Dam Monitoring and Decision Support System

The dam itself is a system consisting of technical objects and natural elements, although created by human activity. The interaction of both (technical and natural) elements includes challenges in monitoring, forecasting, decision support system, and warning. Usually, but not necessarily, the whole chain of responsibilities is in the hands of a single body that is responsible for monitoring, controlling, and decisions taken for the dam. Therefore, a strong decision support system is needed for dam safety and ideal operation. The Dam Monitoring and Decision Support System is part of the MicroStep-MIS product portfolio.

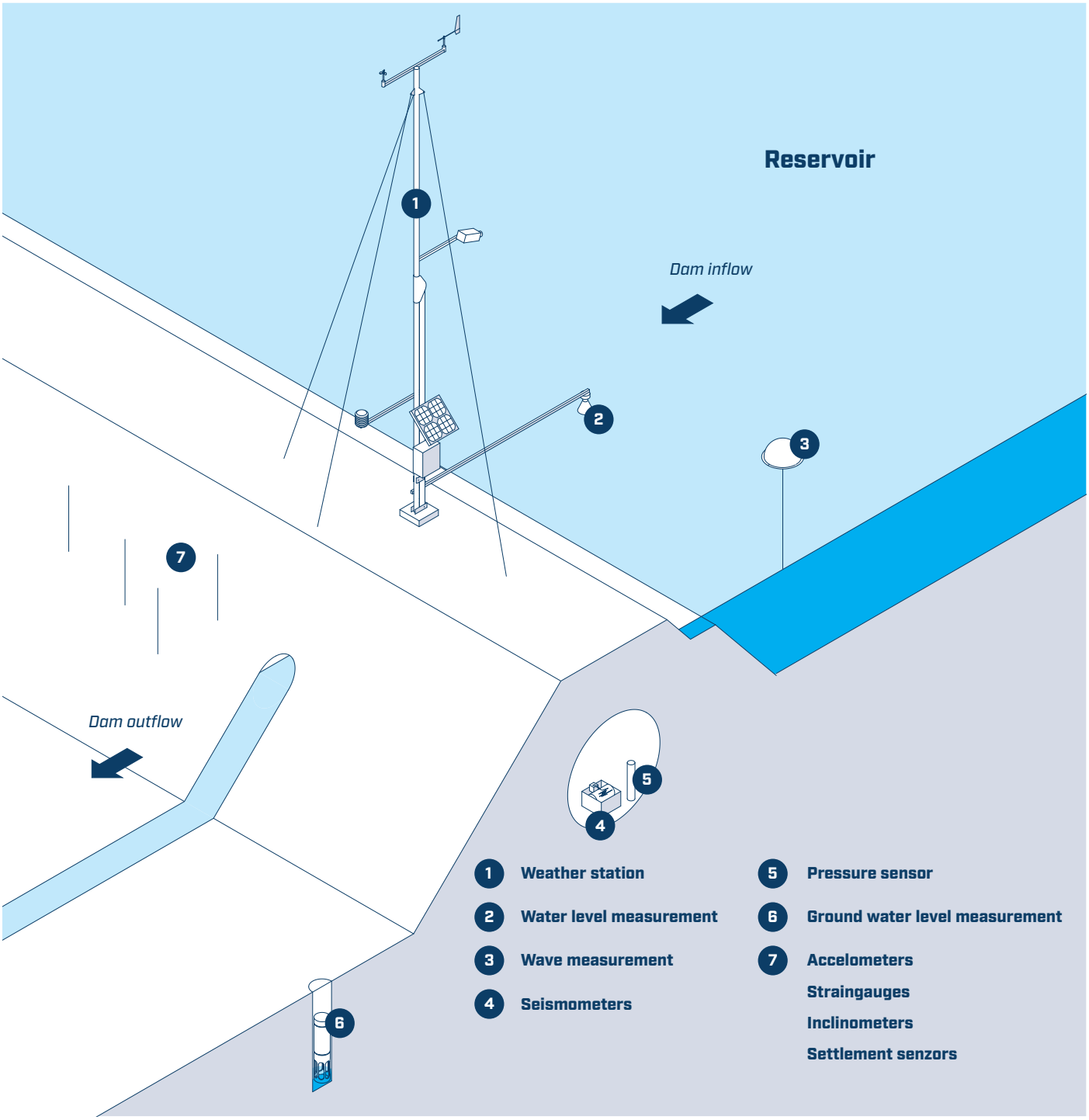
The dam authority needs to know:

- the actual condition of technical objects - dams, dams, gates, overflows;
- the actual state of natural objects - the water level in the dam, waves in the reservoir, water flows in the reservoir, the amount of water flowing into the reservoir and flowing out of the reservoir;
- prediction of the state of natural objects for the next period (meteorological and hydrological forecast).

All data should be available in real-time. Good monitoring, forecasting, and warning system allow the operator to make the right decisions at the right time and without delay.

Monitoring System

All dam monitoring devices are connected to one monitoring system, which collects data in the real-time, provides pre-processing and processing of measured data, and releases data in user-friendly visualization mode.



