

Rehabilitation of SHP low head plants

Guidelines and case studies

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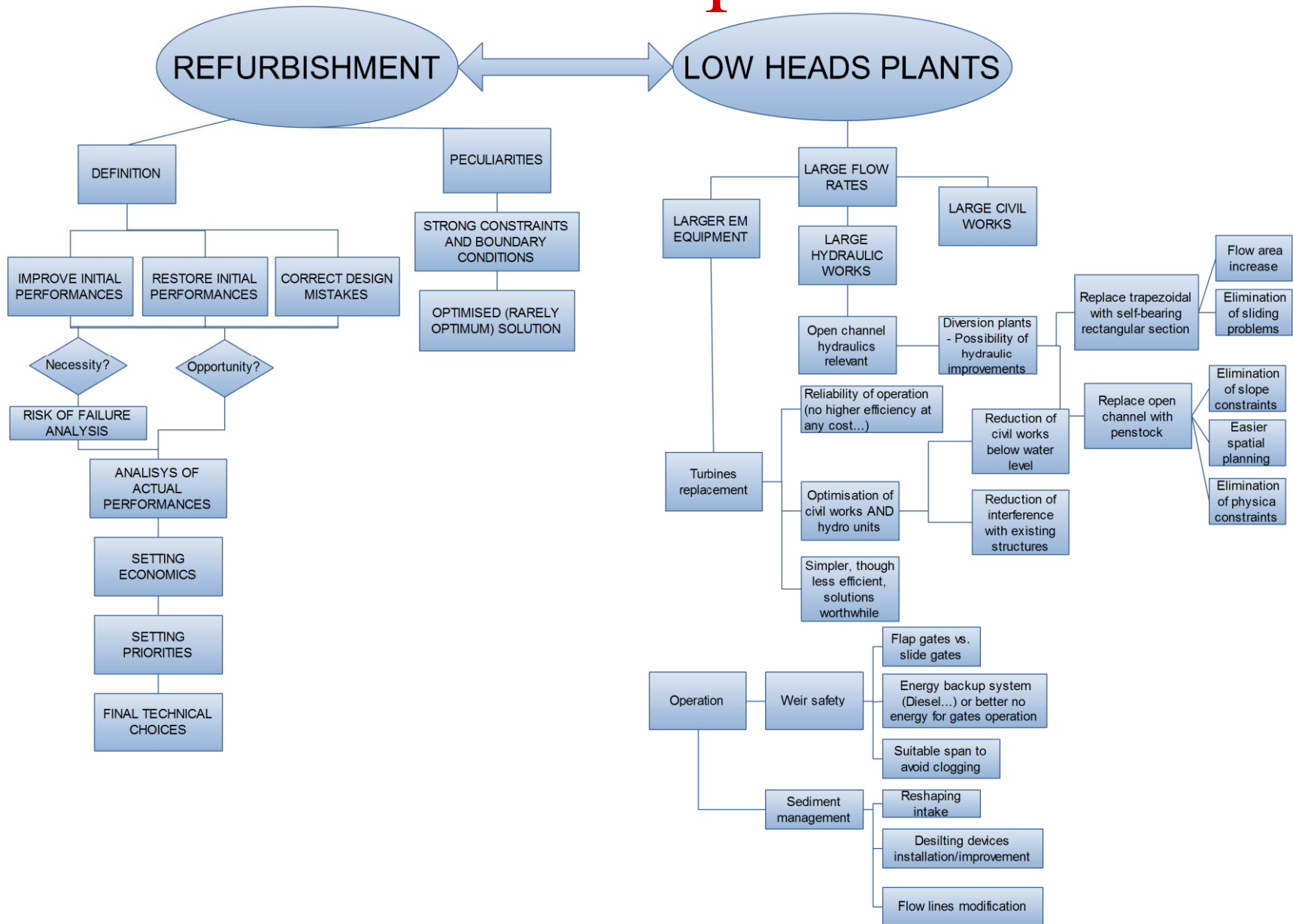
Rehabilitation

Restoration of the integrity of the main parts of the plant, with restoration or even improvement of the global performance of the plant in terms of energy output and reliability of operation

Low Head

- low head = $1,5 \div 30$ m
- very low head = $1,5 \div 3$ m

Mind map.....



