



Themes # 2 Monitoring of Dams

Technical Monitoring of the HPP “Piva” Dam

Author Name
Energoprojekt-Hidroinzenjering J.S.C.
Serbia



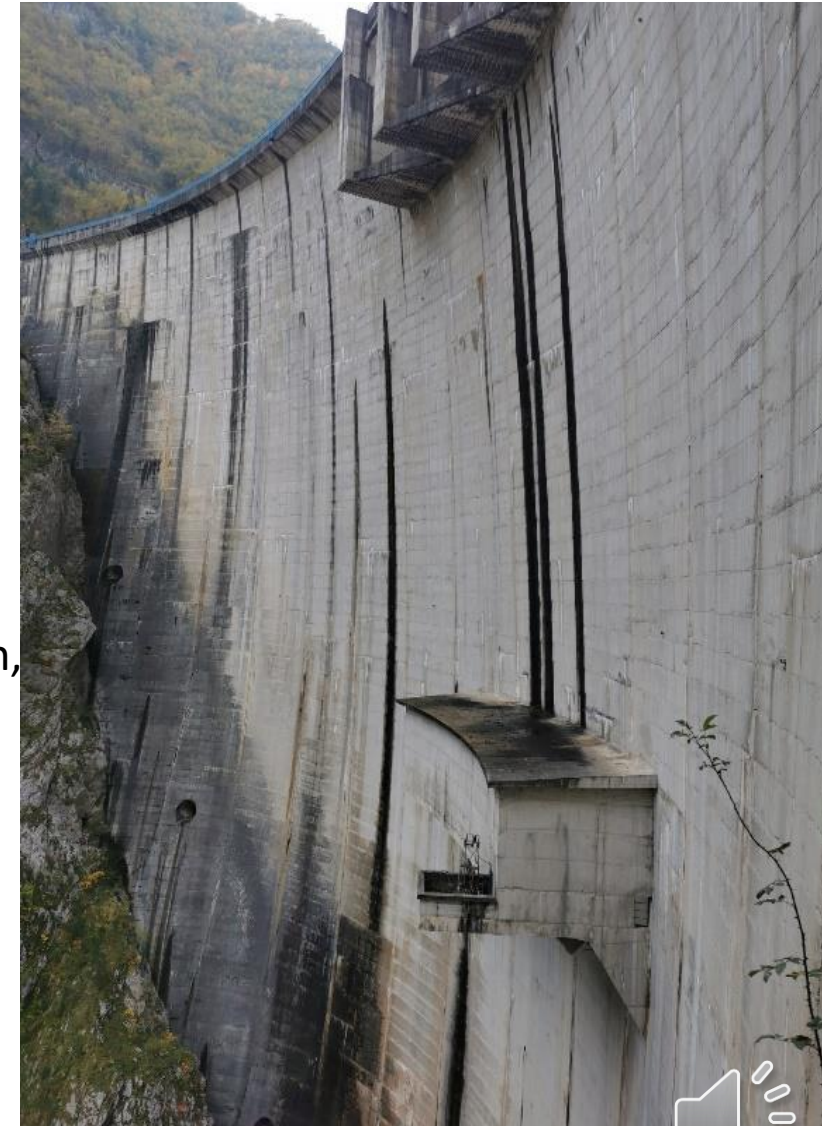
HPP "Piva", reservoir run-of-the-river plant, with one of the largest concrete arch dam in the world, has been in operation since 1976. Its basic operation is production of electricity. All structures of the hydropower plant are: supply pipelines, machine hall, tailrace tunnel, transformer hall, and switchgear are underground, and placed in the left abutment next to the dam. The designer of the dam is "Energoprojekt Hidroinženjering".





