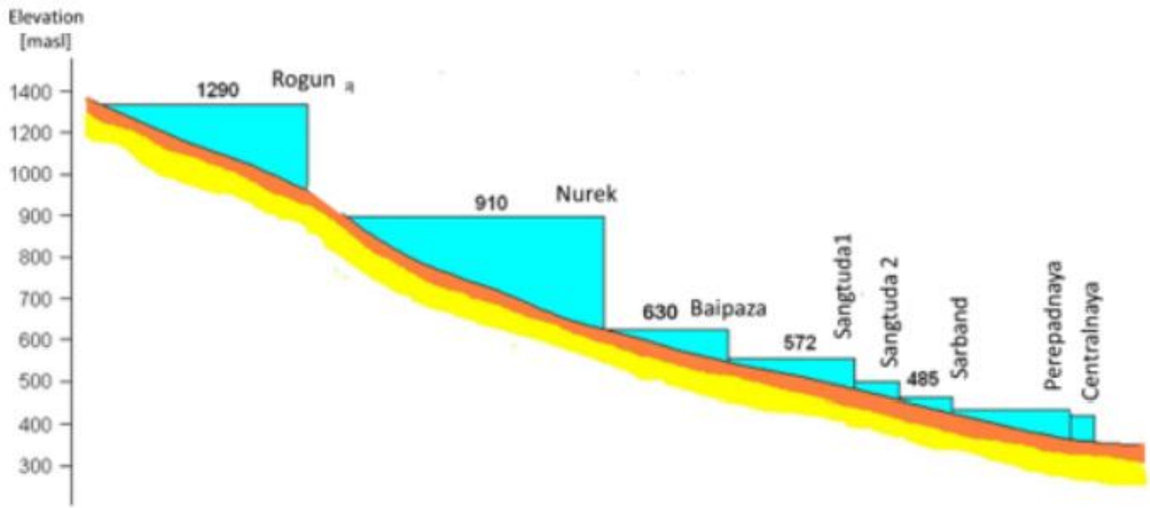
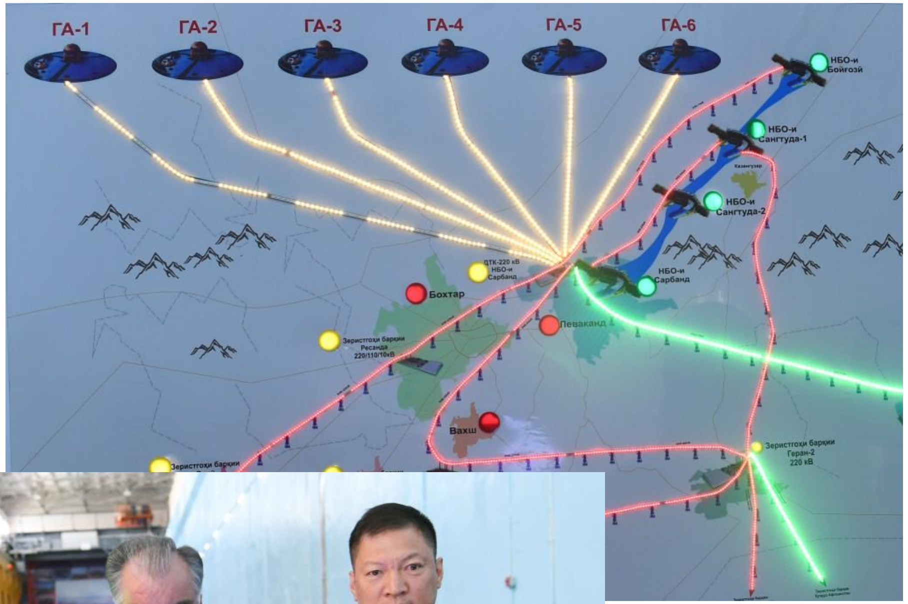




The Vakhsh River (Amu-Darya catchment)