Fields of action

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

η =many options γ =no options (by now)

H =some options Q =some options

T =many options

Improvement of weir operation safety

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

- $H_g = 8,85 \text{ m}$

- $Q_{\max} = 22 \text{ m}^3/\text{s}$



Improvement of sediment management



Desilting gate too small



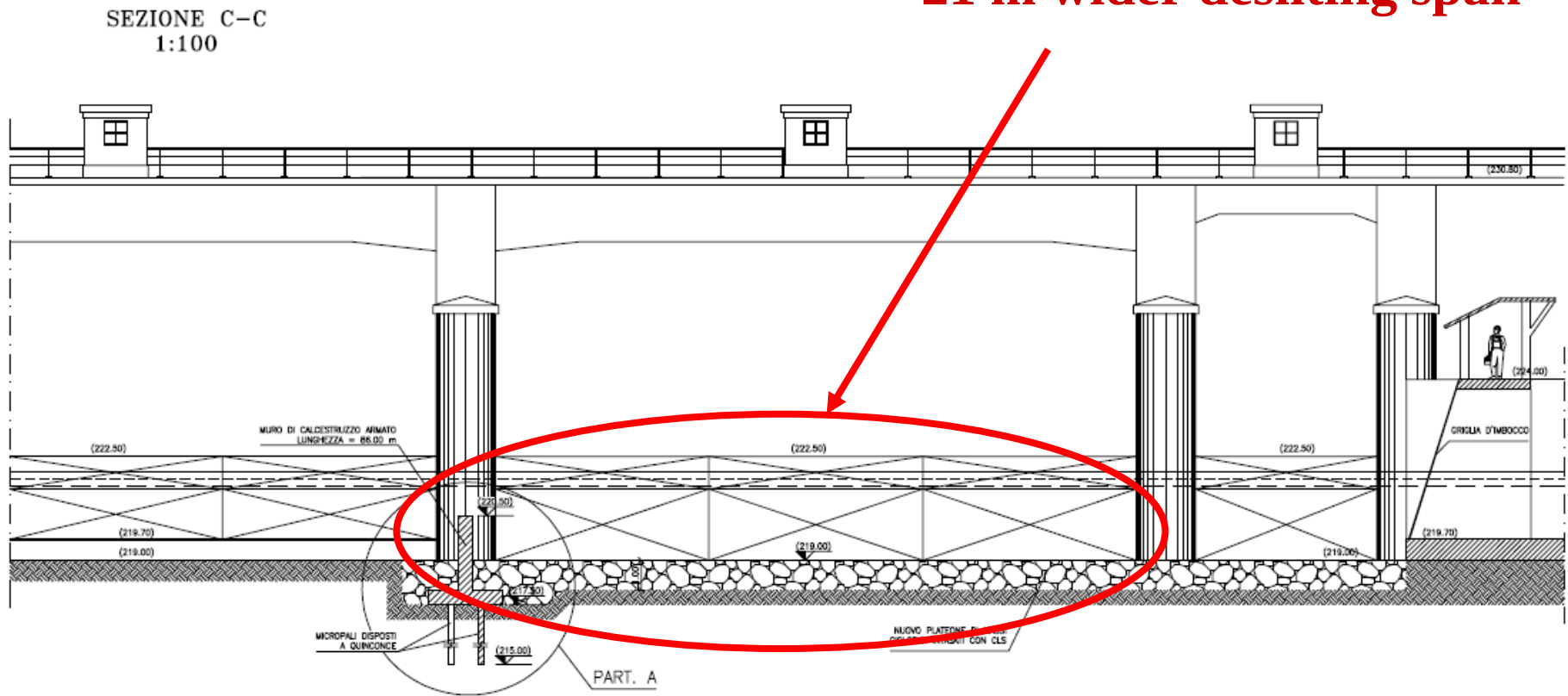
$$\bullet H_g = 12,87 \text{ m}$$

$$\bullet Q_{\max} = 75 \text{ m}^3/\text{s}$$

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

Improvement of sediment management

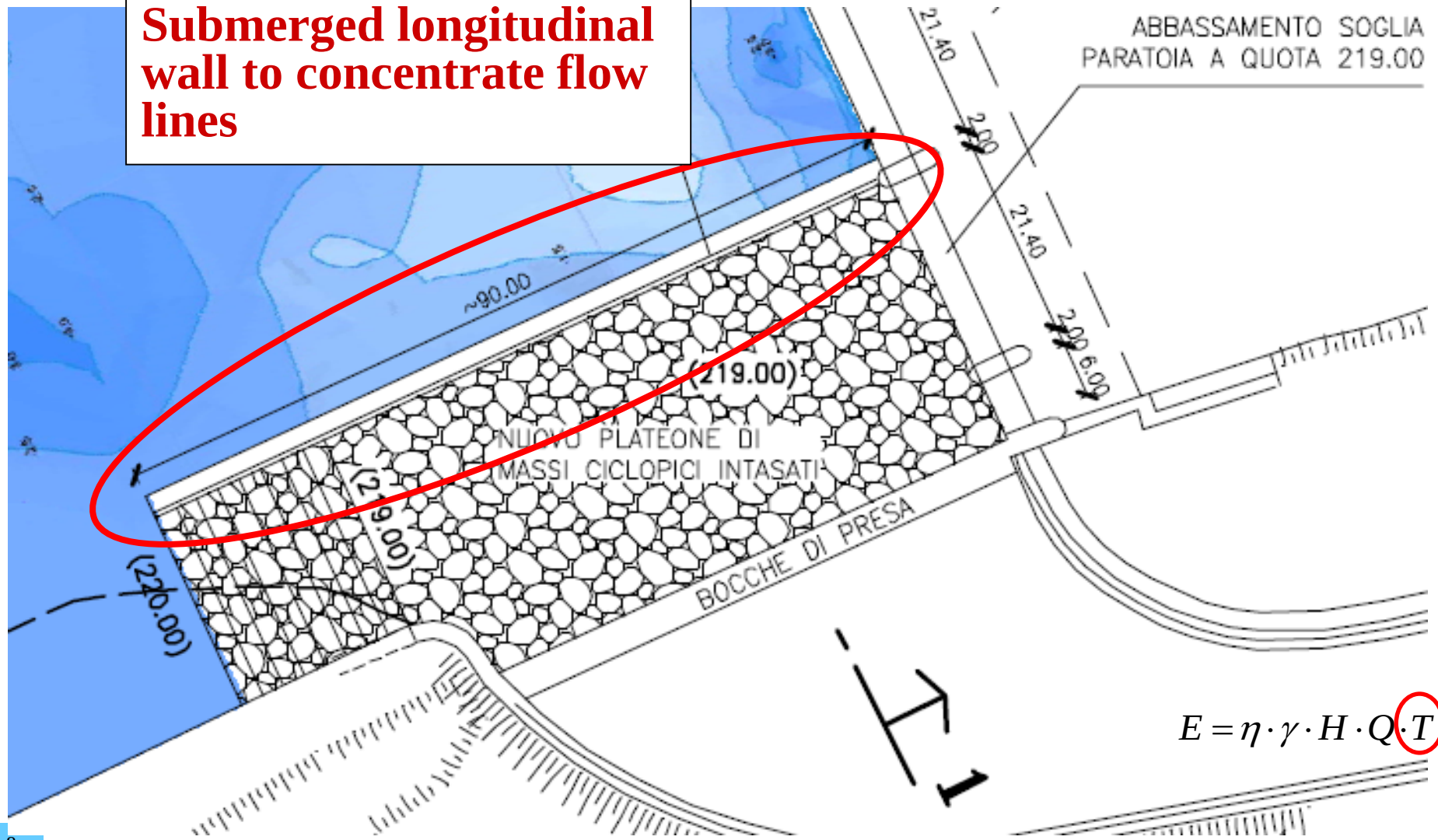
21 m wider desilting span



$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

[illegible]