Basic technical characteristics of the HPP “Piva“ are:

- Installed capacity - 342 MW,
- Concrete arch dam of 220 m structural height, hydraulic height 190 m, arch length at the crest 268.6 m, and arch length at the chute level 40 m,
- Total storage capacity - $824 \times 10^3 \times 10^3 \text{ m}^3$,
- Active storage capacity - $746 \times 10^3 \times 10^3 \text{ m}^3$,
- Designed annual electric power generation - 860 GWh,
- Energy value of the reservoir 275 GWh,
- Three spiral turbines with vertical axis (250 o/min) "Francis" type,
- Three three-phase generators with vertical axis (250 o/min) of 120 MVA each,
- Three three-phase transformers (15,75/220 kV) of 120 MVA each,
- Normal water level elevation – 675.25 meters above sea level,
- Elevation of minimum operational level – 595.0 meters above sea level,
- Installed flow capacity - $3 \times 80 \text{ m}^3/\text{s}$.
- Catchment area of the HPP "Piva" is 1.760 km^2 .





The HPP Piva structure, with its size and significance, requires a high degree of maintenance and continuous monitoring of the structure condition, reservoir, and all accompanying parts that constitute the system, and ensure its functionality and stability. Guided by the fact that, due to potential damage of some part of the structure, its functionality would be endangered, and in case of potential collapse of the structure or its part, human lives in the area downstream of the dam would be endangered, a complex system of technical monitoring of the dam was designed and executed. By arrangement of instruments, selection of physical quantities to be measured, and the measurement programme, a database is obtained on the basis of which it is possible to assess the condition of the structure, and act in a timely manner in case of some damage, so as not to further propagate them.

For the requirements of measuring and monitoring, a total of 108 mechanical and 1005 electrical instruments were installed.

Over time, the majority of electrical instruments stopped working, due to various damage of the equipment and cables. Precisely for this reason, and keeping in mind the importance of the structure, Energoprojekt Hidroinženjering has prepared the Design “Rehabilitation and Modernization of the System for Technical Monitoring”.

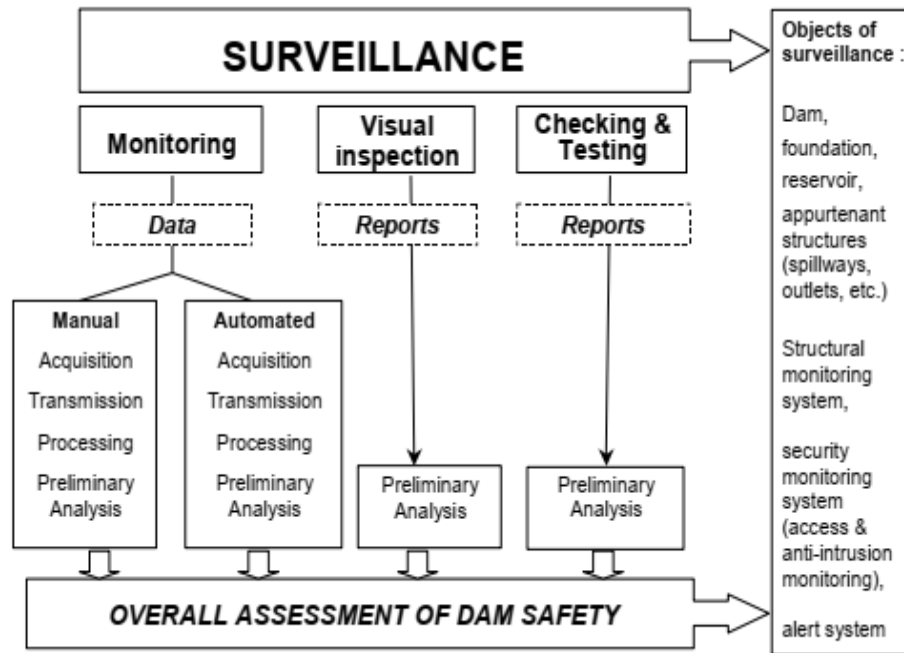
For the purpose of monitoring of the HPP Piva dam, a Study of the limit values of relevant and characteristic physical quantities was prepared, which helps in quick assessment of the obtained results, thus obtaining data on the areas that need to be analysed in more detail.