Golovnaya HPP

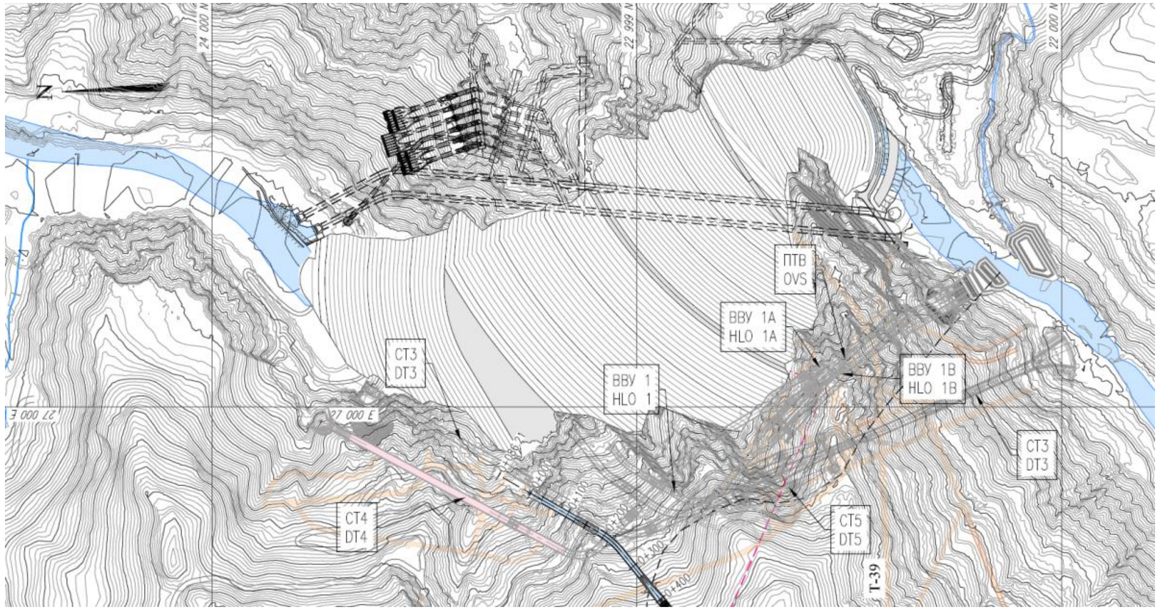


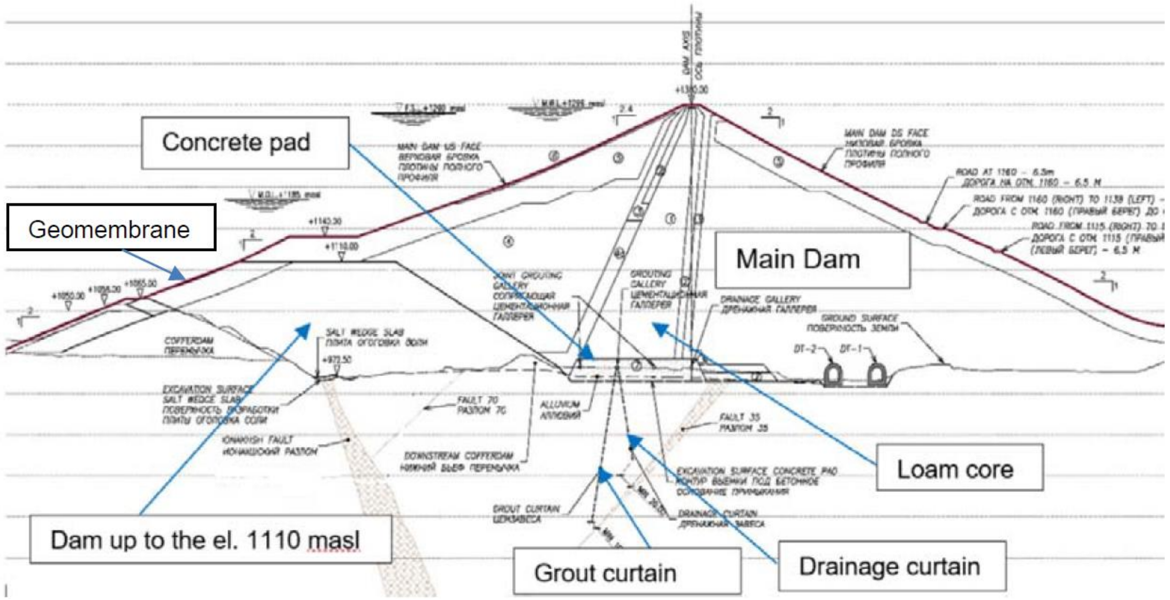
Tajikistan President
Emomali Rahmon / April 23