Submerged longitudinal wall to concentrate flow lines



$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

Improvement of floating debris management $E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$



- $H_g = 10,50 \text{ m}$
- $Q_{\max} = 60 \text{ m}^3/\text{s}$



Units: improvement of efficiency

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$



Units: improvement of efficiency

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$



Old open flume Francis

- $H_g = 10,50 \text{ m}$
- $Q_{\max} = 60 \text{ m}^3/\text{s}$



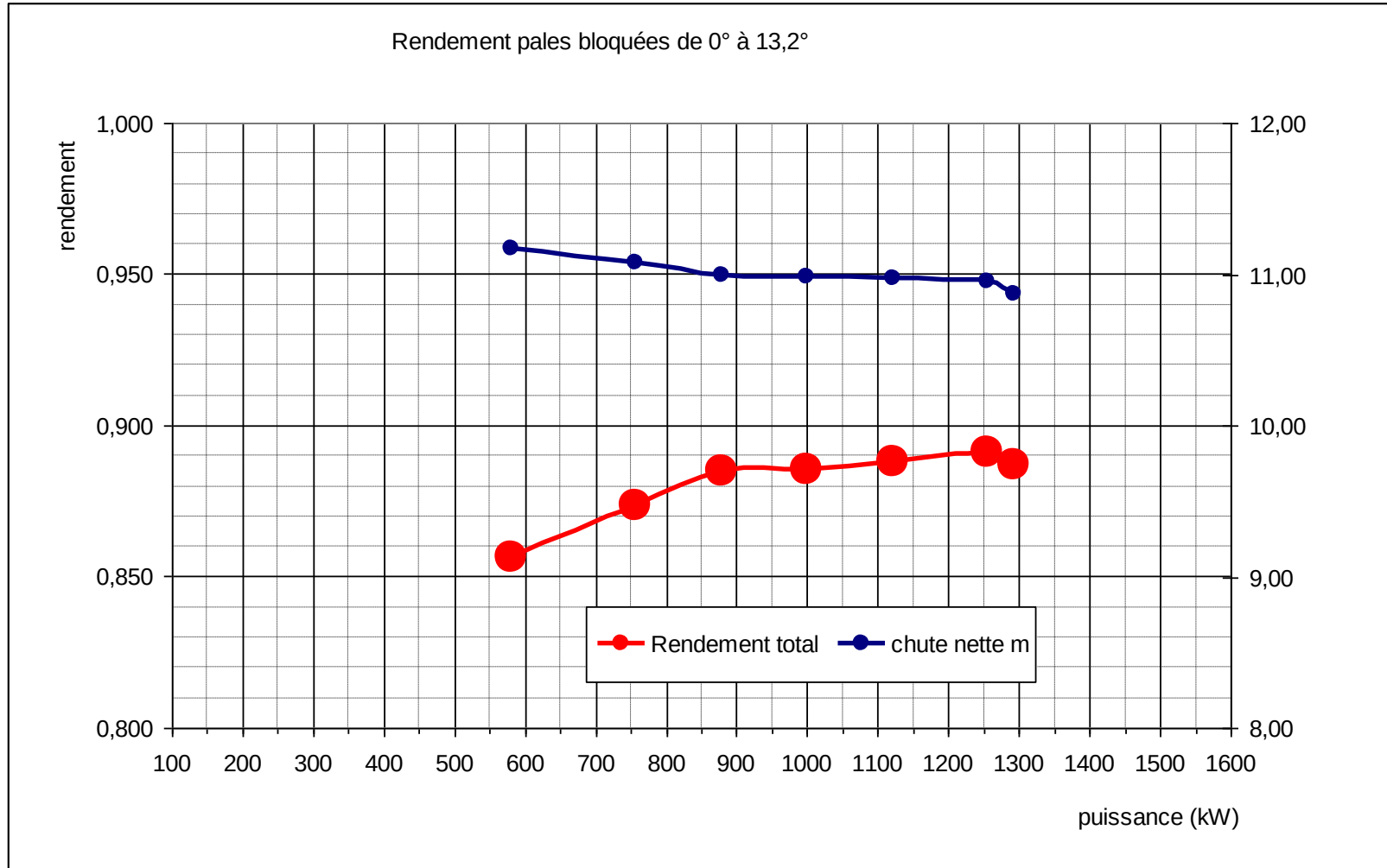
Units: improvement of efficiency



New permanent magnet vertical bulb units
 $\eta_{\text{avg}} > 87\%$

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

Units: improvement of efficiency



New permanent magnet vertical bulb units $\eta_{\text{avg}} > 87\%$
Old units (1922): $\eta_{\text{avg}} < 70\%$ (estimated)

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

Units: improvement of efficiency – new draft tube



⚠ WARNING 	⚠ WARNING 
ERECTION RISKS VERY HIGH DUE TO WATER	CAREFUL HYDRAULIC DESIGN NEEDED TO AVOID GLOBAL EFFICIENCY DECREASE!!!



Headrace channel: hydraulic performance improvement

$$E = \eta \cdot \gamma \cdot H \cdot \cancel{Q} \cdot \cancel{T}$$

← Trapezoid cross section

- $H_g = 7,97 \text{ m}$