Concept of monitoring

The following figure explains the extend of the definition of the concept of monitoring used in this project:



2. Monitoring – data – automated:

- Hydrological measurements;
- Meteorological measurements;
- Measurements of relative movements with pendulums;
- Measurements of dilatations in radial joints in the dam body;
- Measurements of rotation in vertical plane;
- Measurements of strains in the rock in dam abutments;
- Measurements of local strains / stresses in concrete;
- Measurements of seepage water quantities;
- Measurements of pore pressures in dam foundations;
- Hydrogeological measurements;
- Seismic observations;

3. Monitoring – data – manual/automated:

- Hydrological measurements;
- Measurements of relative movements with pendulums;
- Measurements of dilatations in radial joints in the dam body;
- Measurements of rotation in vertical plane;
- Measurements of strains in the rock in dam abutments;
- Measurements of seepage water quantities;
- Measurements of pore pressures in dam foundations;
- Hydrogeological measurements

4. Visual inspection

Modernized technical monitoring system in HPP Piva involves the following measurements and observations:

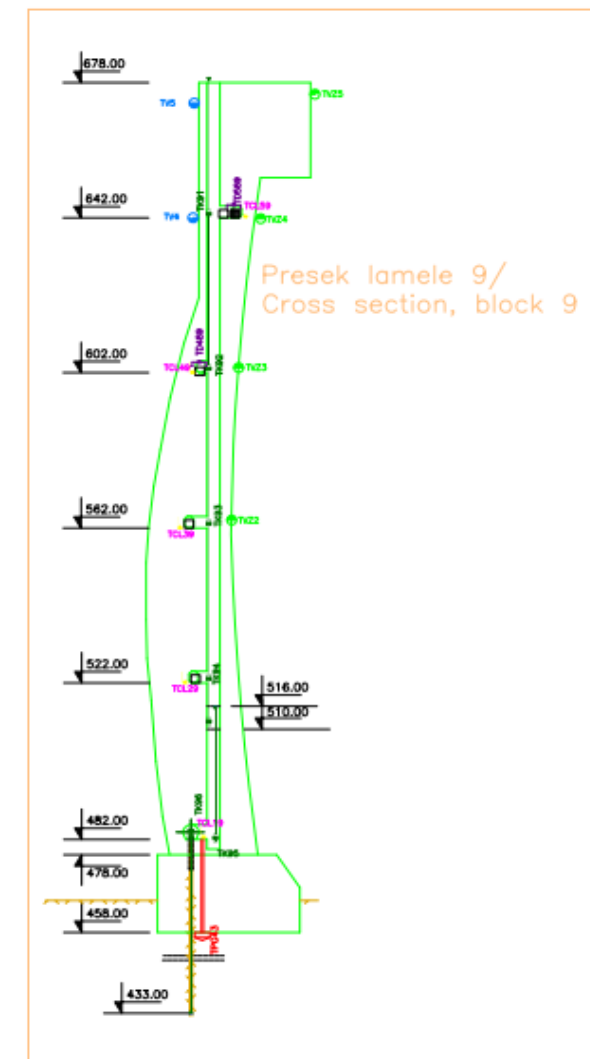
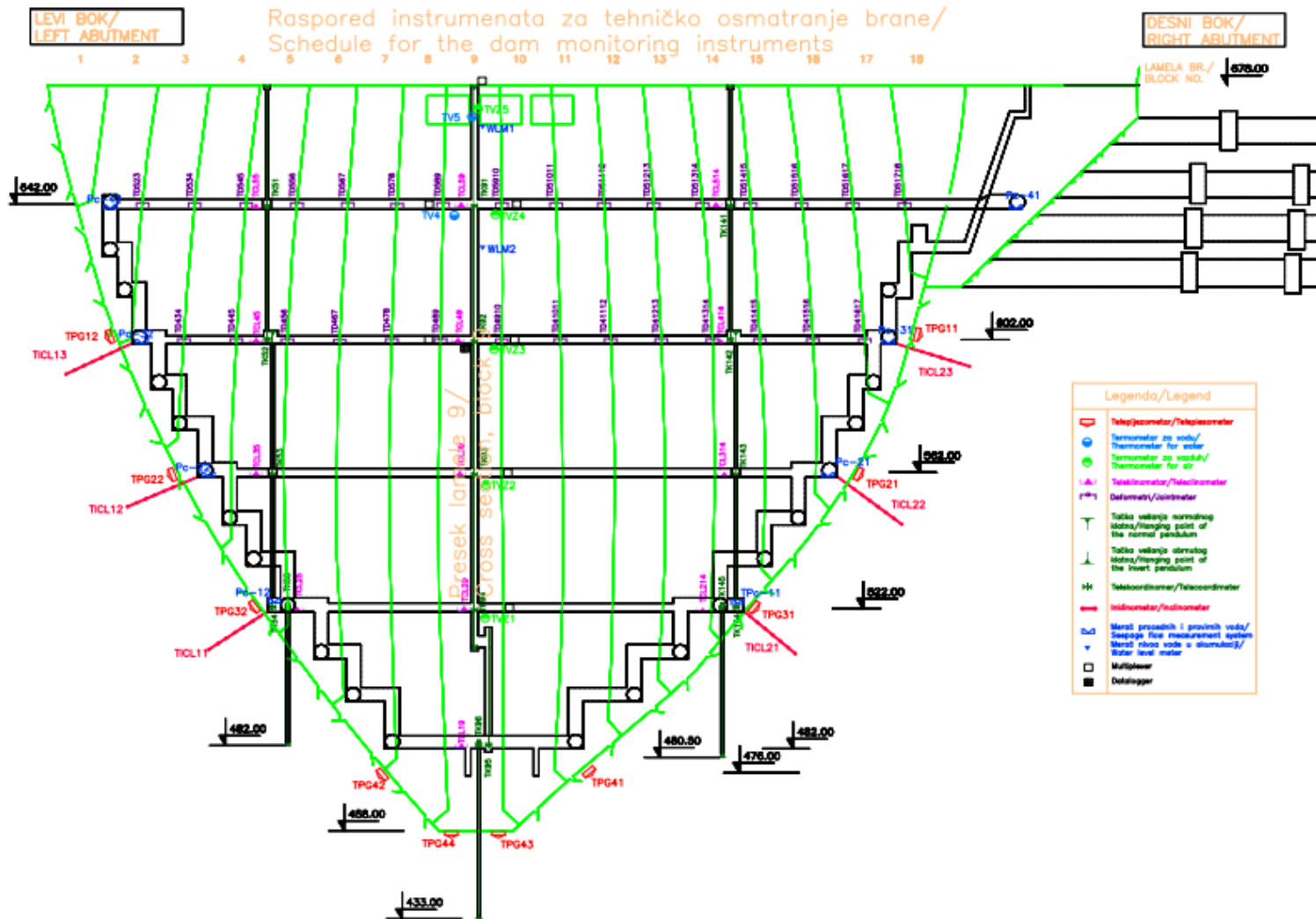
1. Monitoring – data – manual:

- Geodetic measurements





Schedule for the dam monitoring instruments





Measurements and data storage

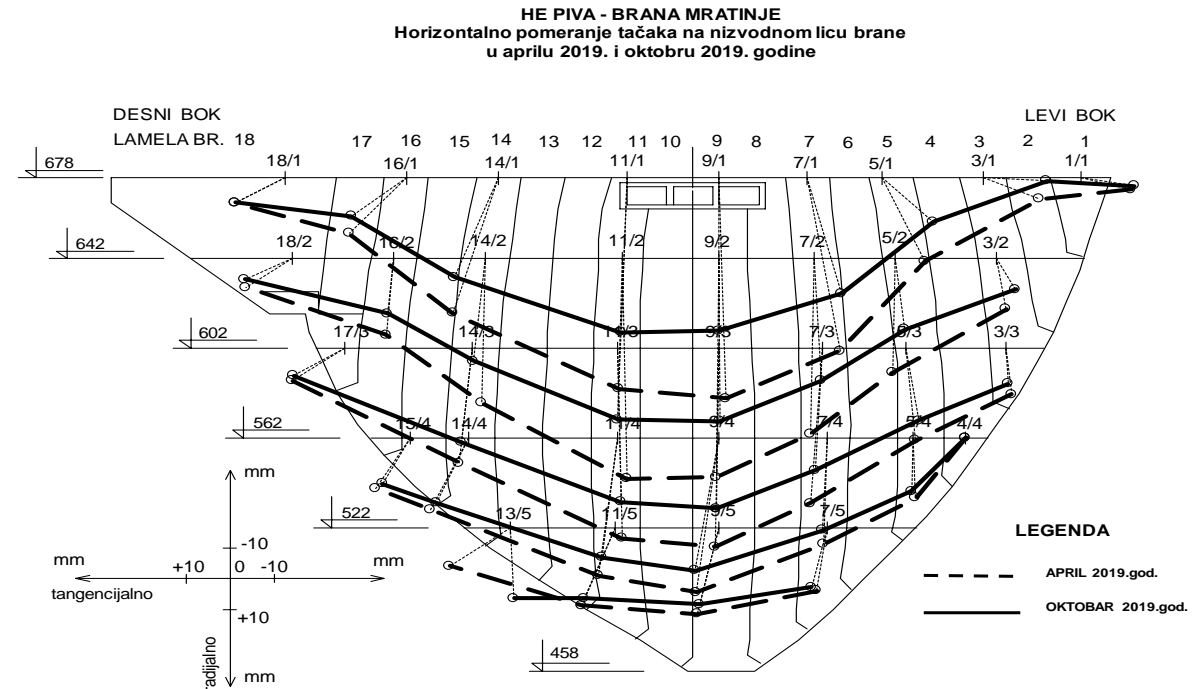
The automatically collected data is stored on a central server.

