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STUDIES FOR NUCLEAR AND PUMPED-STORAGE POWERPLANT ŻARNOWIEC



GENERAL INFORMATION

- In the 70-ies in Poland there was the shortage of electric energy and peak power energy in particular
- Proposal for a pumped-storage and nuclear power plants at the location Żarnowiec, 1972
- Pumped-storage power-plant (PS) 716 MW (4 reversible units), use of the lake as lower reservoir, upper reservoir artificial
- Nuclear power-plant (NP) 4x440 MW_E (PWR), use of the lake as cooling water reservoir
- Advantage of this system – no losses for the transmission of electric energy from NP to PS
- 1973 beginning of comprehensive studies (lake and the region)
- 1976 beginning of the construction of PS, completion 1983
- 1982 beginning of the construction of NP, 1990 closure
- 2010 Proposal of NP in Żarnowiec

AIM AND THE SCOPE OF THE STUDIES

AIM OF THE STUDIES:

- provide necessary information for the design and future exploitation of PS and NP

SCOPE OF THE STUDIES

- Hydrologic, hydrodynamic, thermal and hydro-biological studies of the lake in natural conditions,
- Meteorological conditions in the region of the lake
- Catchment of the lake
- Thermal regime of the lake under the influence of heated water discharge
- Water balance of the lake under the influence of heated water discharge and operation of PS
- Hazard to NP and possible consequences in case of damage of the upper reservoir of PS

PUMPED-STORAGE POWER-PLANT



- Upper reservoir: artificial, surface area 135 ha, total capacity 15.9 mln. m³, operational capacity 13.8 mln. m³, water level variation 16 m
- 4 penstocks: length 1100 m, diameter 7.10 to 5.40 m, discharge 700 m³/s
- PS: 4 reversible Francis units, 716 MW, max.head 125 m
- Outflow channel: length 835 m, max. Depth 13 m, bottom width 100 m, flow velocity 1m/s
- Lower reservoir: Lake Żarnowiec, daily water level variation 1 m

