Politecnico di Torino

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Dams and environment: engineering solutions for the future

TORINO , 28 maggio 2025

PSP: a key role in grid reliability. An Italian project

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ITCOLD – II Concorso Fotografico



PSP: a key role in grid reliability. An Italian Project.

Franco Maugliani
Turin, May 28th, 2025

Lombardi

Agenda



Contra, 1965, 220 m

1. El apagòn: April 28th 2025
2. Italian Blackout: September 23th 2003
3. Next ?
4. Italian Scenario
5. PSP developments in Italy
6. An Example: Pizzone II
7. First design and redesign for acceptability
8. Hints for engineers
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1. El apagòn: April 28th 2025

On Monday, 28th April 2025, at 12:33, in an estimated lapse between 5 and 15 minutes, a widespread blackout hit Spain, Portugal, some regions in the south of France.

The full official recovery required a time of about 23 hours, till about 11:15 of the following day.

The Iberian network operator, REE Red Eléctrica de España, supplied the curve of the collapse, showing a sudden drop of the power available on the grid from 26 to 10 Gigawatt.

At the time of the collapse the generation figures were as follows:

a. 65,73% from not programmable renewables:

- 54,86% from solar photovoltaic;
- 10,87% from wind;

b. 9,86% from hydroelectric;

c. 10,52% from nuclear generation

d. Remaining part: thermal generation and others





1. El apagòn: April 28th 2025

The causes are still under investigation.

Possibly a combination of events linked above all to the structural vulnerability of the electricity grid:

- the event was triggered by **a fault on a high-voltage transmission line** between French and Spanish Catalonia (confirmed by REE)
- the disconnection generated **an uncontrolled frequency oscillation** on the interconnection (till to 48 hz), causing an "islanding" phenomenon that isolated the Iberian electricity system from the rest of Europe.
- Shortly thereafter, **a cascade of generator shutdowns** (mostly renewables) occurred along the entire grid, aggravated by the insufficient contribution of automatic compensation mechanisms for voltage and frequency fluctuations.

The fault is not from renewable generation, but a fault of the grid, due to its intrinsic characteristics.

Around 90% of renewables were again on grid after 4.5 hours; nuclear generation, after emergency shutdown for lack of refrigeration, was restored after 24 hours.

Some news about Iberian grid at the date:

- Interconnection capability with rest of Europe: only 3% of national installed capacity (15% recommended)
- Storage capability: 60 MW of battery energy storage systems BESS and about 3'300 MW of pumping storage plants PSP (Italian figures: 5'700 MW of BESS and 4'400 MW of PSP): during the blackout only 1,3 GW of PSP were in grid connected operation.

Problems include **weak interconnections**, **insufficient storage and power reserve**, **obsolete networks** and **rigid nuclear**.

Investments in dynamic demand response management systems (BESS, PSP, advanced "grid forming" inverters) are needed.

1. El apagòn: April 28th 2025

Detachment of PV and wind generation

The rules for the grid connection of a generation unit requires an interface device, capable of acting for the protection of the grid and of the plant.

The reference is an international standard, which enlists a total of 38 protection types (IEEE C37.2- 2008: Standard for Electrical Power System Device Function Number, from which Italian reference CEI 0-16 and Guida Tecnica TERNA Criteri Generali Protezioni Rev. 01-2018).

"**81 max and min frequency**": the protection detaches the generator from the grid in case of a grid frequency out of range.

Both the wind and the photovoltaic generators are connected to the grid by means of **a static inverter** that, being historically developed from the older small size devices, follows the frequency from the grid and is not capable to mitigate or control deviations from the nominal grid frequency.

This behavior is stopped by the interface device at the lower and upper frequency set up, acting as a protection, by detachment of the generator from the grid.

It is required a complete redesign of software and hardware of the inverters ("grid forming" inverters).

On the contrary "rotating" generators, thanks to their mechanical inertia and rotating speed regulators, can compensate variations in the grid frequency: for this type equipment the cause for a diminishing of the generator's speed and frequency is usually an overload, and the equipment can compensate the overload by injecting reserve power in the grid (usually they are not working at full load).

Static inverters for PV and wind don't have this capability: they always operate at the maximum instantaneous power from the field converters, with no power reserve.

2. Italian Blackout: September 28th 2003

On Sunday, 28th September 2003, between 03:00 and 03:28, a total blackout hit all the regions of Italy, from Alps to Sicily, with the exception of Sardinia.

The full official recovery was at 9 in the North, 16:30 in the Centre, 19 at South, at 22 in Sicily (maximum 19 hours).

A study from UCTE, Union for Co-ordination of Transmission of Electricity, supplies the curve of the collapse, showing a progressive drop of grid frequency and progressive detachment of energy imports and generation units, with a sudden drop of the power available on the grid from 27,5 to 0 Gigawatt.

At the moment of the collapse the generation figures wee as follows:

a. 27,5 GW total load of which 3,5 GW of pumping
b. national production of 20,4 GW of which 18,7 GW thermal
c. Nominal power of plants in operation 25 GW (of which 3,4 from self producers)
d. Italian need of 27'444 MW was covered by means of about 25% of import (6'651 MW, of which 3'610 from Switzerland, 2'212 France, 638 Slovenia, 191 Austria, 300 MW from Greece)
e. Active interconnection with European grid: n. 15 AT (n. 6 380 kV, n. 9 220 kV) plus n. 1 AT CC with Greece



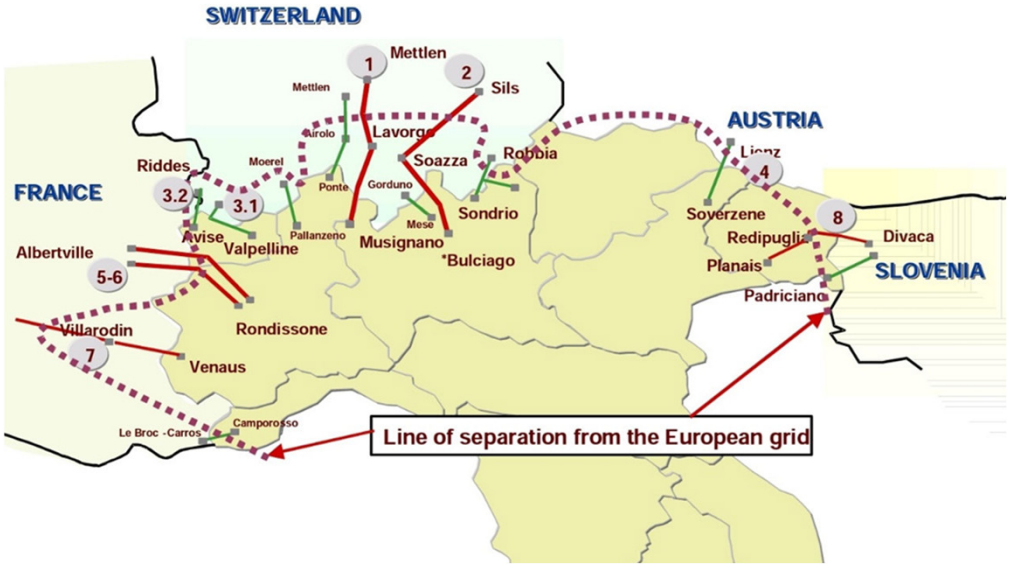
Italian Generation System in September 2003		
Total Power	81 GW	100 %
Thermal	58 GW	72 %
Hydro	21 GW	26 %
Wind	0,9 GW	1 %
Photovoltaic	0 GW	0 %

2. Italian Blackout: September 28th 2003

According to UCTE the Italian system, equipped with load shedding devices was considered capable to properly cope with the loss of a single element of its network, including any interconnection link with foreign countries or the loss of the largest unit in service (security criteria N+1).

Events:

- 03.01.42: fault on the 380 kV Mettlen-Lavorgo line in Switzerland, due to a probable contact and discharge between a phase of the line and a tree; attempts to re-close failed, with loss of the line the import load was redistributed to other lines, especially Swiss ones, overloading them
- 03.10: Swiss telephone request to the GRTN control center in Italy to reduce imports by 300 MW; the criticality that would have required a greater reduction (for example, disconnection of pumping) was not reported.
- 03.25.21: due to a probable discharge to earth, automatic disconnection of the 380 kV Sils-Sloazza line, in Swiss territory. Cause: possible lengthening of the conductors from over heating with reduction of the distances to the ground under the high current caused by the overload.
- 03.25.30: sudden redistribution of the import load, which overloaded all the remaining interconnection lines with foreign countries in the north, then opening of their switches.

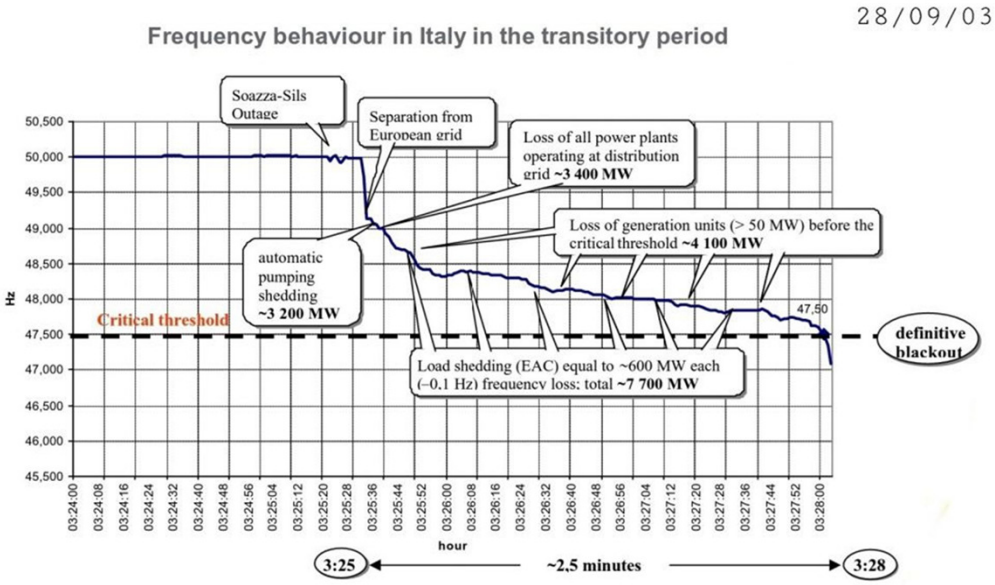


2. Italian Blackout: September 28th 2003

Events:
In Italy, the generators began to slow down **with a drop in frequency**:

- at 49.7 Hz, the automatic separation of medium and small-sized generators connected to the distribution lines took place;
- from 49.8 Hz, the pumping systems began to self-exclude;
- at 48.5 Hz, the load shedding devices began to intervene at the primary AT/MT (High Voltage/Medium Voltage) cabins, which progressively excluded the less essential medium voltage distribution lines;
- as noted in retrospect, several generation groups, particularly thermal ones, disconnected from the network before the prescribed 47.5 Hz;
- the frequency dropped to the fateful 47.5 Hz, causing the disconnection of the remaining groups – which had nevertheless reacted by increasing their power – and at 03.28.00 the collapse became total with the exclusion of Sardinia, Capri and Pantelleria.