- $Q_{\max} = 16 \text{ m}^3/\text{s}$

Rectangular cross section



Headrace channel: improvement of operation safety



← Open channel

Steel Penstock



$$\bullet H_g = 27,30 \text{ m}$$

$$\bullet Q_{\max} = 5,0 \text{ m}^3/\text{s}$$

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

Units replacement: upgrading

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

	Old plant	Rehabilitated plant	%
Owner	Elettra 2000 S.p.A.		
Commissioning year	1903		
Maximum flow rate	10.0 m ³ /s		
Medium flow rate	7.5 m ³ /s		
Net head	9.50 m		
Units	5 Francis		
Rated capacity	1,500 kVA		
Operating hours	6,550 MWh		
Energy production	4,680 MWh		



Tasks: New Kaplan unit, new powerhouse, complete and reliable automation, new tailrace canal, weir crest raise, rehabilitation and upgrade of supply canal, new fish passage, reliable discharge of environmental flow rate.

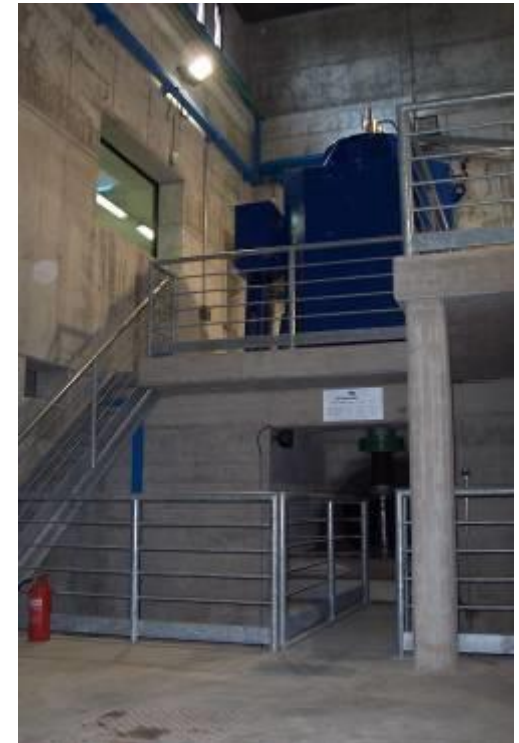
Critical constraints: inclusion in a productive area, excavations in narrow places, new *bypass* facilities, old plant in operation during most of the working time

Project costs (2006): 4,628,000 €

Intensive cost: 2,755 €/kW; 0.51 €/kWh

Units replacement: upgrading

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$



Units replacement: restoring initial efficiency $E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$