LAKE ŻARNOWIEC

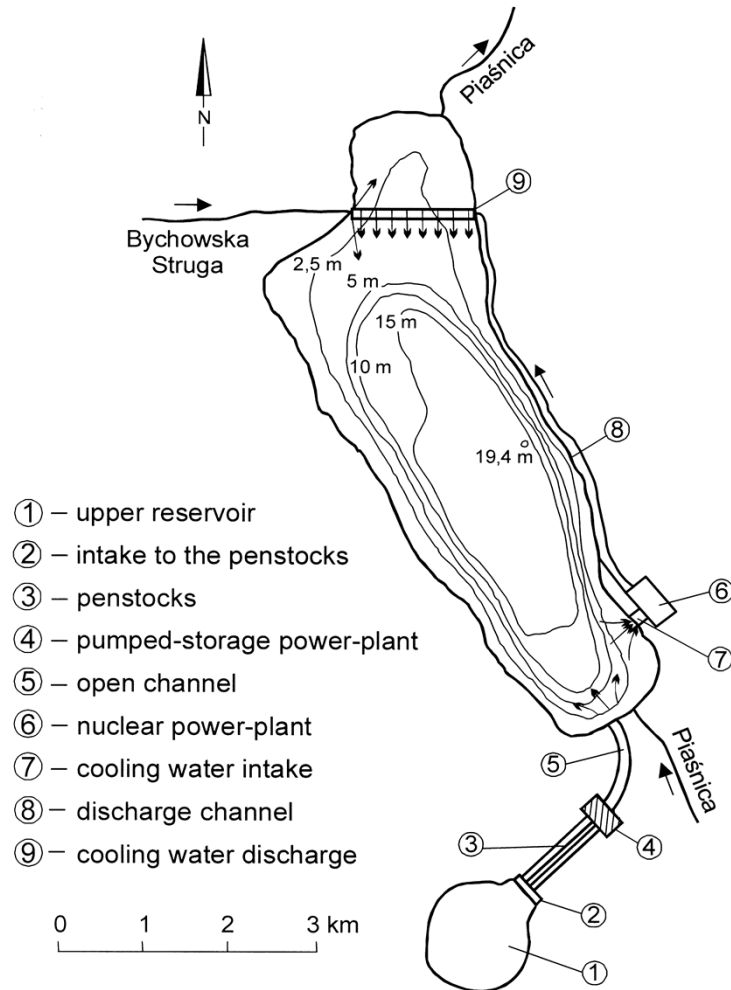


- good fishery state
- good water quality
- use for recreation

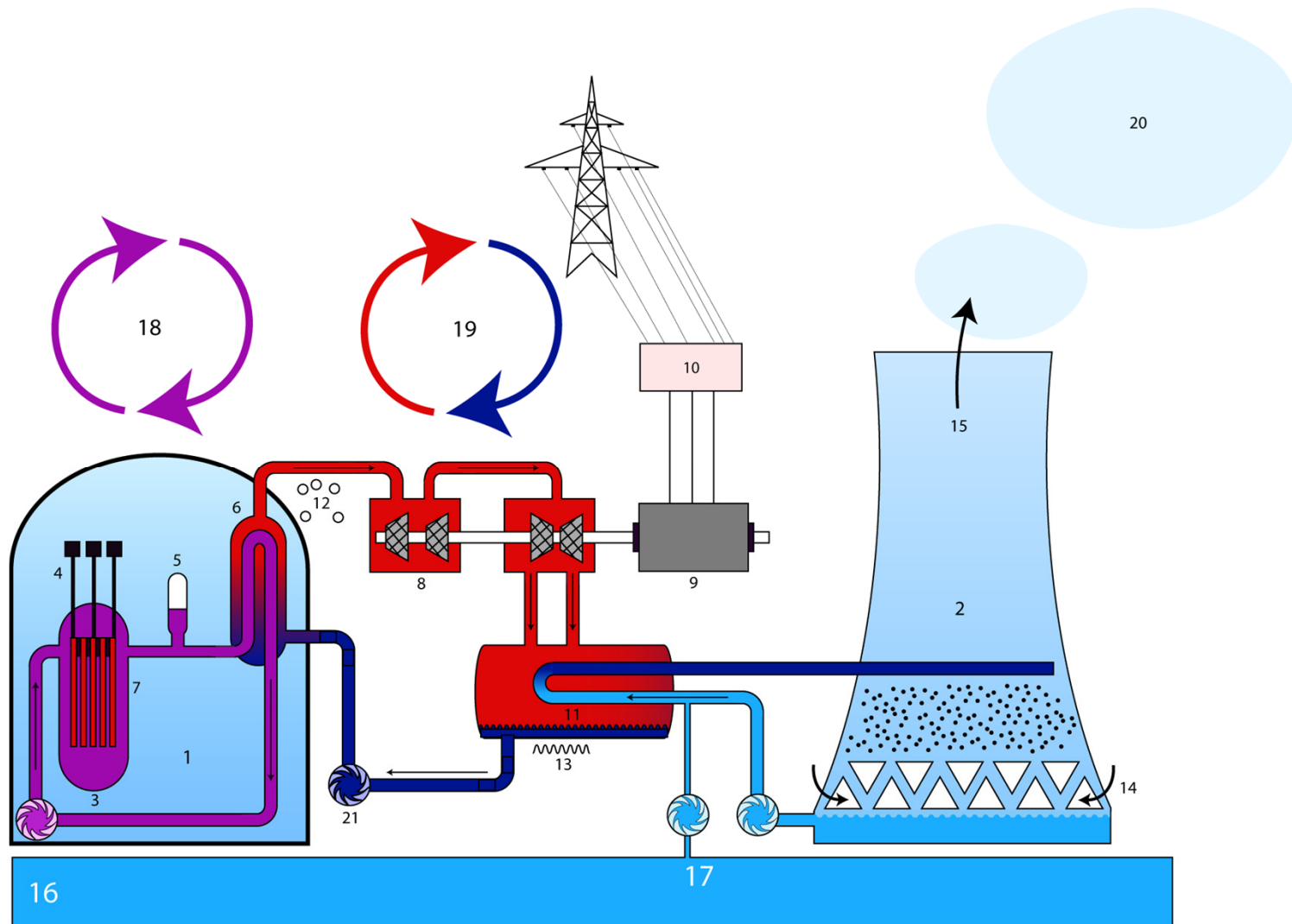
- glacial origin
- Catchment – Piaśnica River
- Surface area – 1432 ha (1330 – 1520)
- Depth: maximum - 19.4 m, average - 8.4 m, water level 1.34 m asl
- Volume – 120 mln.m³ (113 – 127)
- Length – 7610 m
- Maximum width – 2600 m
- Water temperature: maximum 23 °C, average 8 – 9 °C
- Wave height (max.) – 1.5 m
- Wind speed (max.) – 20 m/s
- Surface inflow: 2 rivers, 1.6 m³/s
- Underground inflow – 0.6 m³/s
- Water abstraction for irrigation during vegetation season up to 2 m³/s
- In winter covered with ice (0.5 m)
- 1 natural outflow to the sea (5 km)