The UCTE graph summarizes the trend of the network frequency and the occurrence of the blackout within 2 minutes and 30 seconds from Italy's isolation from abroad.
The long time required for recovery was attributed to inadequate black start procedures (failure of “load rejection” procedures for the black start of generators, difficulties in paralleling of already powered network parts).



(Source: A. Clerici, Astrolabio, October 2023)

3. Next ?

"The blackouts that affected the Iberian Peninsula earlier this week should be a wakeup call—not just for Spain and Portugal, but for policymakers all over the world."

"Governments and regulators need to rethink their approach. Far too often, the public conversation focuses narrowly on the merits or costs of individual technologies— hydropower, solar, wind, nuclear, or gas. This is missing the point.
What matters most is grid stability and system reliability.
The question must not be: "Is this source cheap?" or "Is that technology clean?" It must be: "Can this grid deliver reliable, affordable, clean electricity whenever people need it?"
And within that conversation, storage is what I have often called "the ignored crisis within the crisis."

"Batteries are often presented as the solution. They are cheap, easy and quick to install. As a recovering politician, I can fully appreciate the attraction. They certainly have a vital role to play, especially for short-duration balancing. But relying on batteries alone for long-duration storage is a red herring. They cannot feasibly or affordably provide the level of multi-hour, multi-day energy backup needed to keep entire grids stable at scale.

Pumped storage hydropower (PSH), however, is a different story.

Pumped storage already accounts for over 90% of the world's long-duration energy storage. It is a proven, robust technology with more than a century of success behind it—and, crucially, it offers massive potential for future growth. Pumped storage helps mitigate the intermittency of renewables by storing surplus solar and wind energy, releasing it when production drops."

"A stable, flexible, and decarbonized grid is achievable. But only if we stop treating storage as an afterthought—and start treating it as the cornerstone."

Malcolm Turnbull, May 1st, 2025



Malcolm Turnbull
President of the International Hydropower Association (IHA),
Chair of the Global Alliance for Pumped Storage
Former Prime Minister of Australia

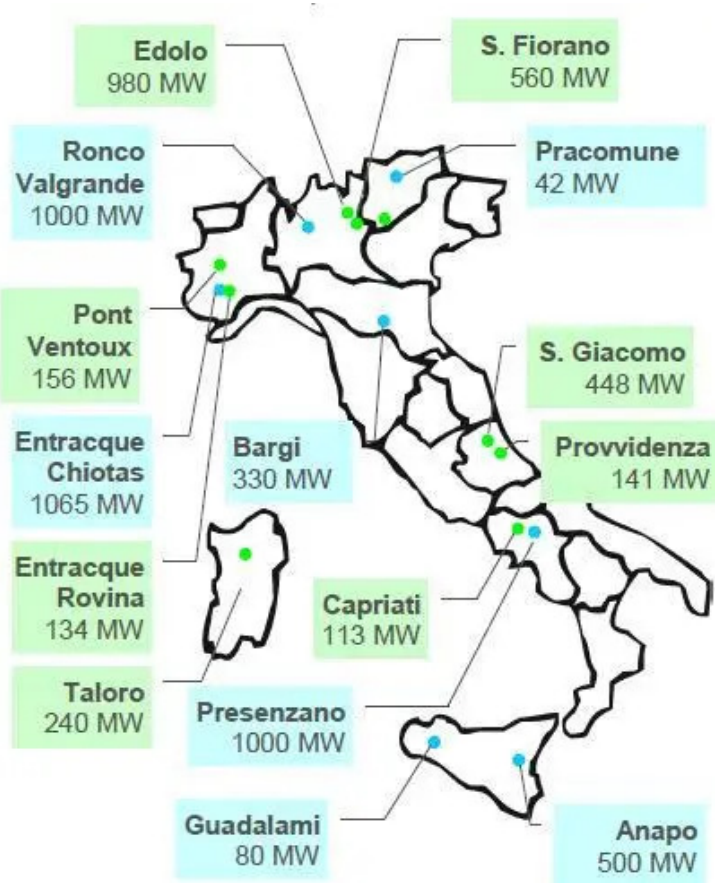
4. Italian Scenario

Servizi	Risorse	Termo elettrico	FER non progr.	Consumo	Idro / Pompaggi	Batterie
Fast reserve						
Primaria						
Secondaria						
Terziaria						
Riduzione congestioni						
Bilanciamento						
Interrompibilità						

Legenda adatto

con limiti

inadatto



Capability of different grid resources to supply ancillary services of frequency/power regulation - Source: Edison

4. Italian Scenario

From "Documento di Descrizione degli Scenari 2024" TERNA

Figura 20 - Ripartizione zonale a) capacità Installata FER [GW] e b) capacità energetica degli accumuli, escl. pompaggi esistenti [GWh]

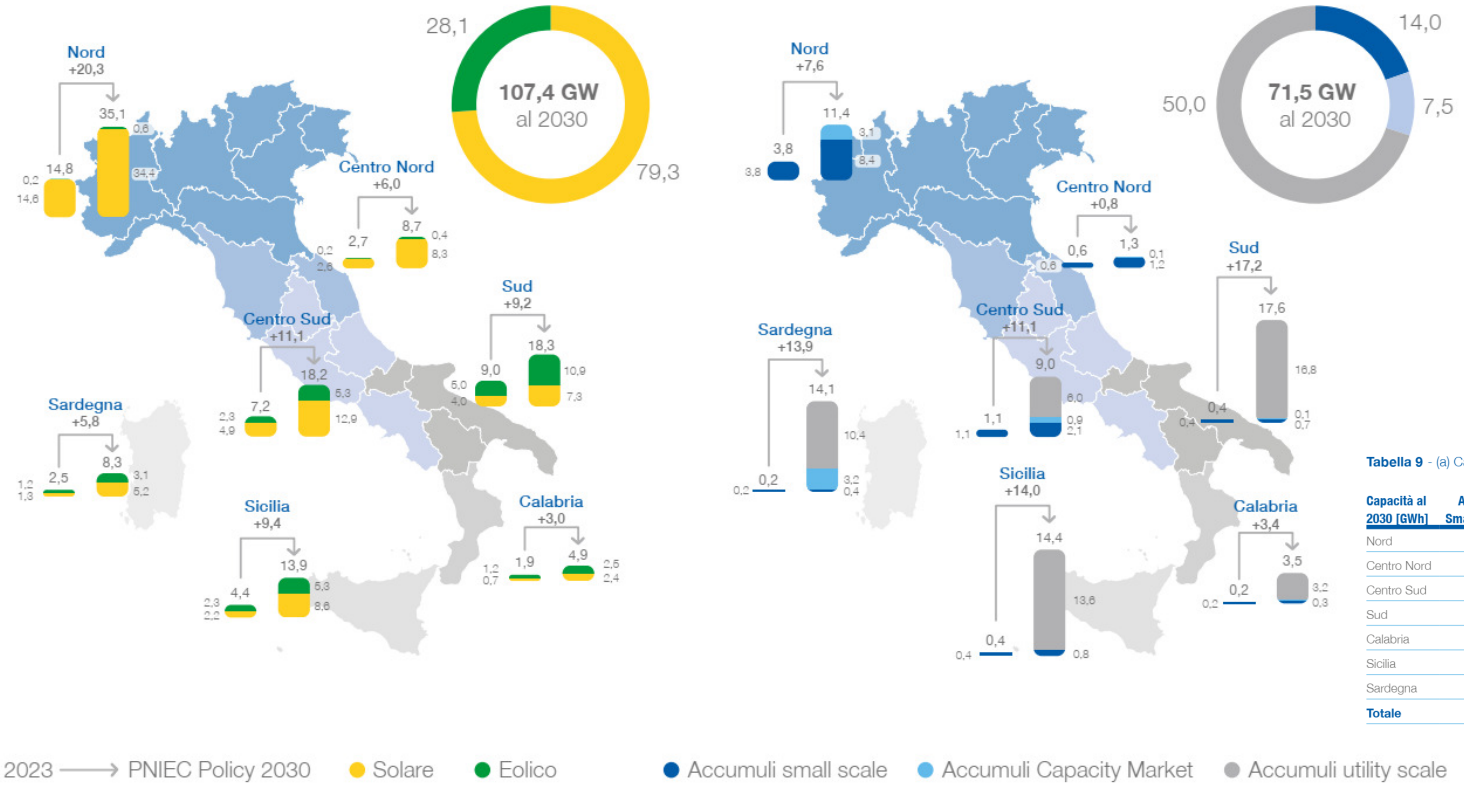


Tabella 9 - (a) Capacità energetica accumuli al 2030, (b) incremento accumuli al 2030 [escl. pompaggi esistenti]

Capacità al 2030 [GWh]	Accumuli Small Scale	Accumuli Aste CM	Accumuli Utility Scale	Somma accumuli
Nord	8,4	3,1	0,0	11,4
Centro Nord	1,2	0,1	0,0	1,3
Centro Sud	2,1	0,9	6,0	9,0
Sud	0,7	0,1	16,8	17,6
Calabria	0,3	0,0	3,2	3,5
Sicilia	0,8	0,0	13,6	14,4
Sardegna	0,4	3,2	10,4	14,1
Totale	**14,0**	**7,5**	**50,0**	**71,5**

Incremento vs 2023 SdA [GWh]	Accumuli Small Scale	Accumuli Aste CM	Accumuli Utility Scale	Somma accumuli
Nord	4,6	3,1	0,0	7,6
Centro Nord	0,7	0,1	0,0	0,7
Centro Sud	1,0	0,9	6,0	8,0
Sud	0,3	0,1	16,8	17,2
Calabria	0,2	0,0	3,2	3,4
Sicilia	0,4	0,0	13,6	14,0
Sardegna	0,2	3,2	10,4	13,9
Totale	**7,4**	**7,5**	**50,0**	**64,8**

5. PSP Developments in Italy

In the last 5 years Lombardi was the technical partner in the development of new PSPs for the main electric utilities in the Italian market, by using experience from projects in Switzerland (where the building of PSPs never stopped in the last two decades) and worldwide.

