Behaviour of the embankment dam

Suggested theme for the 16th ICOLD BW

Pavel Žvanut, Slovenian National Building and Civil Engineering Institute
Barbara Likar, Slovenian National Building and Civil Engineering Institute
Žiga Likar, Geoportal d.o.o.
Vanja Selan, Elea iC d.o.o.
Mateja Klun, University of Ljubljana, Faculty of Civil and Geodetic Engineering

Introduction

- Embankment dam is the most common dam type in the world, since they represent over 60% of all constructed dams worldwide.

- Seepage control plays an important role in embankment dam safety.

- The most common causes of embankment dam failures are associated with internal erosion.

Theme: The embankment dam

- The theme is devoted to the analysis of a zoned embankment dam in Slovenia.

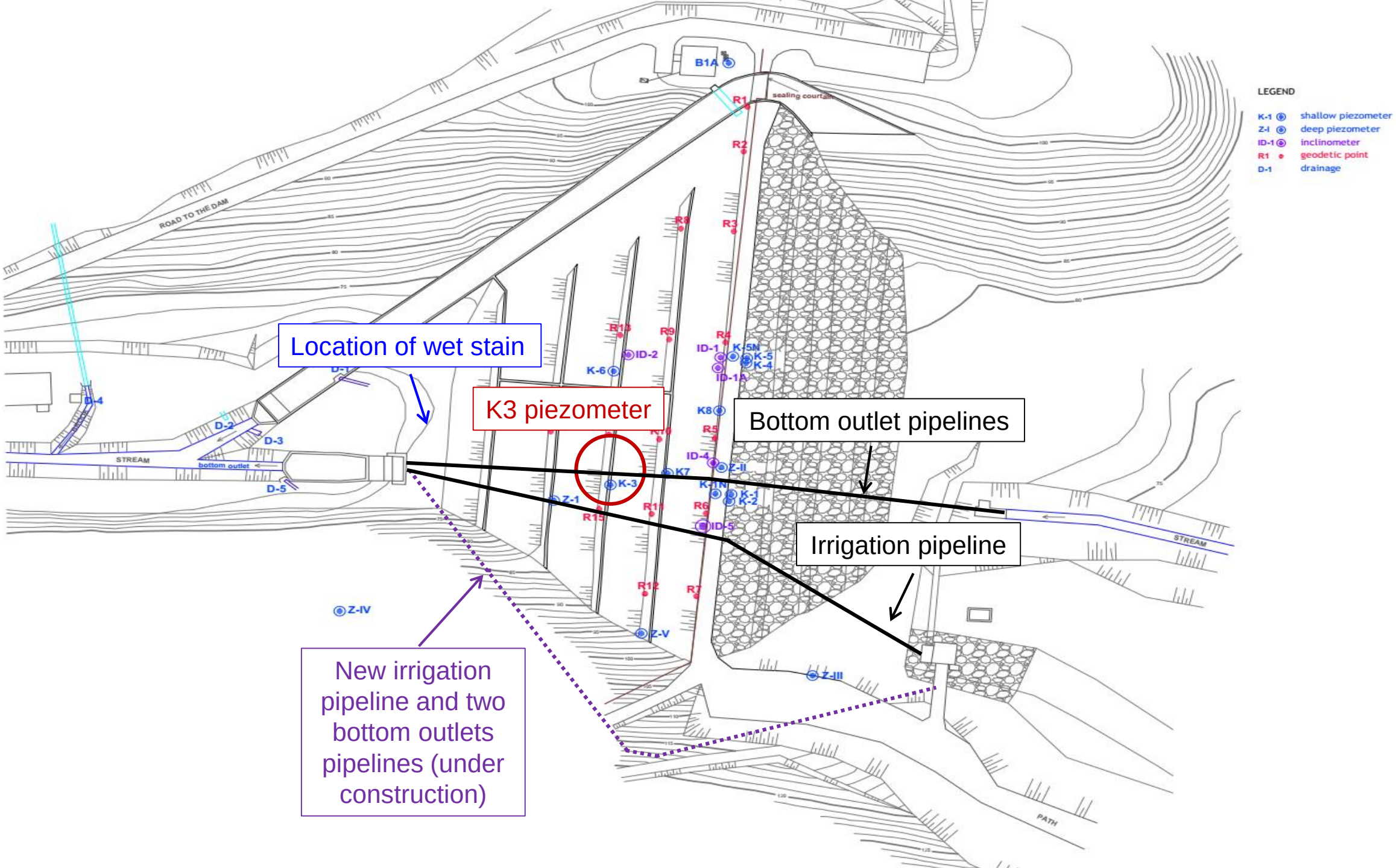
- The dam is regularly monitored:
  - Geodetic measurements (vertical and horizontal displacements);
  - Vertical inclinations (4 inclinometers);
  - Water level, temperature and specific electrical conductivity (piezometers);
  - Drainage outflow, chemical analysis of water;
  - Water level in reservoir, ground accelerations, meteorological parameters;
  - Geological inspection.