NUCLEAR POWER-PLANT

- 4 x 440 MW (PWR)
- Cooling water 90 m³/s, $\Delta T = 9.2$ °C



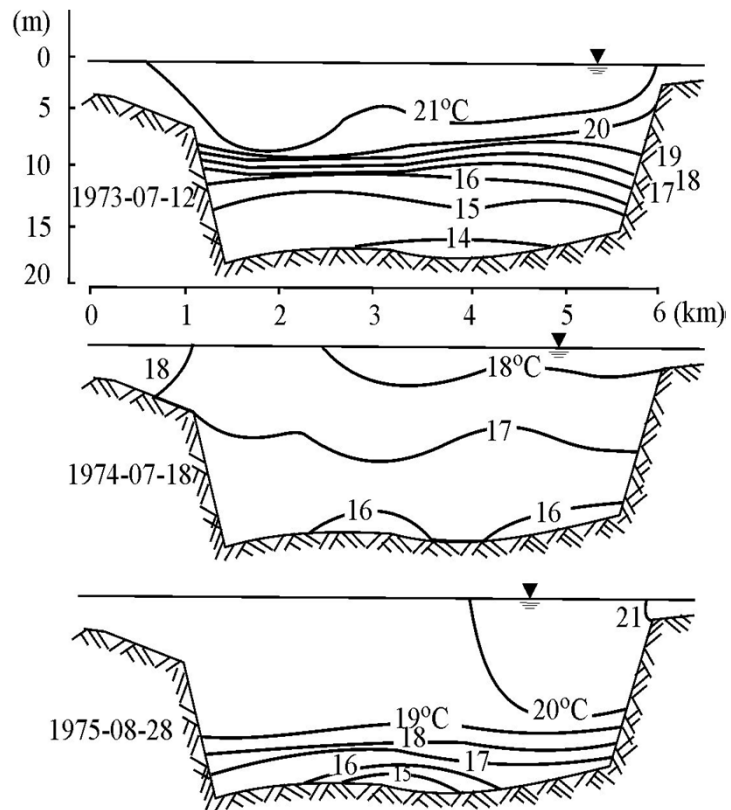
HOW NUCLEAR POWER PLANT WORKS



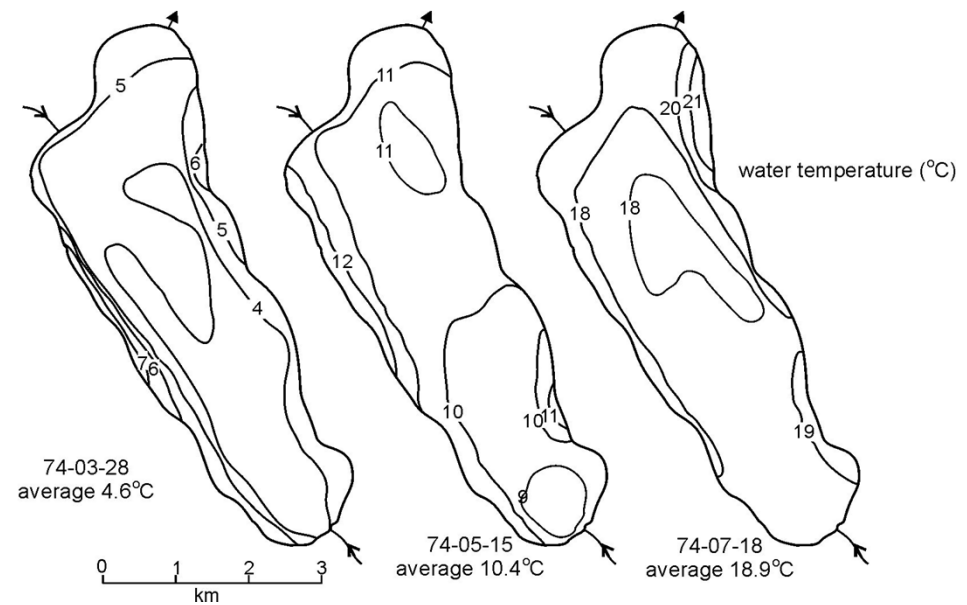
LAKE THERMAL REGIME

(natural conditions)