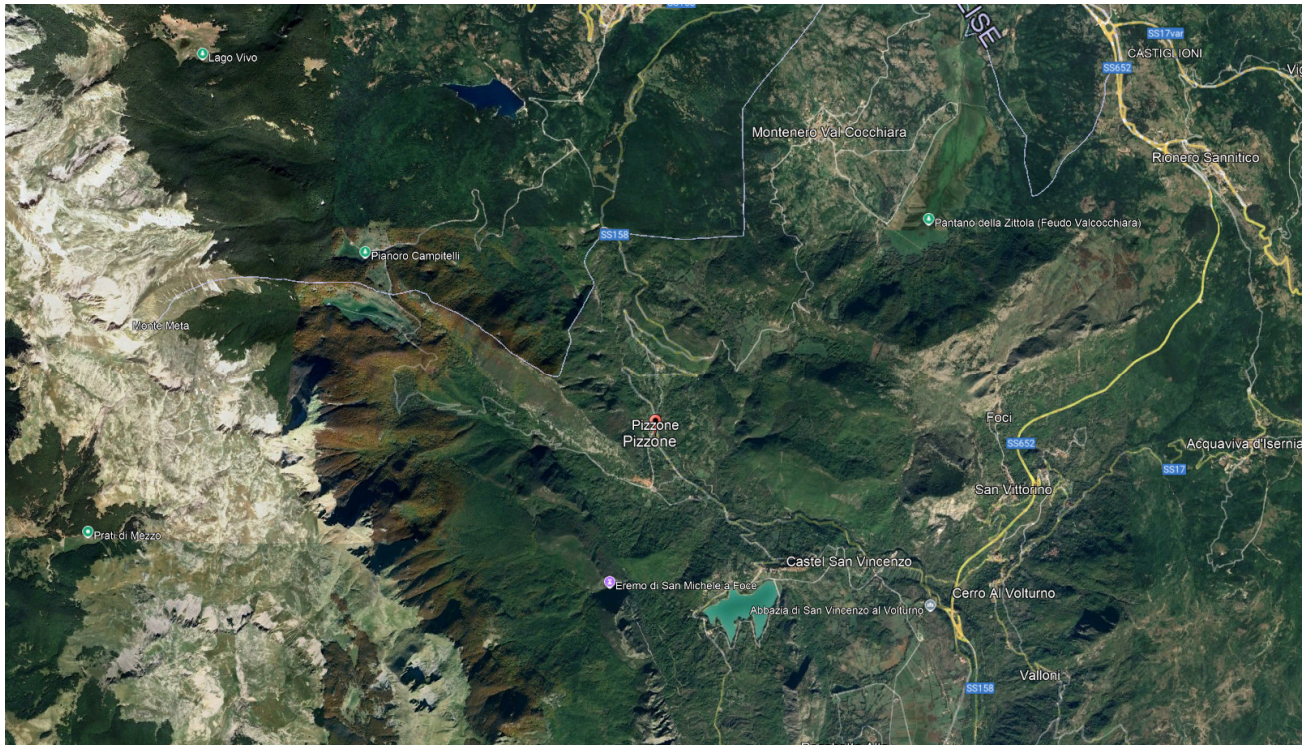
The main critical points in the development of a PSP project capable to get the construction phase are not financial or technical but generally

- Relationships with local stakeholders
- Environmental opposition (not environmental issues, usually cleverly solved by a skilled designer)
- Uncertainty in the rules to accomplish the administrative authorization process (water rights, environmental authorization, general authorization)

Some simplifications are possible with reference to existing HPPs suitable for the conversion to PSPs (using existing infrastructures, dams and basins, without construction of new ones) but in most cases it is required a design taking systematically in account any external condition, overcoming the most adequate technical and economic design principles, that are not to be considered the most relevant drivers of the design (the best technical project possibly is not the one to be built).

Furthermore, the design must be systematically verified with the stakeholders during development and must be modified following new hints and indications.

6. An Example: Pizzone II



Reference geographical framework: Central Italy, between Abruzzo and Molise

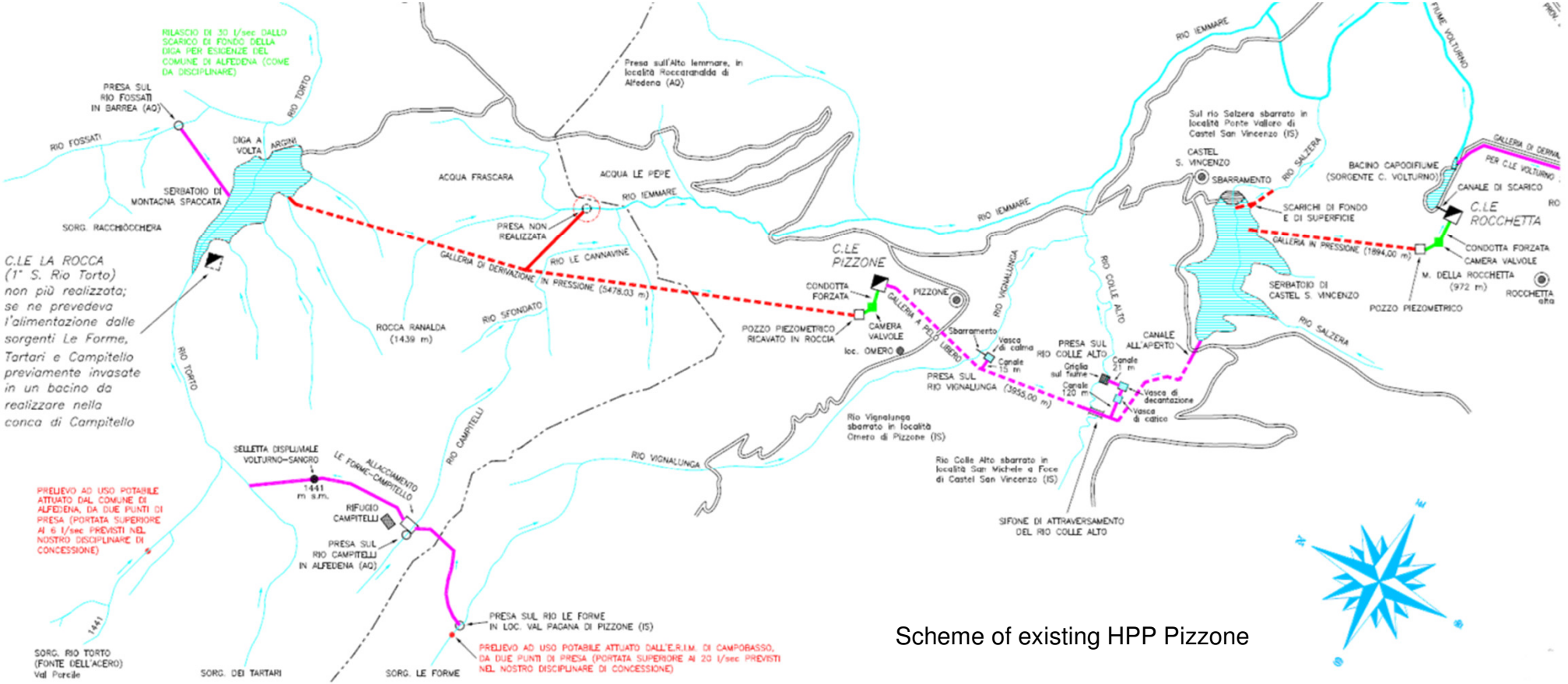


Castel San Vincenzo: downstream basin



Montagna Spaccata: upstream basin

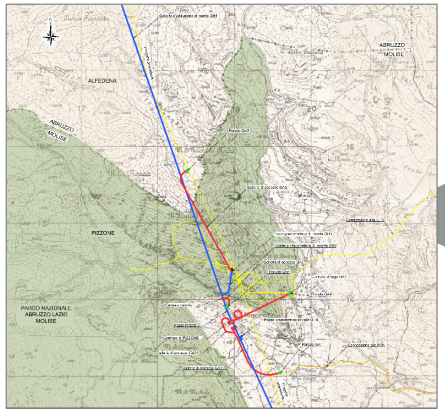
6. An Example: Pizzone II

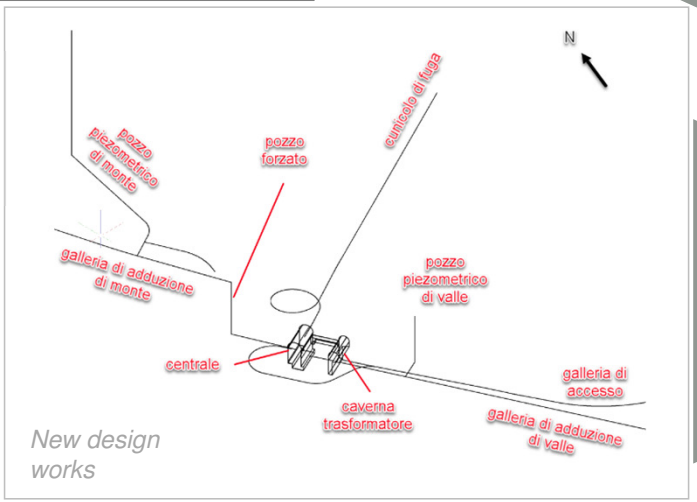


Scheme of existing HPP Pizzone

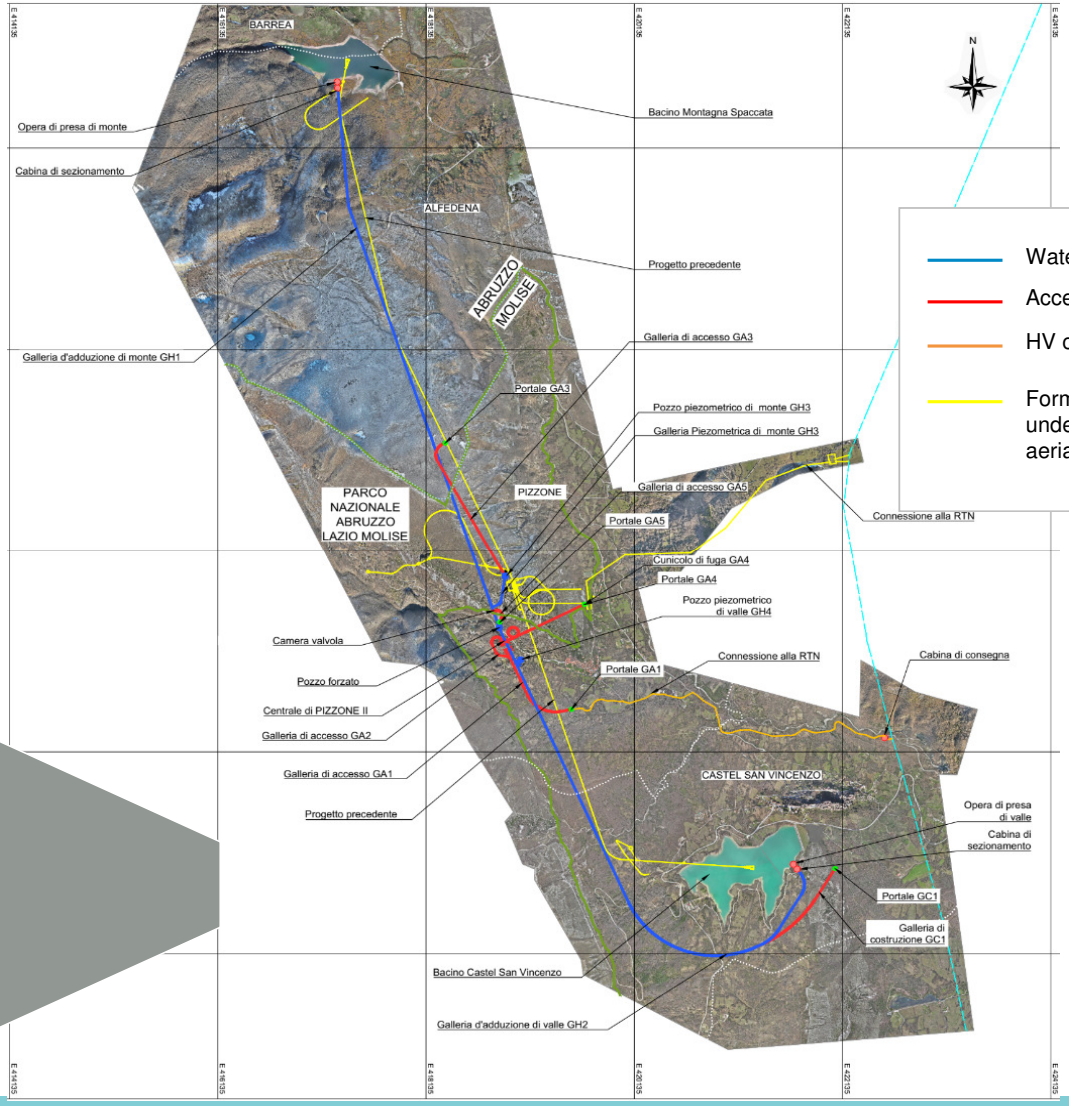
7. First design and redesign for acceptability