Geodetic measurements, as a part of technical monitoring, have been performed manually and continuously since the Zero surveying in 1975, and 91 control measurements have been conducted so far.

Horizontal displacements are determined in relation to the monitoring points at the dam downstream face, arranged in five levels with elevations of 522.0 masl, 562.0 masl, 602.0 masl, 642.0 masl, 678.0 masl, which is a total of 34 points.

Vertical displacements are determined for points set on the dam crest. There are 40 points at the upstream, and 40 points at the downstream side of the dam crest being monitored.

Geodetic measurements are performed by modern geodetic instruments, of high accuracy and precision.



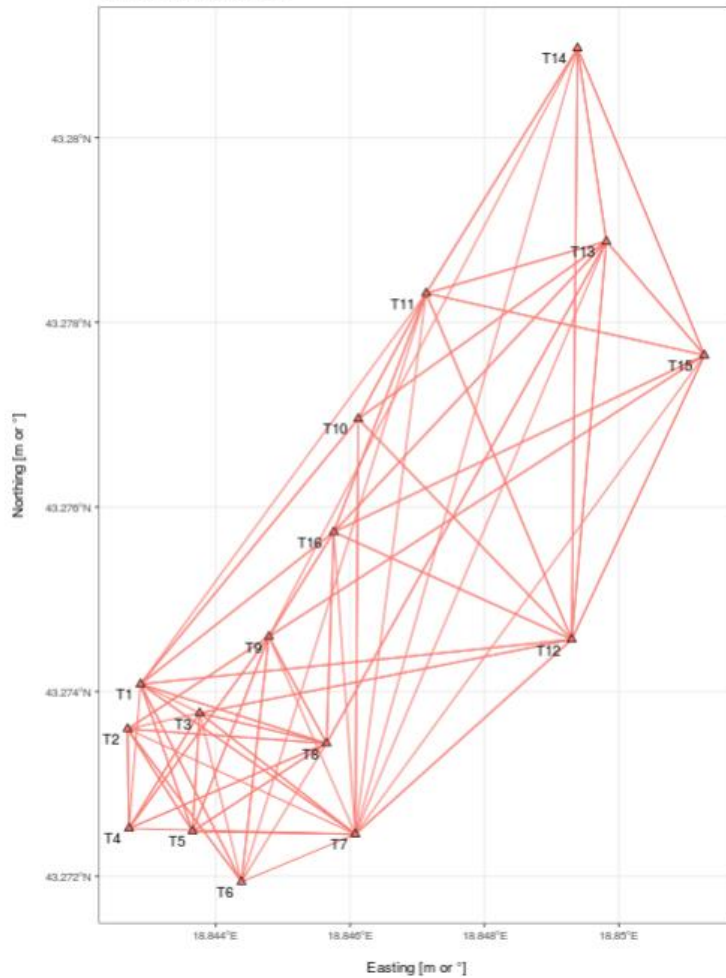


Processing of geodetic data

MAIN EDIT MAP POINTS OBSERVATIONS MAP

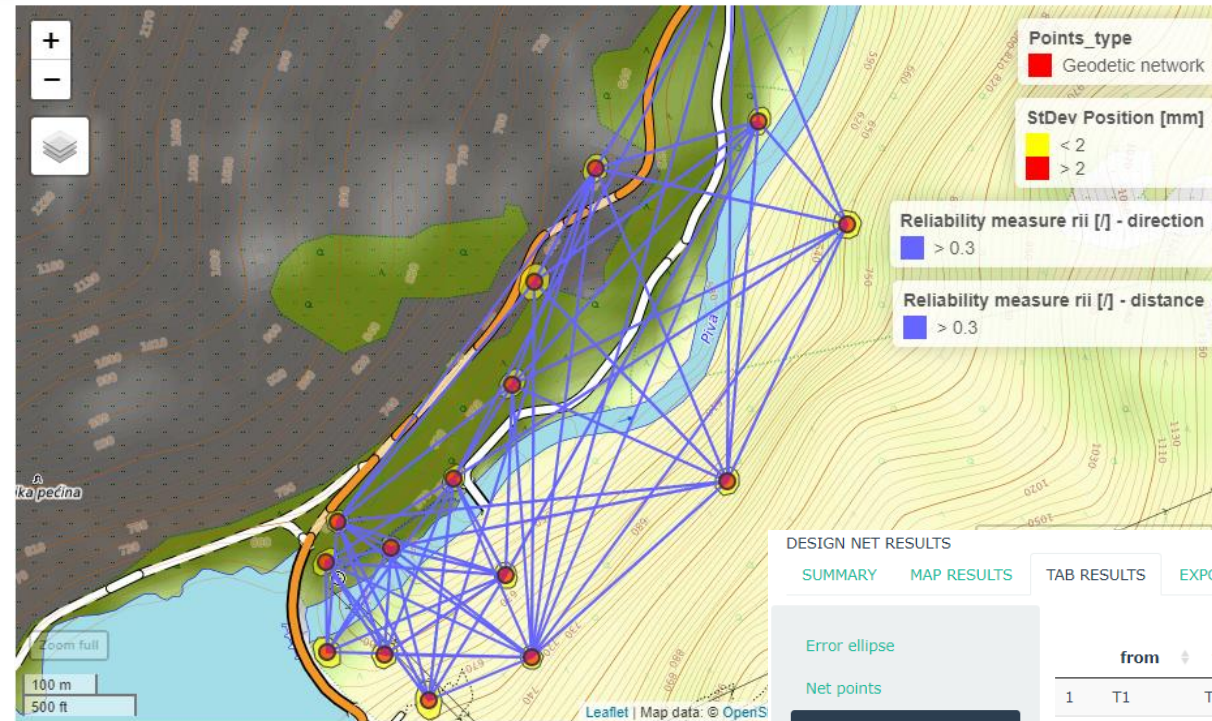
WEB MAP PLOT

GEODETIC 2D NETWORK
Points and Observational plan