Basic information on the dam

- Zoned embankment dam with a clay core.
- 35 m high, crest length 177 m.

The story of the dam

- The dam is over 30 years old.
- In 2007 during regular maintenance a wet stain was spotted. Moreover, one of the piezometer indicated rising levels of water in the dam body.
- The reservoir level was depleted from 98.8 m a.s.l. to 92 m a.s.l.
- There are three conduits passing through the body of the dam, irrigation pipeline and two bottom outlets. The origin of leakage was recognised to be the irrigation pipeline crossing the dam body. The irrigation pipeline was later filled with concrete.
- The reservoir has been drawdown for over 10 years, and after the remedial works, the owner expects to raise the reservoir level back to the nominal level.

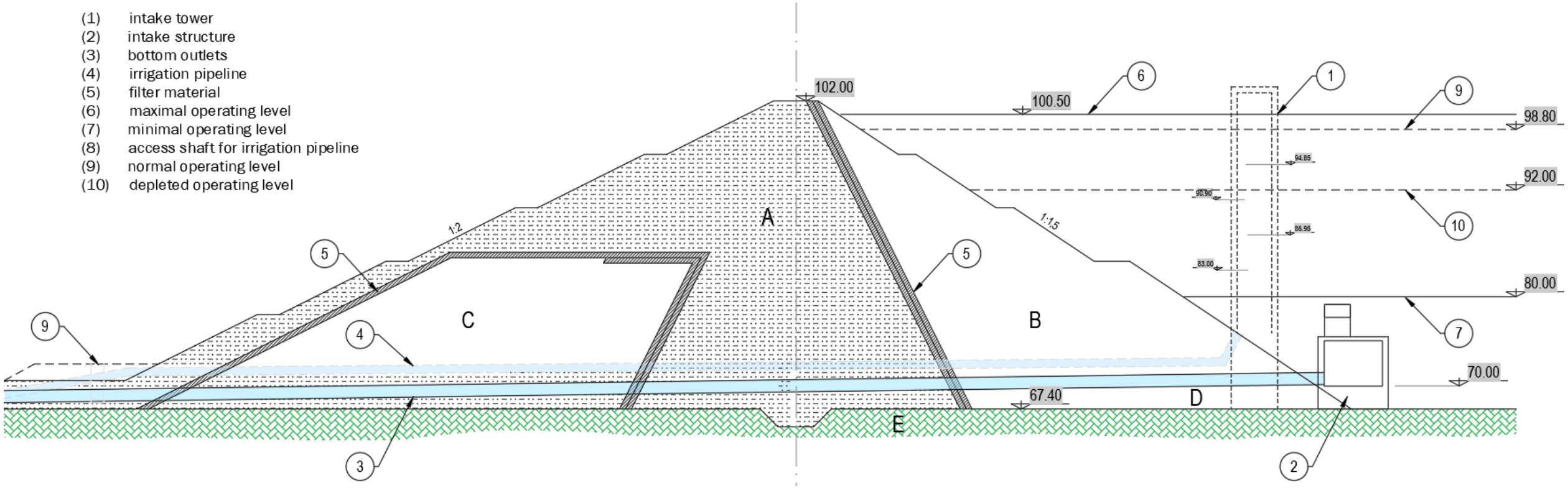

Location of wet stain
K3 piezometer
Bottom outlet pipelines
Irrigation pipeline
New irrigation pipeline and two bottom outlets pipelines (under construction)