Design Layout: Revision vs Original





video



7. First design and redesign for acceptability

Design Layout: Profile

Layout generale profilo longitudinale
Generazione - Qnom = 51.00 m^3/s
Pompaggio - Qnom = 38.50 m^3/s
(1:5000)

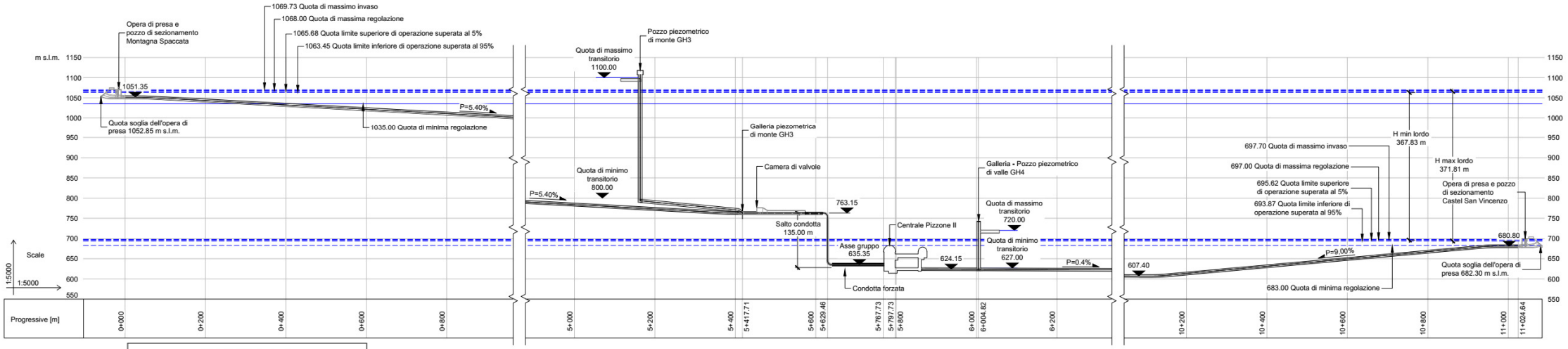


TABELLA 2	
Parametro	Valore
Salto lordo minimo	367.83 m
Salto lordo massimo	371.81 m
Salto lordo medio	369.82 m
Perdite generazione (Q=51 m^3/s)	11.42 m
Perdite pompaggio (Q=38.5 m^3/s)	7.53 m
Salto netto medio (generazione)	358.40 m
Prevalenza netta media (in pompaggio)	377.30 m

7. First design and redesign for acceptability

Points of Attention from Local Stakeholders:

1. **Oscillation of reservoir levels**
2. **Usability of the reservoirs**
3. **Construction sites**
4. **Excavation mode**
5. **Protection of the acquifer**
6. **Cutting plants**
7. **Flora and Fauna**
8. **Connection line**



Completely revised plant design to ensure maximum sustainability of the project and the best compatibility with the territory, considering all the observations received during the investigation on site and the dialogue that has taken place during design with the local communities and municipalities

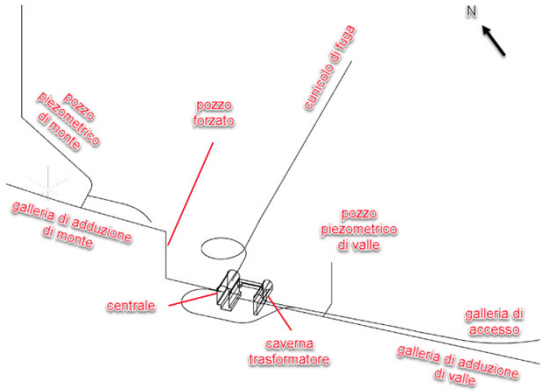
7. First design and redesign for acceptability

The revised design: main technical modifications from local stakeholders observations

Technical Modifications	Effects	
Power reduction from 300 to 150 MW	• The oscillation of the reservoirs has been greatly reduced: Castel San Vincenzo from 4.85 to 2.35 m, Montagna Spaccata from 6.50 to 2.80 m	*Acceptable*
New route of the works	• Excavation route defined according to a principle of hydrogeological protection (3D hydrogeological model) • Construction site areas organized by territorial areas with common services, therefore reduced in number (from 8 to 4) and in surface area used, in anthropized areas outside the PNALM boundaries • Excavation volume in line with the original project (approx. 1 million m3), given the new position of the works and construction sites, outside the PNALM and in areas with less environmental sensitivity • Optimized construction site road system: prevalent use of existing roads with limited adaptation interventions, surface area of the new road system reduced from 38,300 to approximately 4,000 m2 • Forest cutting reduced by 7.5 ha compared to the previous project solution • Positioning of intake structures within the buffer areas already affected by the existing intakes	Excavation volume similar to the previous project and forest cutting reduced to a lesser extent, due to the need to respect environmental constraints in the positioning of the works and construction areas
New connectioin solution	• Execution using an underground duct on existing roads and no longer using an overhead line on a new route: significant reduction in land use (expropriations and forestry easements) and related landscape impact.	*Acceptable*
Technical construction methodology	• Mechanized excavation with TBM, road header and raise borer, without the use of explosives and in waterproof conditions already during the excavation phase • Internal waterproof lining to ensure the impossibility of interaction with the aquifer • Excavated materials: reuse for the production of segments, interventions on dams, creation of beaches • Reduction of site and construction times (from 60 to 48 months)	*Acceptable*

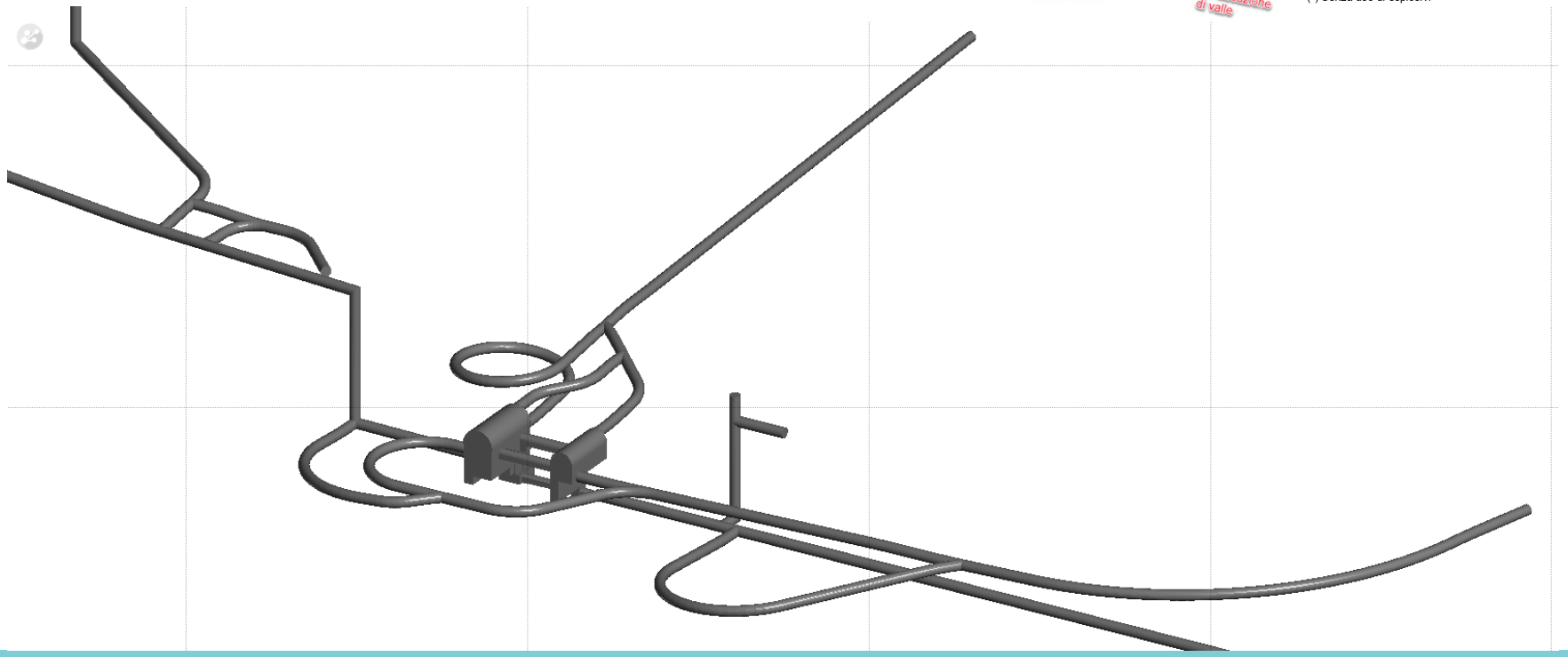
7. First design and redesign for acceptability