DESIGN NET RESULTS

SUMMARY MAP RESULTS TAB RESULTS EXPORT RESULTS



DESIGN NET RESULTS

SUMMARY MAP RESULTS TAB RESULTS EXPORT RESULTS

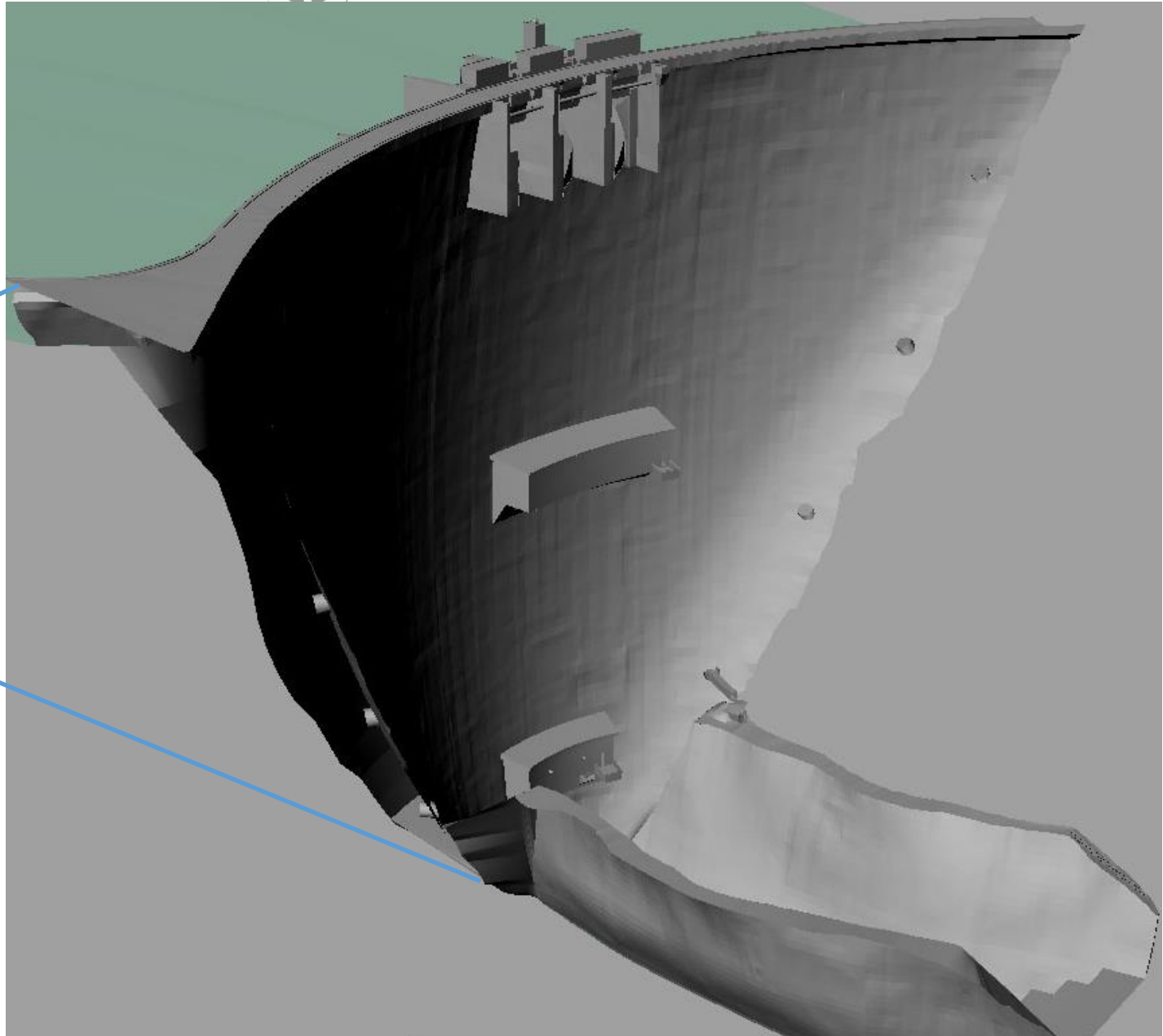
- Error ellipse
- Net points
- Observations
- Plot error ellipses

Search:

	from	to	type	KI	Kv	rii
1	T1	T4	direction	2.3	6.7	0.74
2	T1	T5	direction	1.79	7.21	0.8
3	T1	T6	direction	1.66	7.34	0.82
4	T1	T7	direction	1.19	7.81	0.87
5	T1	T8	direction	1.39	7.61	0.85
6	T1	T10	direction	1.43	7.57	0.84
7	T1	T11	direction	1.31	7.69	0.85
8	T1	T12	direction	1.18	7.82	0.87
9	T1	T16	direction	1.48	7.52	0.84
10	T2	T4	direction	3.56	5.44	0.6



3D model of the HPP
“PIVA” dam obtained by
terrestrial laser scanning





Aside HPP“Piva“ dam, Energoprojekt Hidroinženjering currently performs annual geodetic monitoring of over 20 dams in Serbia and Montenegro. We have conducted geodetic monitoring of over 50 dams in the country and the world, in the previous 70 years.