Longitudinal lake cross-section

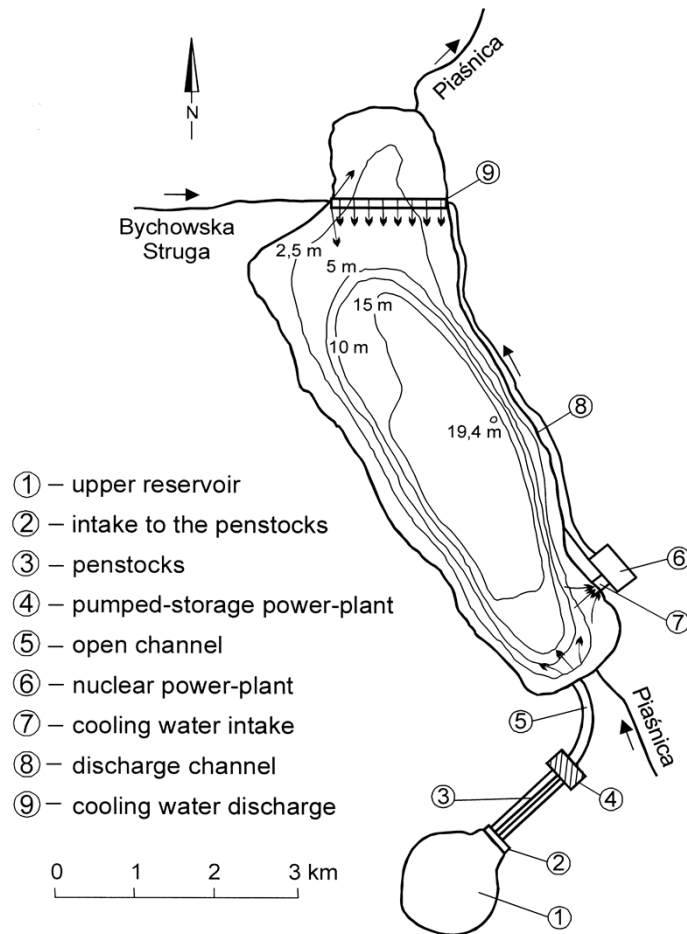


Lake surface temperatures



LAKE THERMAL REGIME

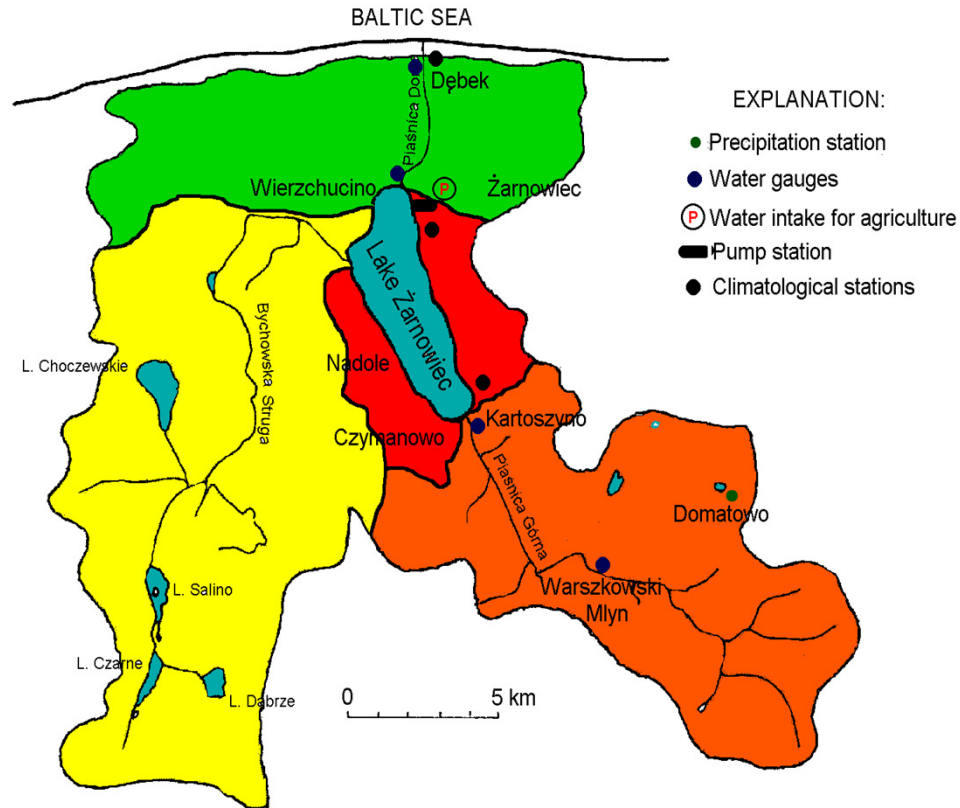
(heated water discharge)



- Hydrothermal model of the lake with water intake and discharge as well as discharge from PS to estimate flow pattern over lake surface
- Calculation of heat losses for various meteorological conditions
- Calculation of heat losses along discharge channel

WATER BALANCE

(Natural conditions)

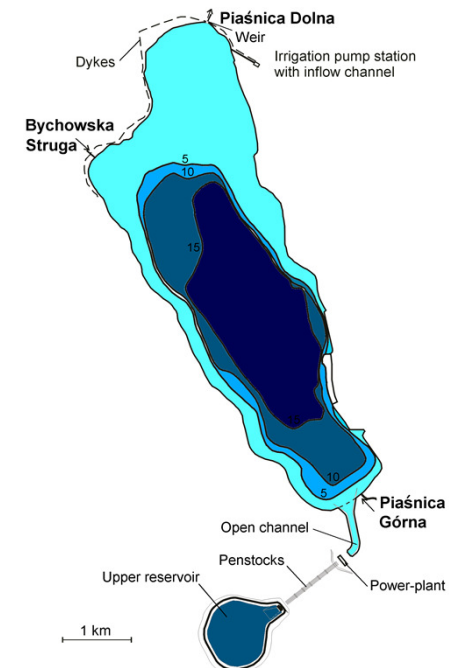


- Surface of Piaśnica catchment 310 km²
- Natural surface inflows
- Groundwater inflow
- Natural outflow to the sea
- Water levels in the lake
- Precipitation
- Evaporation
- Water abstraction for irrigation
- Land use: agriculture, forests, meadows, recreation, wasteland