Main Works



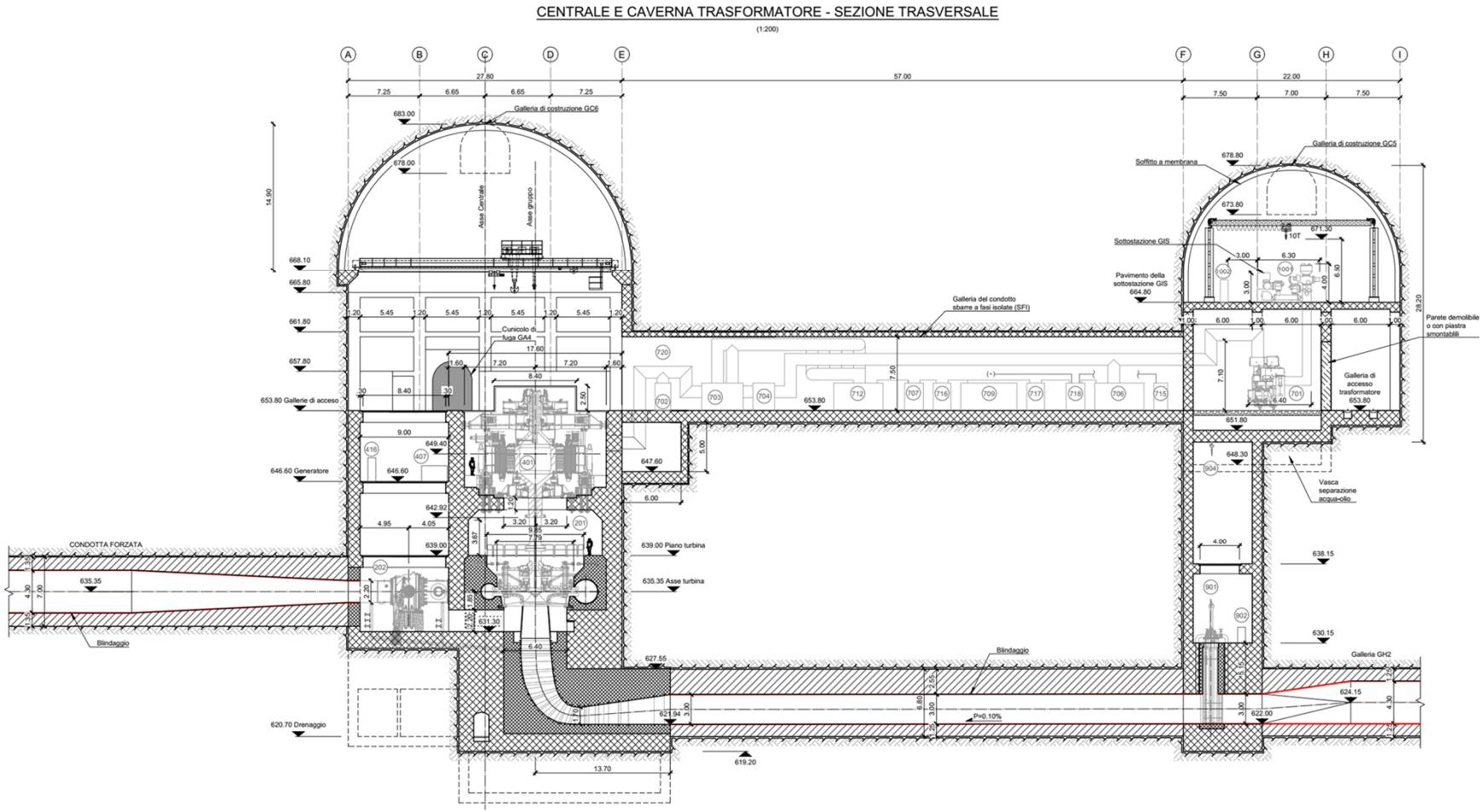
Struttura	Tipo di scavo	Diametro di scavo	Larghezza	Altezza	Copertura di roccia	Unità geologica
[-]	[-]	[m]	[m]	[m]	[m]	[-]
Galleria di accesso principale (GA1)	Convenzionale *	8,7	8,7	6,95	154	Flysch
Centrale in caverna	Convenzionale *	27,8	27,8	40,55	80	Flysch
Portale TBM di monte	Convenzionale *	12	12	9	54	Flysch / Detrito di versante
Tunnel di accesso della TBM di valle	Convenzionale *	10	11	8	41	Flysch
Galleria di adduzione di monte (GH1)	TBM	7,5	-	-	530	Calcare
Galleria di adduzione di valle (GH2)	TBM	6,5	-	-	160	Flysch
Pozzo piezometrico di monte (GH2)	Raise borer	10	-	-	328	Calcare
Pozzo piezometrico di valle (GH2)	Raise borer	9	-	-	116	Flysch
Pozzo forzato	Raise borer	5	-	-	140	Flysch

(*) Senza uso di esplosivi



7. First design and redesign for acceptability

Powerhouse



7. First design and redesign for acceptability

Main Access Tunnel

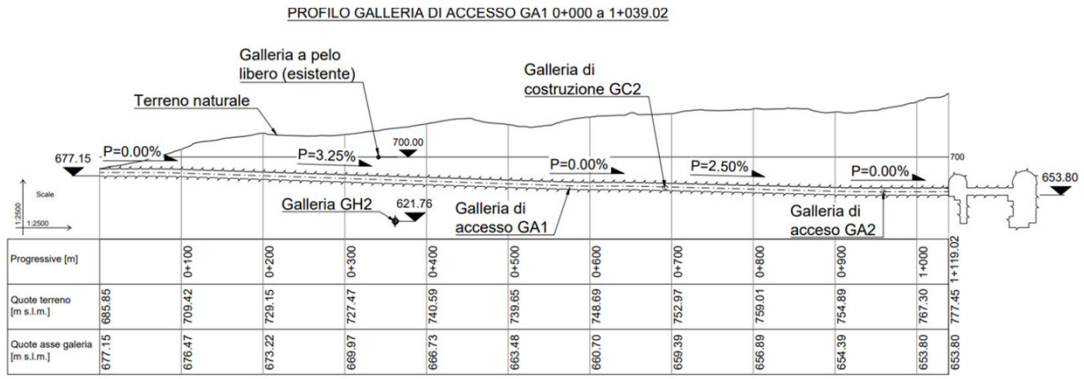


Figura 4: Profilo della galleria di accesso principale.

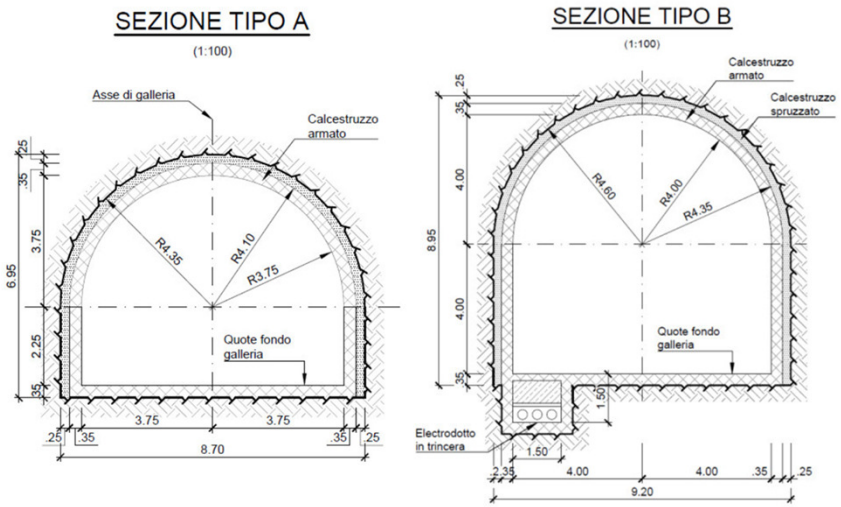


Figura 5: Galleria di accesso principale.

7. First design and redesign for acceptability

Piezometric Shafts

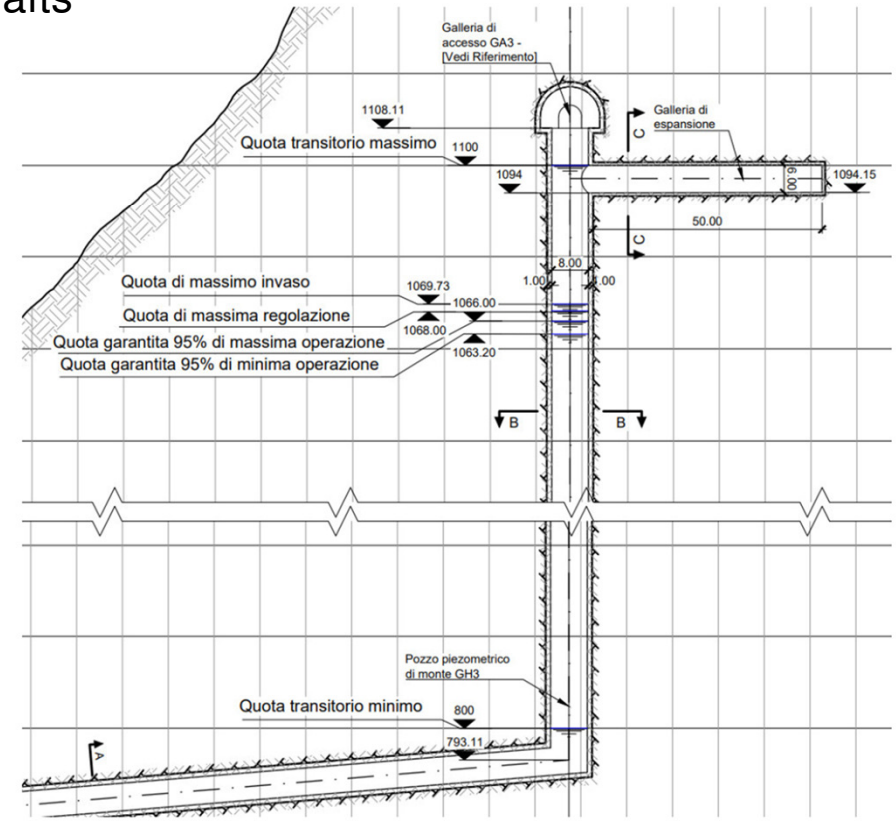


Figura 8: Pozzo piezometrico di monte.

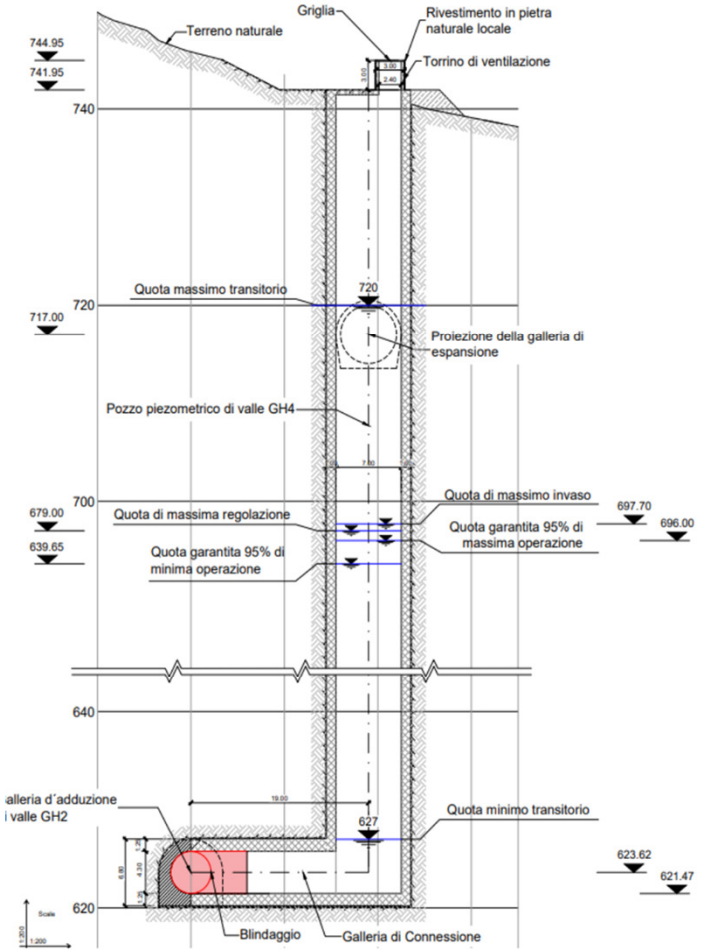


Figura 9: Pozzo piezometrico di valle.