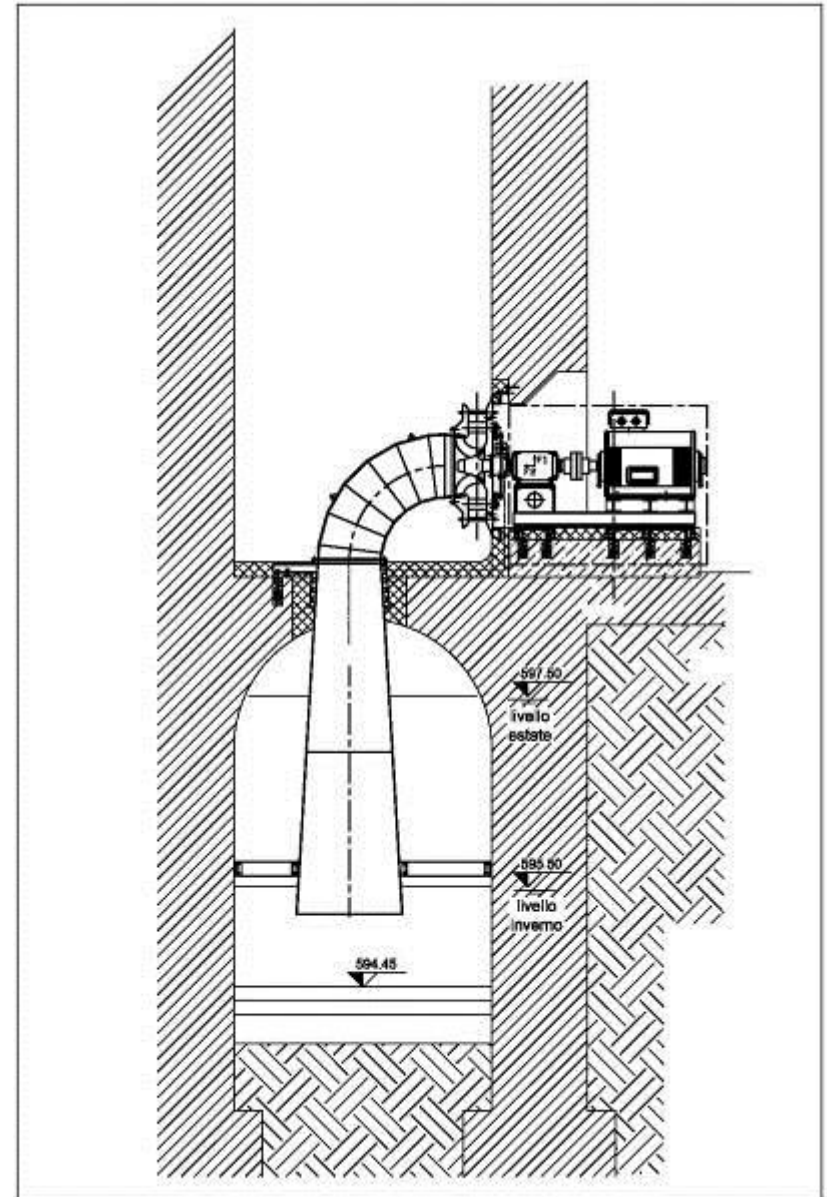


- $H_g = 15,0 \text{ m}$
- $Q_{\max} = 12 \text{ m}^3/\text{s}$



Units replacement: restoring initial efficiency $E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$

- $H_g = 10,0 \text{ m}$
- $Q_{\max} = 1,1 \text{ m}^3/\text{s}$



Units replacement: improving safety of operation



- $H_g = 10,5 \text{ m}$
- $Q_{\max} = 3 \times 4,3 \text{ m}^3/\text{s}$



$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

Hydraulic works replacement: improving safety of operation

$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$



Units replacement: improving safety of operation



$$E = \eta \cdot \gamma \cdot H \cdot Q \cdot T$$

FINAL REMARKS

Deep analysis of possible hydraulic improvement where often wide margins are available

Look for the solution with minimum risk of uncertainties even if it's not the theoretically best possible

Don't search for higher units efficiency at any cost

Overall optimisation (electromechanical AND hydraulic/civil) rather than exasperated solutions referred to one aspect only

1% less efficiency is quickly paid back by a safer and simple operation

Prefer solutions without civil works below downstream water level



THE END