LEGEND
K-1 shallow piezometer
Z-I deep piezometer
ID-1 inclinometer
R1 geodetic point
D-1 drainage
ROAD TO THE DAM
STREAM
bottom outlet
sealing courtain
PATH
B1A
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R15
ID-1
ID-1A
ID-2
ID-4
ID-5
K-1
K-2
K-3
K-4
K-5
K-5N
K-6
K7
K8
K-1N
Z-I
Z-II
Z-III
Z-IV
Z-V
D-1
D-2
D-3
D-4
D-5

Cross-section of the dam

LEGEND

(A) clayey silt material
(B) rockfill material
(C) tailing and clayey silt material
(D) clay material
(E) Impermeable rock base

(1) intake tower
(2) intake structure
(3) bottom outlets
(4) irrigation pipeline
(5) filter material
(6) maximal operating level
(7) minimal operating level
(8) access shaft for irrigation pipeline
(9) normal operating level
(10) depleted operating level



Theme formulation

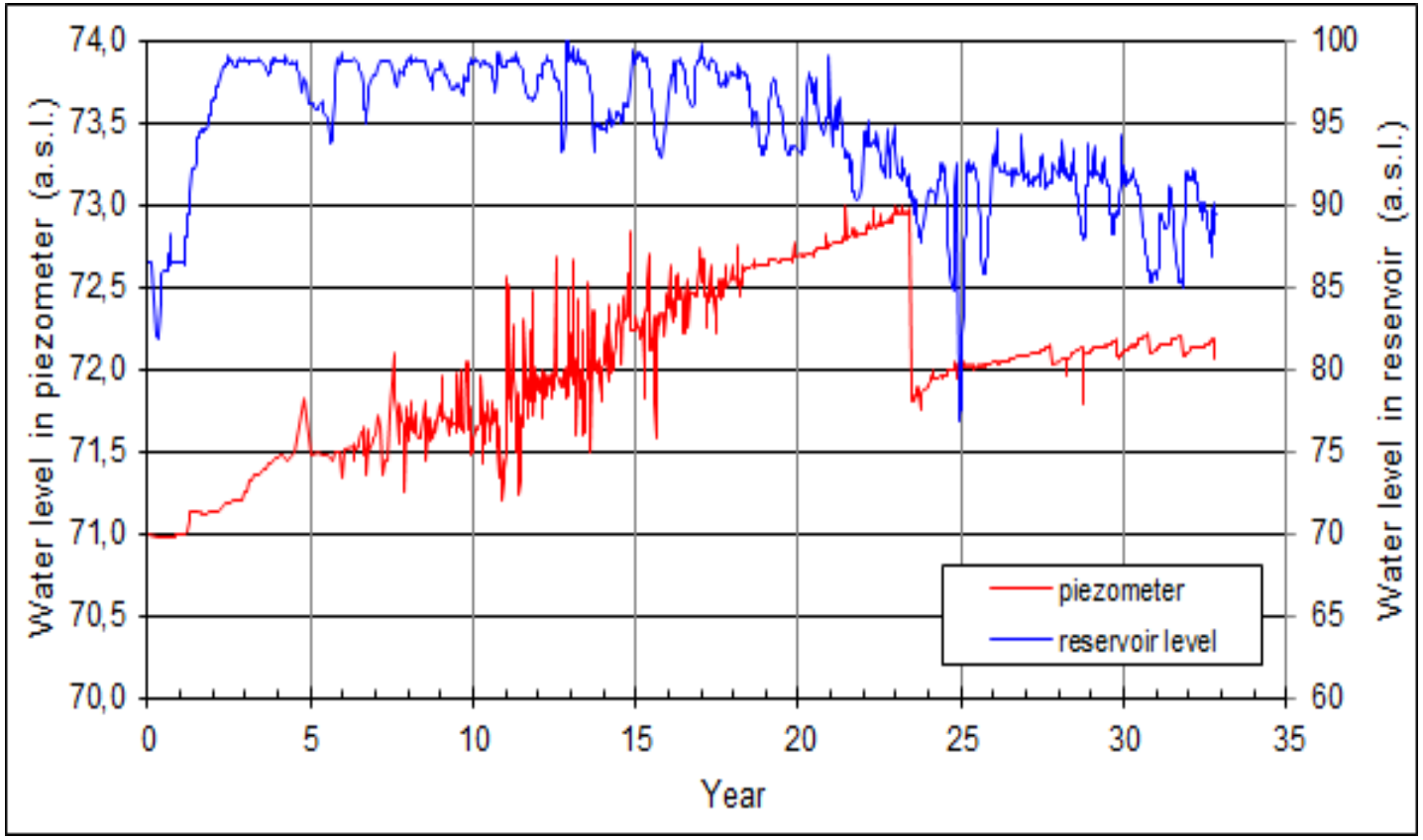
- Contributors will receive:
  - CAD geometry model;
  - Measured monitoring data since construction;
  - Design material properties for the dam and foundation.