7. First design and redesign for acceptability

Pressure Shaft

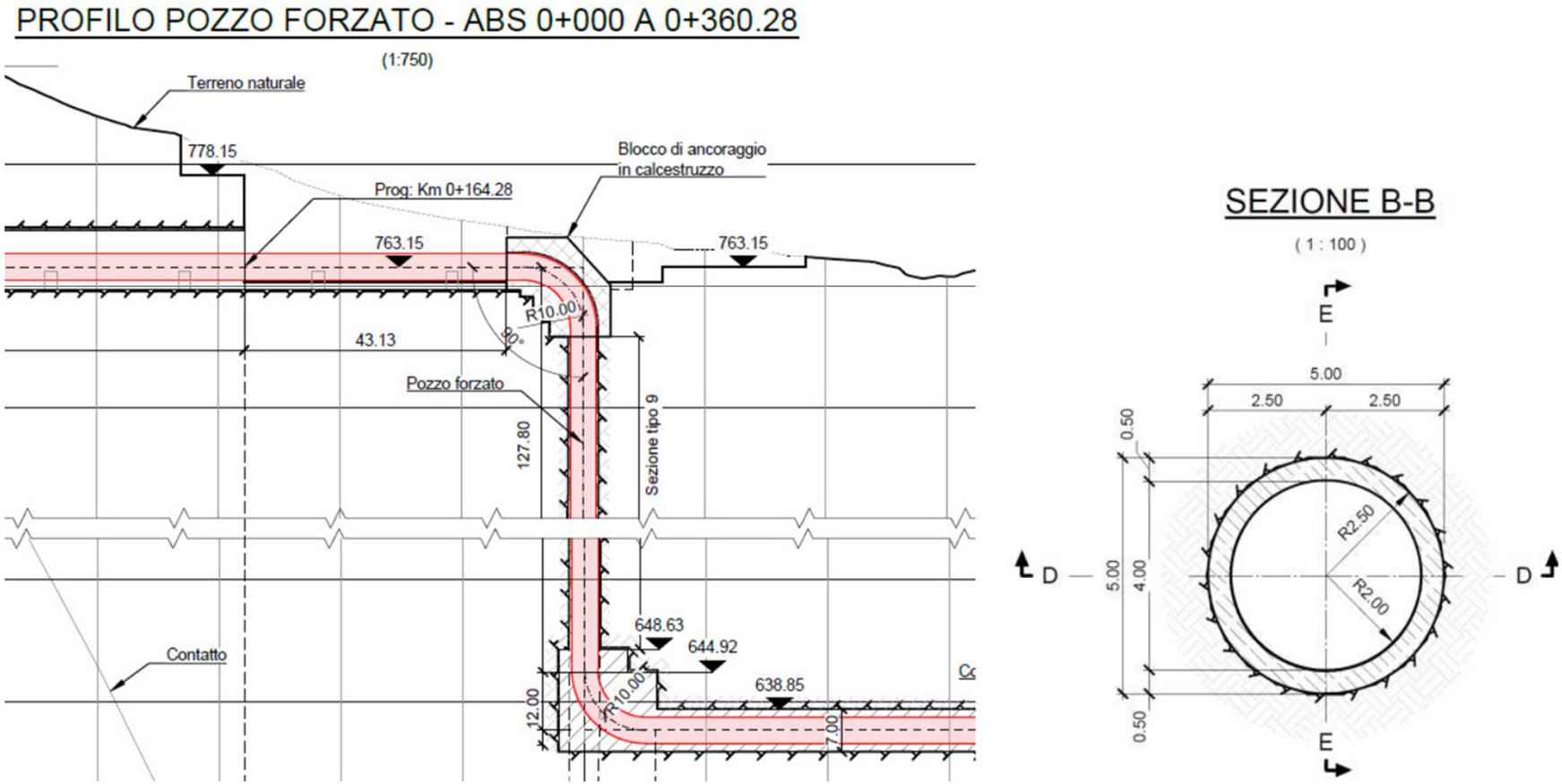


Figura 10: Pozzo forzato

7. First design and redesign for acceptability

Upstream Hydraulic Tunnel

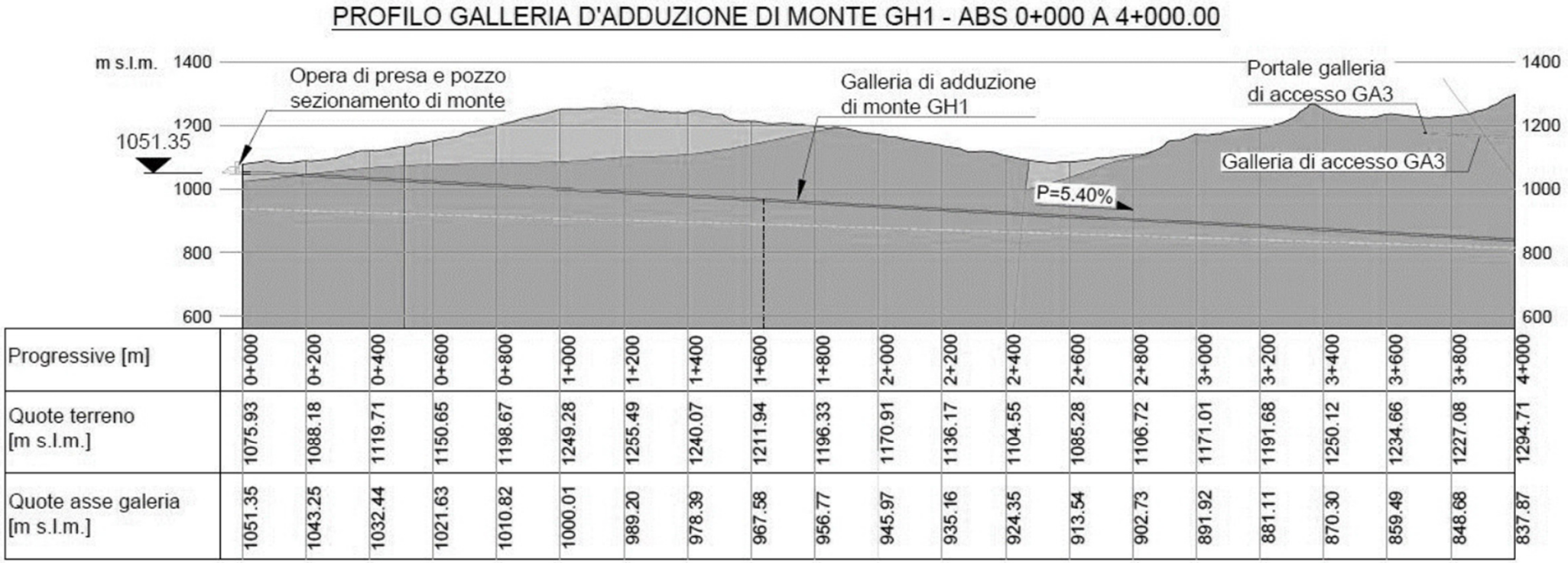


Figura 11: Galleria di adduzione di monte.