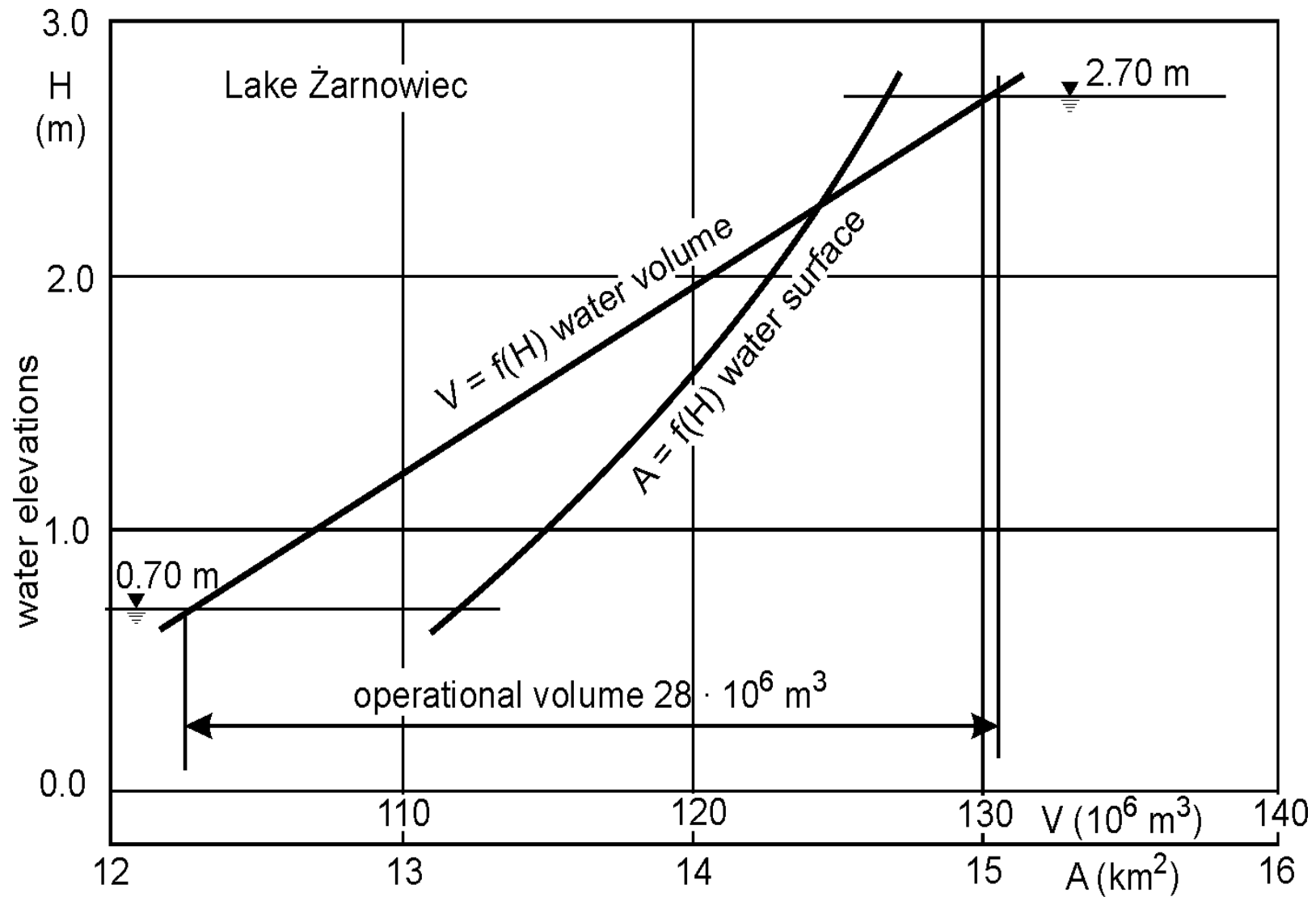
WATER BALANCE OF THE LAKE DURING THE OPERATION OF PS AND NP

DATA NECESSARY FOR CALCULATIONS

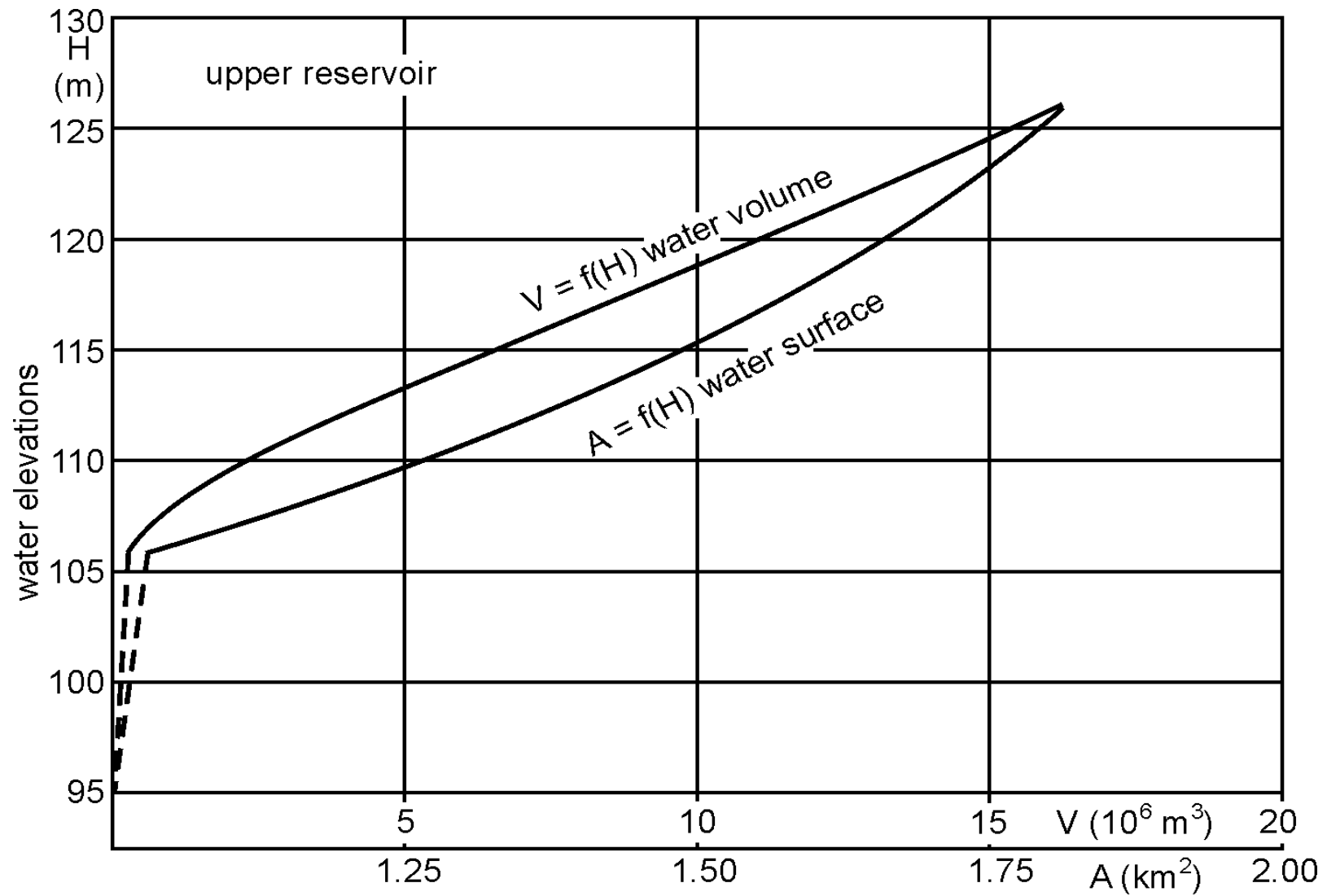
- Calculations for one year (1966) with time step of 1 h
- Water levels in the lake 2.70 to 0.70 m asl with control of the outflow to the Lower Piaśnica and irrigation
- Water surface area of the lake and the upper reservoir
- Surface inflow to the lake (average monthly values) $1.32 - 2.28 \text{ m}^3/\text{s}$