- Participants will be asked to:
  - Built a 2D and a simplified 3D models of the dam (full 3D optional);
  - Consider monitoring data;
  - Perform mandatory and optional tasks.

Monitoring data

Example of the piezometer measurements

- Rising water level in piezometer K3 was observed after 6 years of operation.



Tasks

Case	Tasks
Case 1 (Mandatory, Optional)	**Task 1:** Construction of a 2D model. Calibrate the model using dam surveillance. Estimate the as-built characteristics of the dam. **Task 2:** Evaluate the initial state after the reservoir is filled to the nominal level. Estimate the dam condition before the detection of leakage. **Task 3 (Optional):** Using calibrated data of 2D model, build a quasi 3D FE model (20 m wide section of the dam).
Case 2 (Mandatory, Optional)	**Task 1:** Consider the wet stain using 2D or quasi 3D model. **Task 2:** No action after the appearance of the wet stain.
Case 3 (Mandatory)	**Task 1:** Consider remedial works of the dam, consider long period of reservoir draw-down and its effect of the clay core. **Task 2:** Consider elevation of the reservoir back to nominal level according to the assumed filling times. Evaluate the safety of the dam under the final water level condition of the reservoir.
Case 4 (Optional)	**Task 1:** Seismic analysis.
Finalisation (Mandatory)	**Task 1:** Preparation of the technical paper. **Task 2:** Preparation of the presentation and presentation at the workshop.

*** as an optional case the participants can build a full 3D model and perform the required analysis.**

Outcomes and conclusions

- We expect that the results of this theme will improve our understanding of the dam behaviour, especially water seepage through the dam body and show the applicability of theoretical methods and models compared to the real response of a dam.
- The ageing dams will encounter various conditions in their life-time including longer periods of low-reservoir levels.
- Seepage is a complex phenomenon affected by various parameters; studies have shown that with careful evaluation of monitoring data, accidents and failures can be prevented.
- FEM provides a strong tool in hands of a qualified engineer, while such a complex phenomenon as seepage in an embankment dam can be studied using different modeling assumptions. BW provides a unique opportunity for dam experts to discuss various modelling approaches and assess their formulation on the final results.
- The formulators will provide templates for the participants to submit their results.
- The participants will be asked to describe their modelling approaches in detail. Based on comparison of various approaches, results and monitoring data, we will be able to improve our understanding of the seepage phenomena in embankment dams.

You are kindly invited to participate.

See you in Ljubljana in 2022.

Express your interest in the topic and get in touch with the formulating team.