7. First design and redesign for acceptability

Upstream and Downstream Hydraulic Tunnels

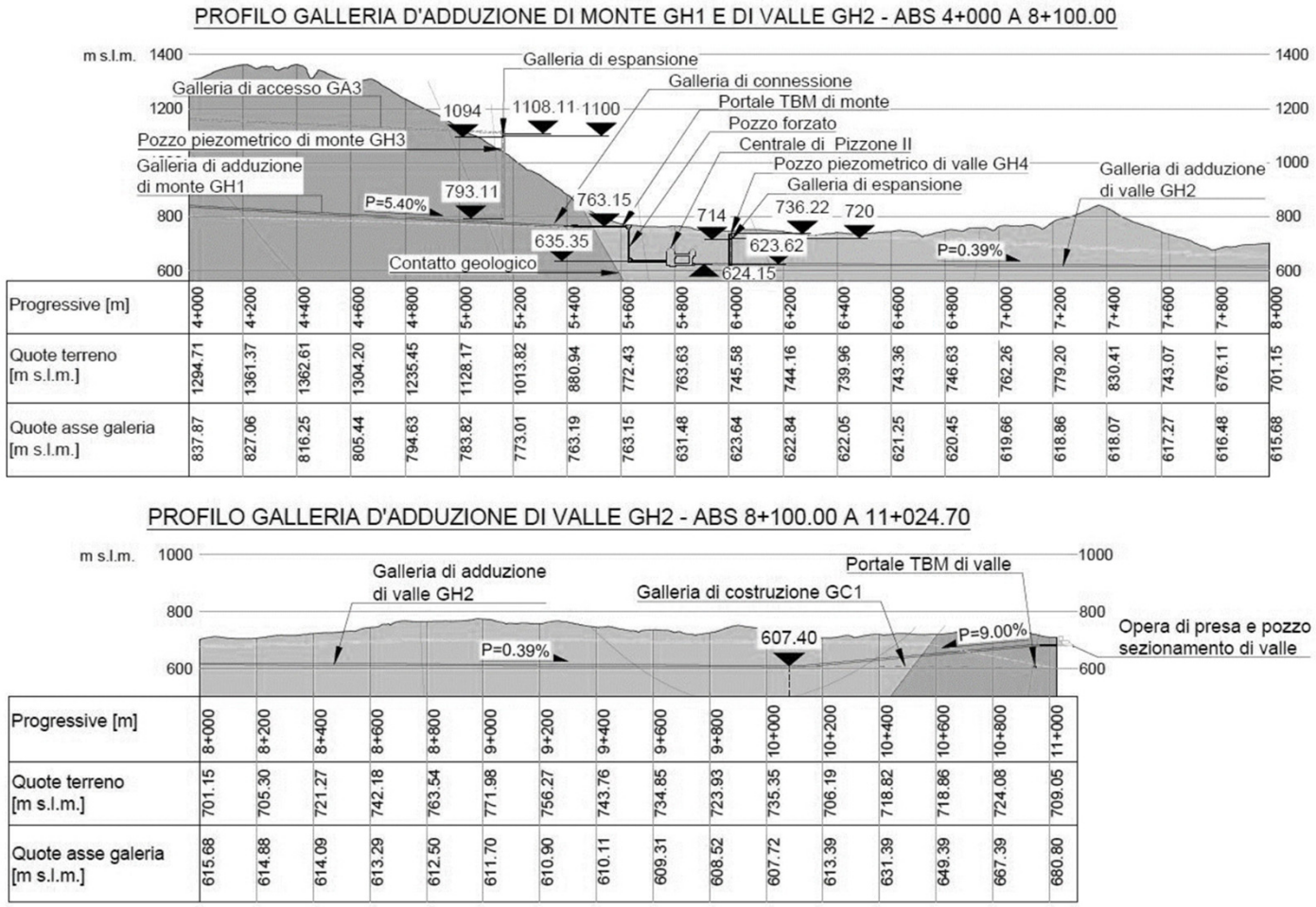
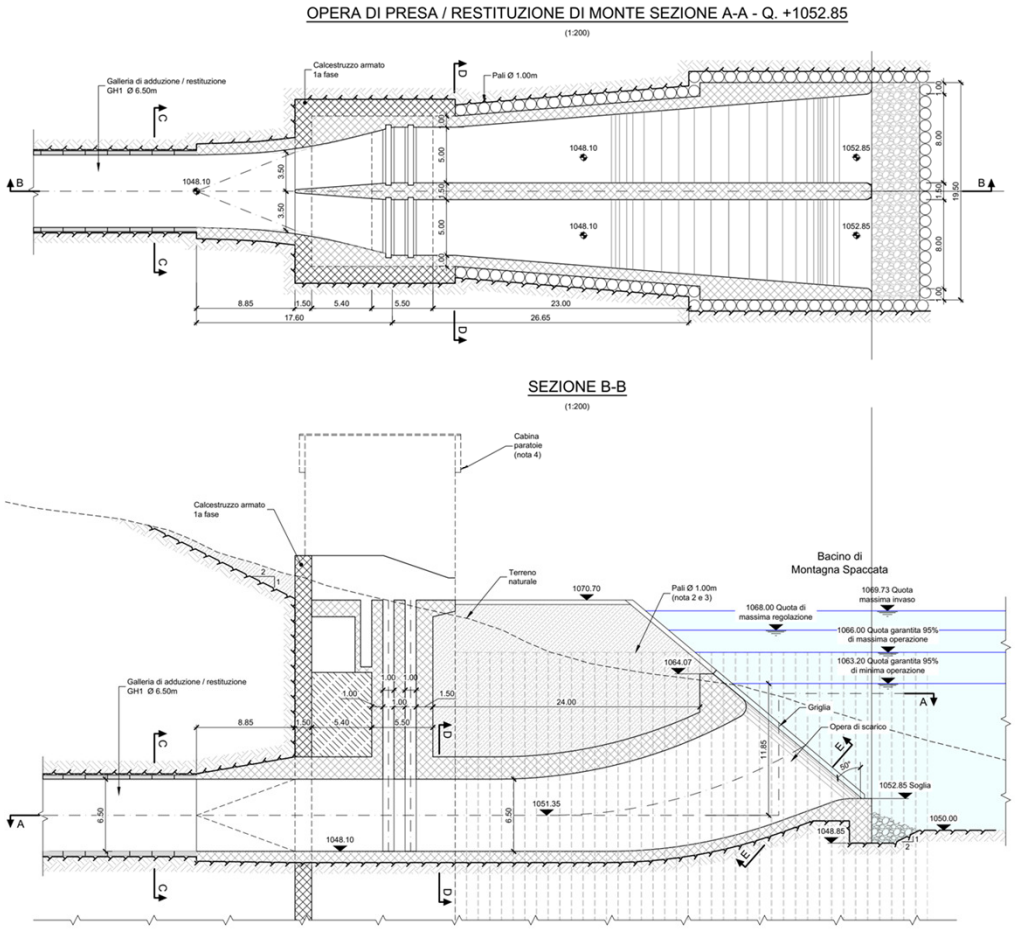
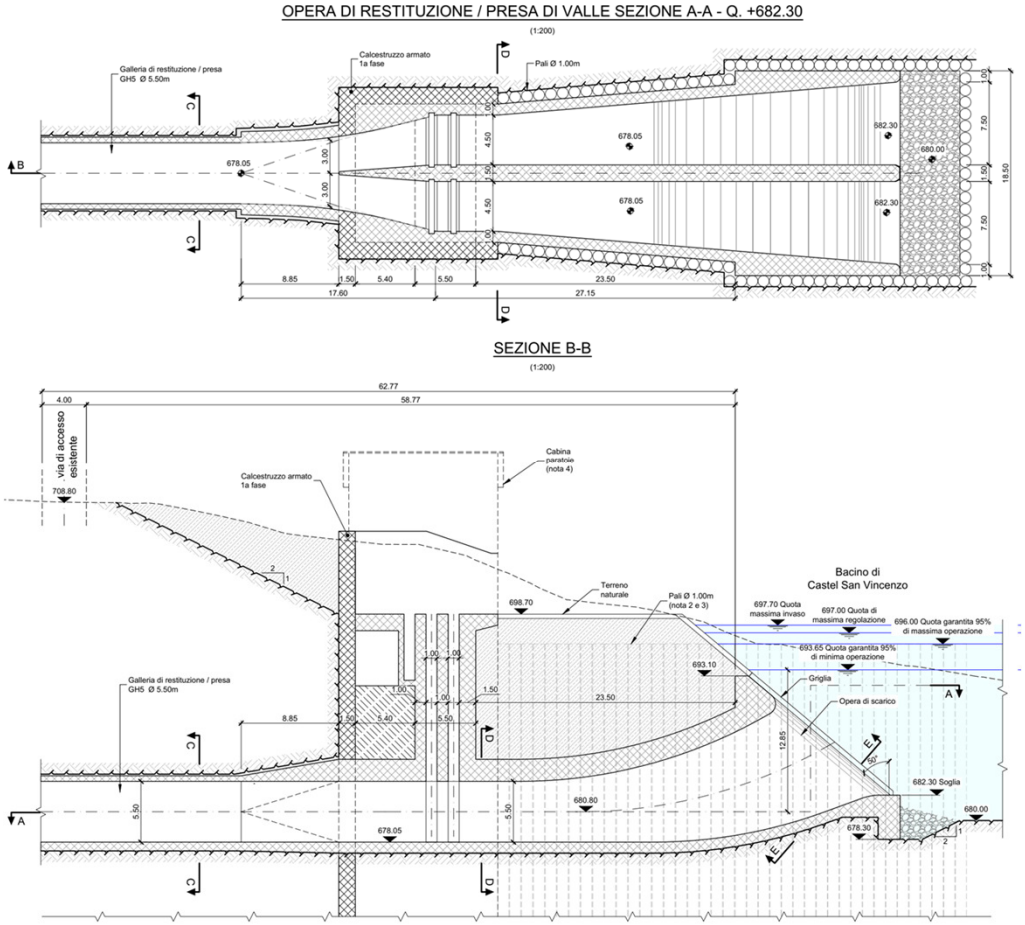


Figura 12: Galleria di adduzione di valle.