- Groundwater inflow $0.43 - 0.79 \text{ m}^3/\text{s}$
- Precipitation $0.63 - 2.32 \text{ mm/day}$
- Natural evaporation $0.32 - 3.84 \text{ mm/day}$
- Additional evaporation $5.59 - 7.31 \text{ mm/day}$
- Irrigation $2.58 - 0.44 \text{ m}^3/\text{s}$
(vegetation season May – September)
- Minimum biological outflow from the lake 0.40 m^3



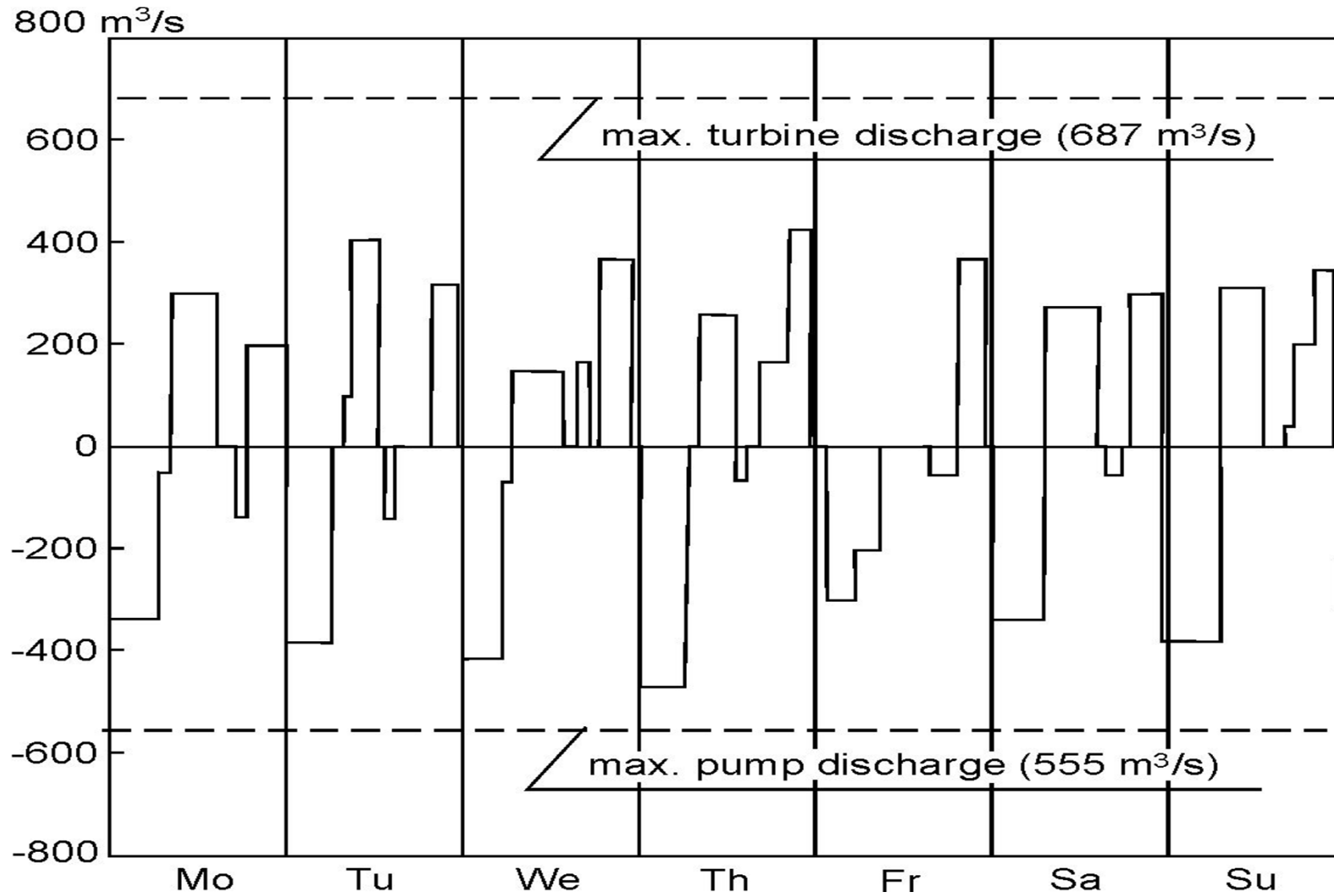
VOLUME AND SURFACE AREA OF THE LAKE ŻARNOWIEC