The Vakhsh River (Amu-Darya catchment)

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Rogun Dam and HPP





The Vakhsh River (Amu-Darya catchment)

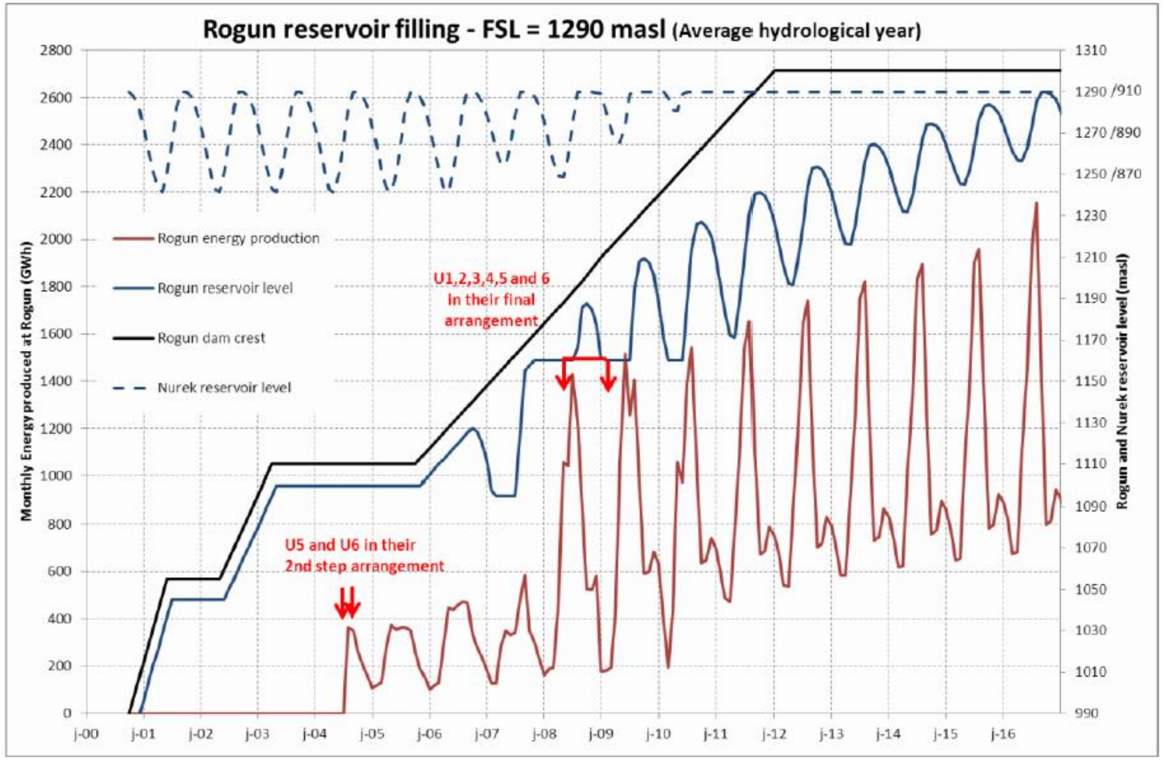
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- Rogun HPP scheme

Table 8-7: Water allocation by country (1992-2010) compared to Protocol 566 (Soviet time)

Allocation by BVO Amu Darya	Tajikistan	Kirgizstan	Uzbekistan	Turkmenistan	Total
Average allocated	8.845 km^3	0.216 km^3	21.378 km^3	20.960 km^3	51.400 km^3
Protocol 566	9.500 km^3	0.400 km^3	29.600 km^3	22.000 km^3	61.500 km^3

Source: ICWC website, data for vegetation and non-vegetation period



Key take aways

- There are around 286 transboundary river basins in the world, covering more than half of the Earth's land surface.
- Transboundary rivers are often a source of conflict between countries, as they can create tensions over water allocation and use.
- Cooperation and management of transboundary rivers are crucial to ensure equitable sharing of water resources and to avoid conflicts between countries.
- International laws and treaties, provide a framework for cooperation and management of transboundary rivers.
- Effective management of transboundary rivers requires a collaborative approach, involving all countries and stakeholders sharing the river basin.
- Sustainable management of transboundary rivers is essential for ensuring access to water resources, supporting ecosystem health, and promoting socio-economic development in the region.