7. First design and redesign for acceptability

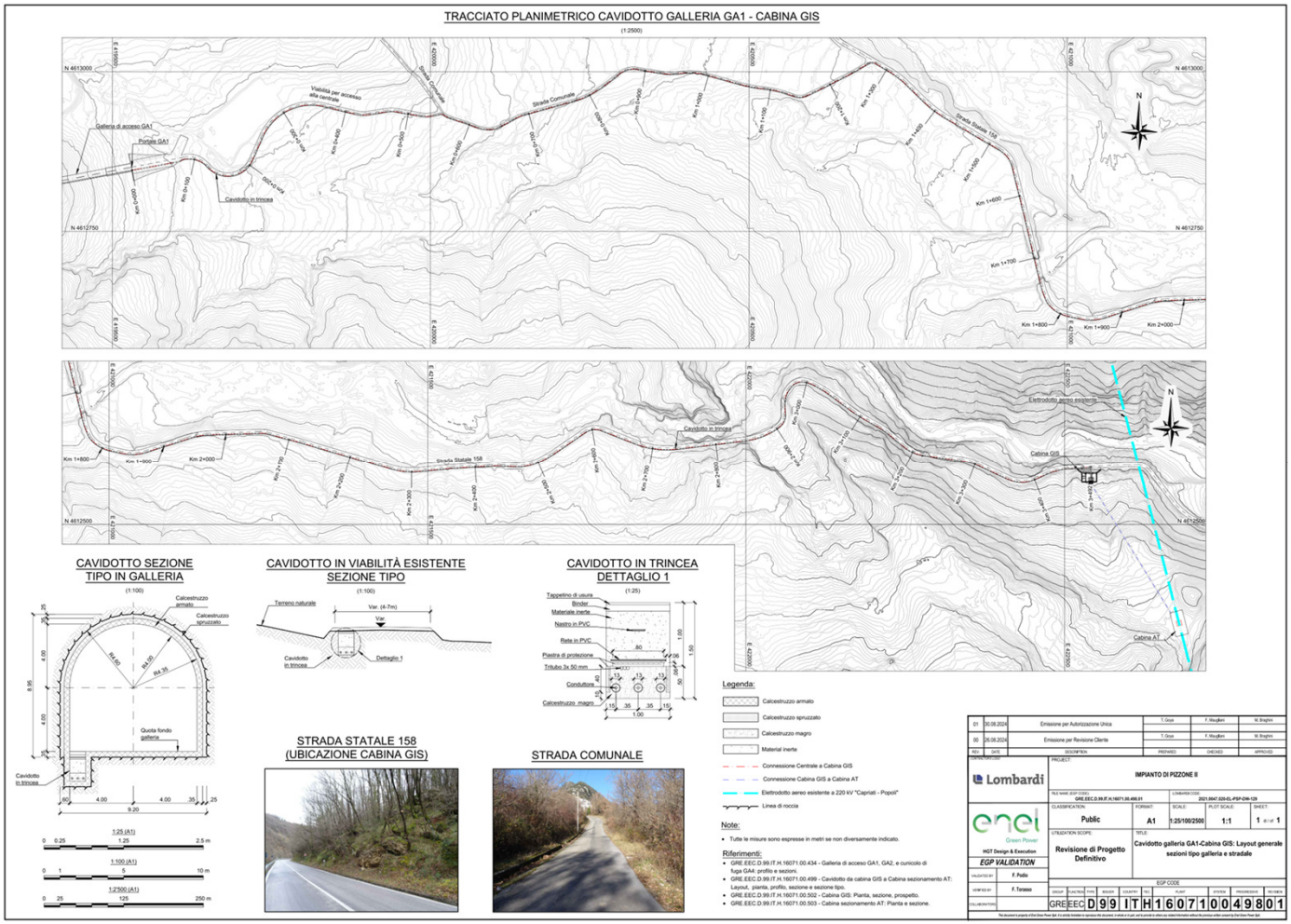
Upstream and Downstream Inlets





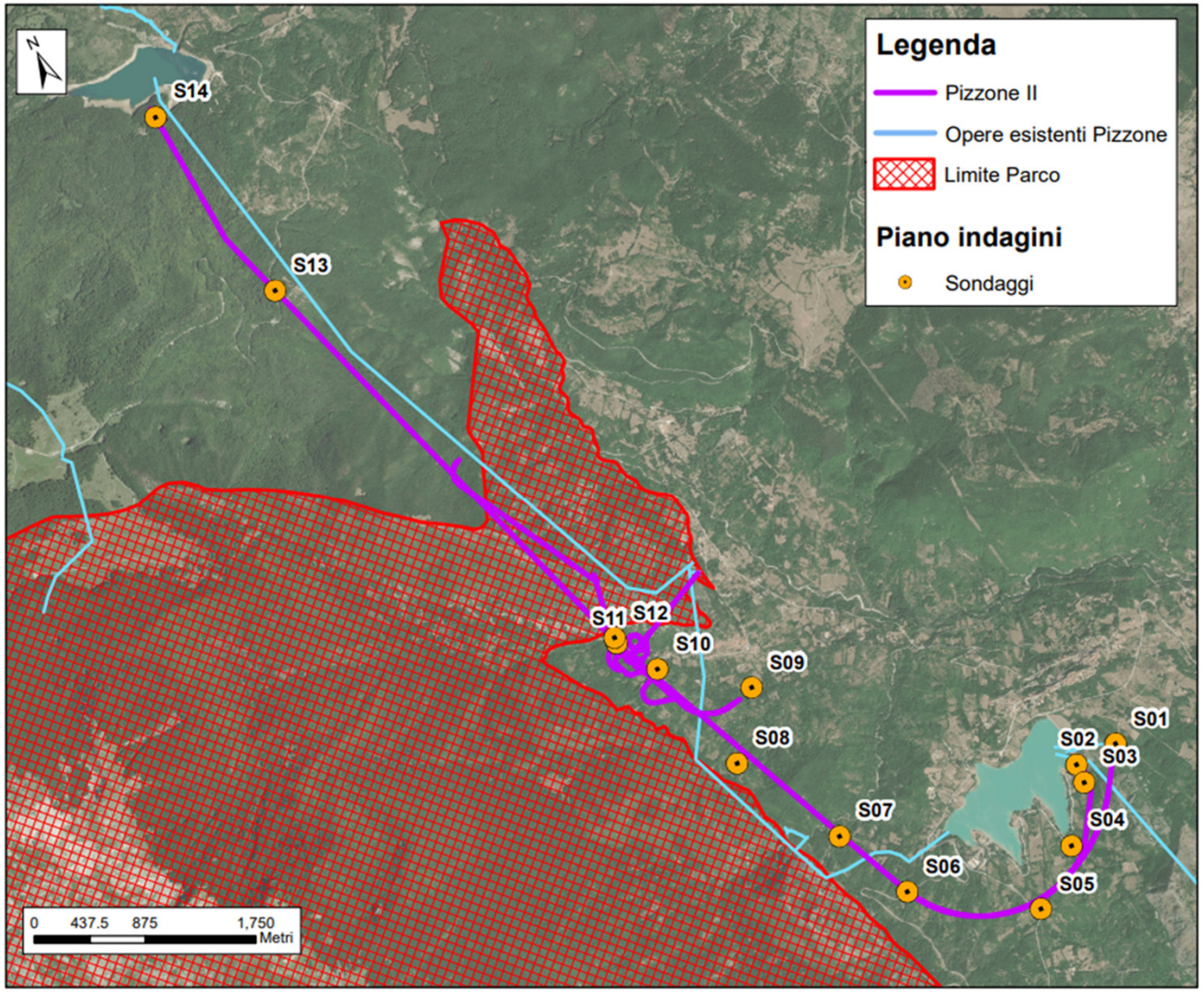
7. First design and redesign for acceptability

HV Connection (cable)



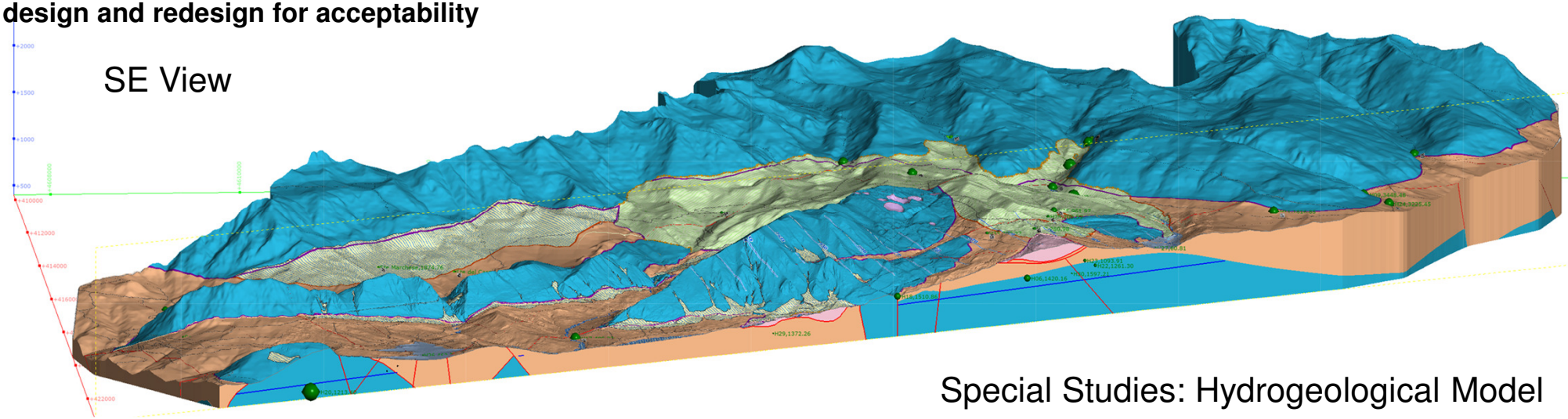
7. First design and redesign for acceptability

Geological and
Geotechnical Surveys

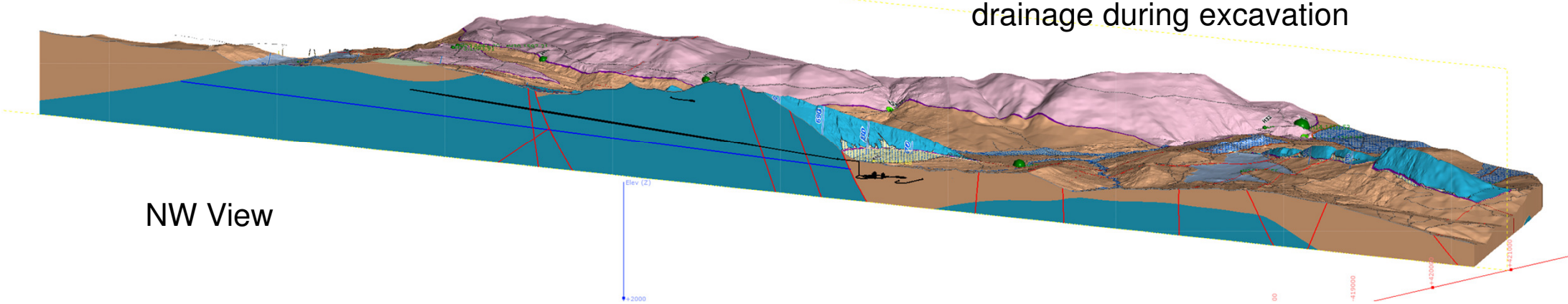


7. First design and redesign for acceptability

SE View



Special Studies: Hydrogeological Model with focus on underground water drainage during excavation



NW View

8. Hints for Future Engineers

Some hints for students approaching civil and hydraulic engineering:

- Civil and Hydraulic Engineering may seem historical matters, fully developed: it is a false opinion.
- As regards hydropower the main activities in Italy in the last 20 years were related to O&M activities, with very few case of new construction.
- Nowadays HPP plants in Italy, with 60 or more years of operation, require a major maintenance, and even a complete refurbishment or reconstruction, with technological update, also as regards civil and underground works maintenance.
- Moreover, the requirement for storage due to the development of not programmable renewables, offers massive potential for future growth of pumped storage (a proven, robust technology with more than a century of success behind it). The projection is for decades of development.
- The limit has not to be considered the Italian national border: hydro plants, both HPP and PSP, are still in development worldwide, with a significant push on due to the requirements of green transition.

The best career advice for a young professional engineer:

At every job you should either learn or earn.
Either is fine. Both is best. But if it's neither, quit.

9. Lombardi Group: activities

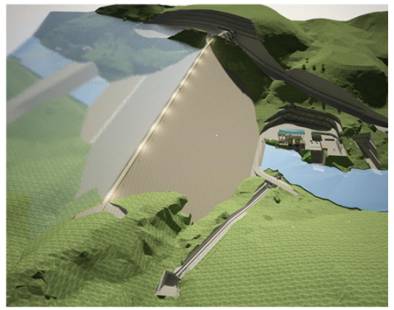


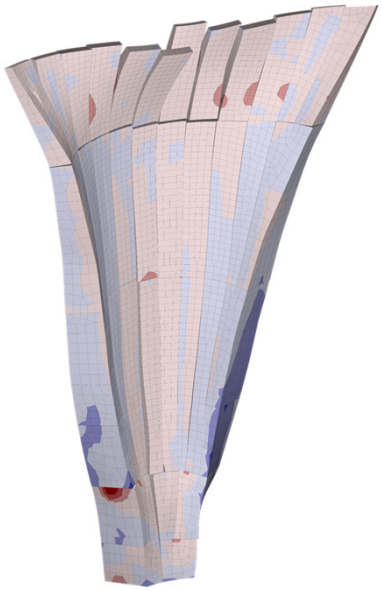
Dr. Giovanni Lombardi (1926-2017)
Institutional Web Site: https://lombardi.group/ita

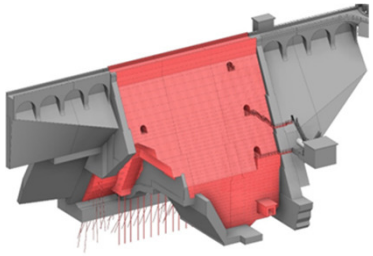
"The continuous will to break barriers, combined with a rigorous methodology, allows the realization of exceptional and complex structures".
"The engineer must also be able to imagine solutions that go beyond the traditional scheme, but then also be able to analyze and evaluate them calmly without being carried away by excessive enthusiasm raised, if necessary, by the originality of his proposal."
A life spent in search of better engineering

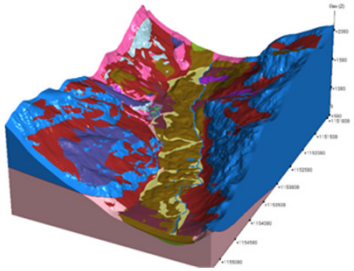


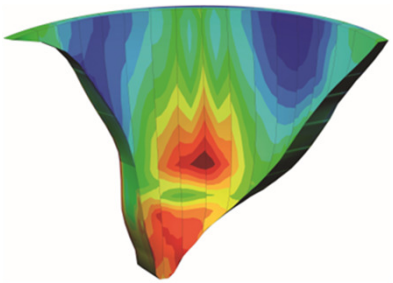


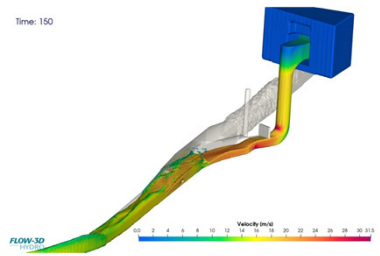




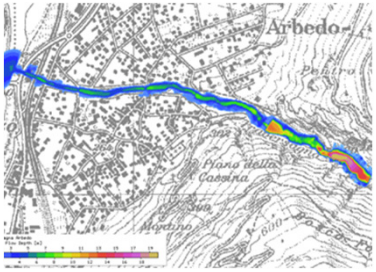














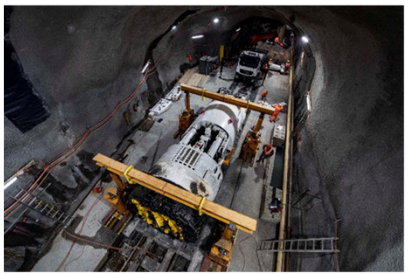


9. Lombardi Group: activities

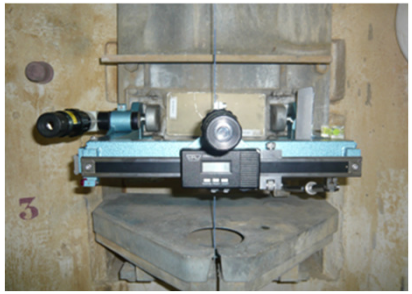















With energy for the future

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