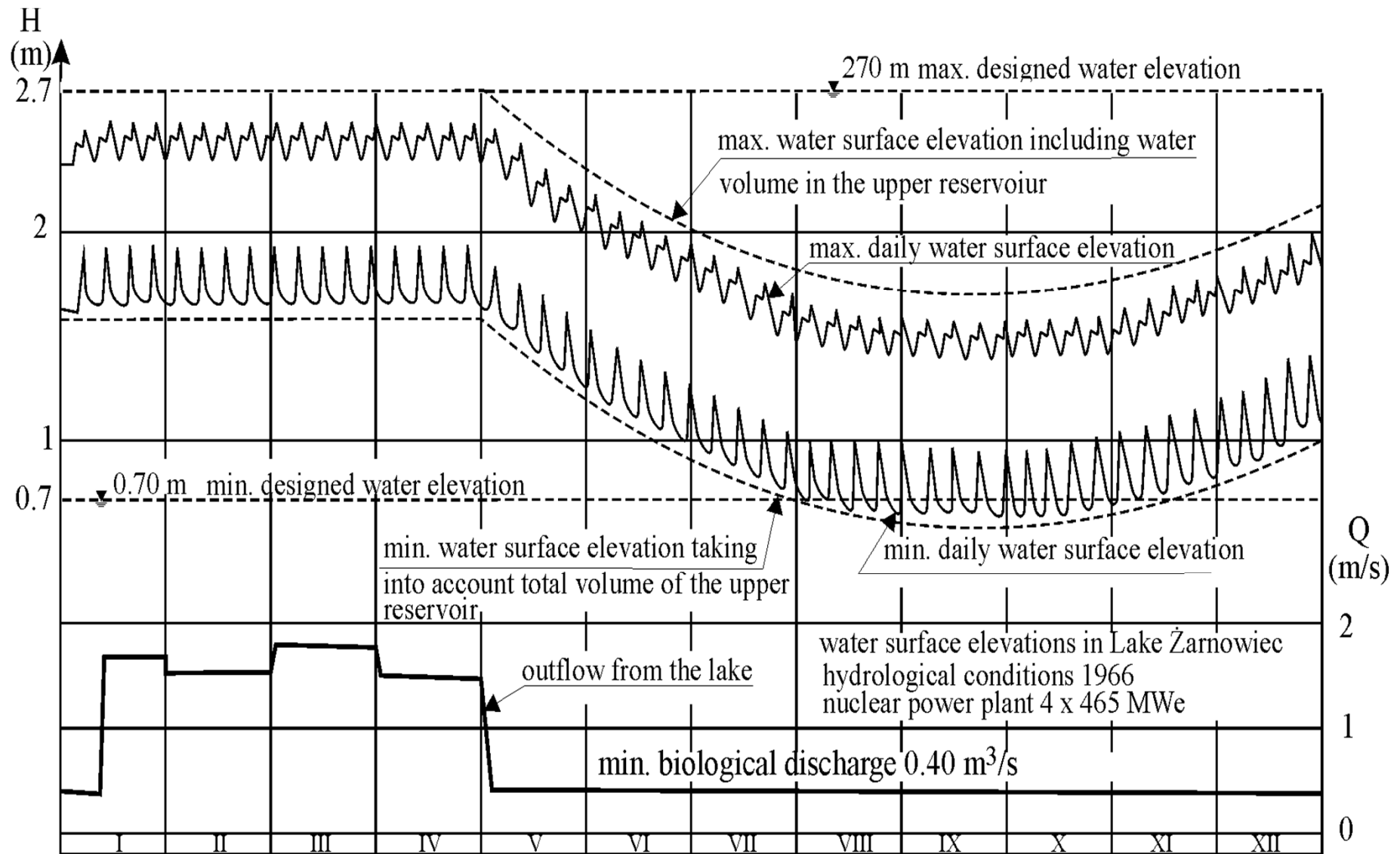
VOLUME AND SURFACE AREA IN UPPER RESERVOIR PS



OPERATION OF PS



RESULTS OF CALCULATIONS

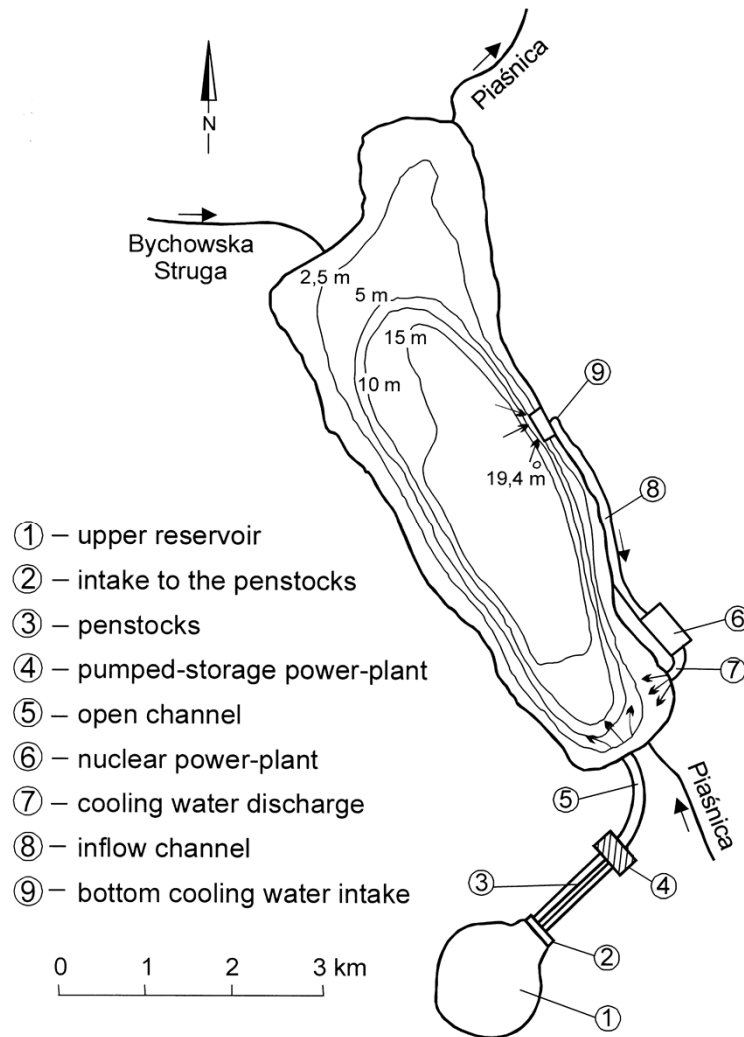


STUDY OF THE DAMAGE OF UPPER RESERVOIR PS



- 5 breach places were chosen in the deepest part of the reservoir
 - Place 1 and 2 appeared most dangerous for cooling water intake of NP.
 - Place 3 causes the damage of PS
 - Places 4 and 5 caused damage to the switchyard
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- Hydraulic model in scale 1:250 without scale distortion was prepared in hydraulic laboratory of HYDROPROJEKT Włocławek
 - Velocity of the wave on the slopes ranged from 14 to 20 m/s
 - Thickness of the wave front reaching the lake was 1.4 – 2.0 m
 - Wave height on the lake was 1.0 – 2.0 m
 - Dangerous phenomenon was density current on the lake

CHANGES IN NP COOLING SYSTEM AS THE RESULT OF HYDRAULIC MODEL STUDY



- Change of cooling system was necessary
- Water intake was moved to the deepest part of the lake
- The area of switchyard was raised higher about 1.0 m
- PS is still endangered in case of breach of upper reservoir
- Density cuurent moving along the lake and transporting large amount of sediment may be still dangerous to water intake

CONCLUDING REMARKS

- Studies and the design for both powerplants may be regarded as sufficient and represent good standard
- There were several additional actions for the future of nuclear energy in Poland (special meteorological station, inventory of vegetation around the place of NP)
- Execution of all constructions represented the highest standard and majority of all equipment would be produced in Poland
- Decision about closing of the construction of NP. was in agreement with social expectations, however, government did not try to persuade people that NP is necessary
- From technical, economical and future of nuclear energy in Poland it was wrong decision
- Continuation of the construction with at least one reactor would give us rich experience and would not cause such enormous economic loss

- ŻAROWIEC IS THE NAME OF SETELMENT, LAKE AND BOTH POWERPLANTS. WHERE IT COMES FROM ?
- IT IS THE NAME OF A BUSH GROWING IN THIS REGION WITH BEAUTIFUL YELLOW FLOWERS



Thank you for your attention