The system is collects data from:

1. Technical objects of the dam

1.1 *Stability of the dam slopes and dam objects via accelerometers, strain-gauges, inclinometers, and settlement sensors. Camera monitoring is very welcome.*

1.2 *Dam seepage processes via pressure sensors.*

1.3 *Dam safety via seismometers.*

2. Technical objects connected with the dam

2.1 *Levees and by-pass channels via piezometers (groundwater level measurement), water level measurement in open channels and pipes.*

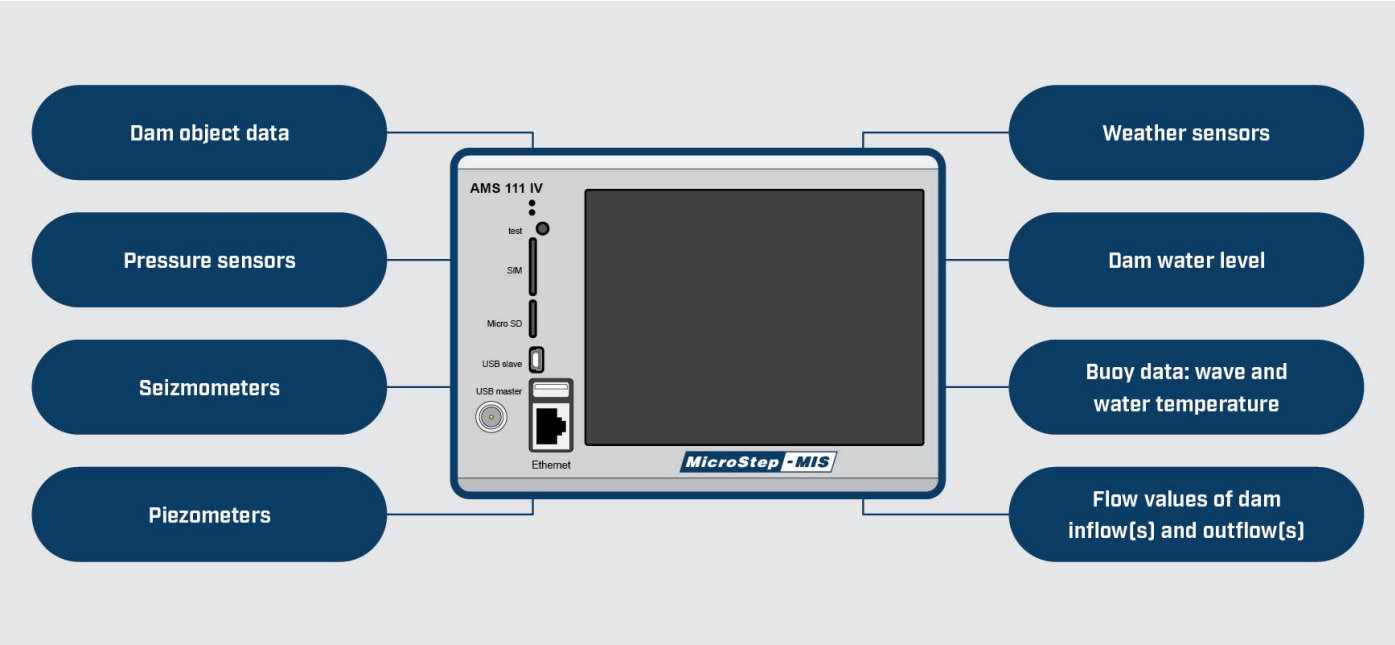
2.2 *The stability of the levees via similar measurement tools as for the stability of the main dam object.*

3. Weather and water bodies

3.1 *Weather information via weather station – temperature, precipitation, humidity, atmospheric pressure, wind parameters*

3.2 *Water surface parameters via water level stations and buoys – the water level in the dam, the temperature of the water, wave parameters, currents in the reservoir.*

3.3 *Water parameters of all important inflows and outflow(s) of the dam reservoir.*



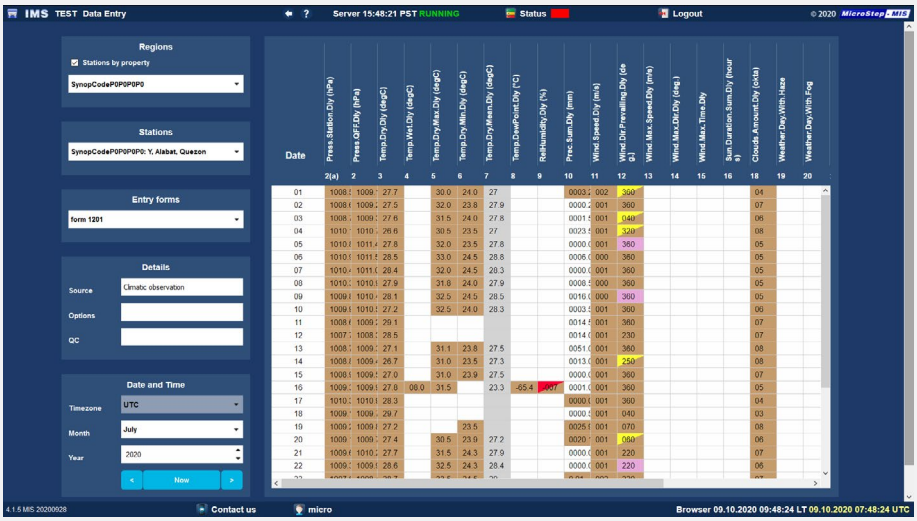
Collection and pre-processing of the measured data are ensured by the smart data logger. The optional collection system is the Data Logger AMS 111 IV.

Data Integration System

MicroStep–MIS has developed a proven integration system IMS4, which is the ideal solution for data processing and storage. The system enables visualization of the data, set-up of system accessories and routines. The system:

- runs in modular form on Microsoft Windows® or Linux® platforms;
- is based on Industry proven technologies - Java, XML, relational SQL databases;
- has Web and Application server integrated within the IMS Central Computer;
- is compliant with applicable regulations and recommendations (WMO, EU, OGC, ISO, OASIS), open for adjustment for compatibility with national practices;
- is available in many language mutations.

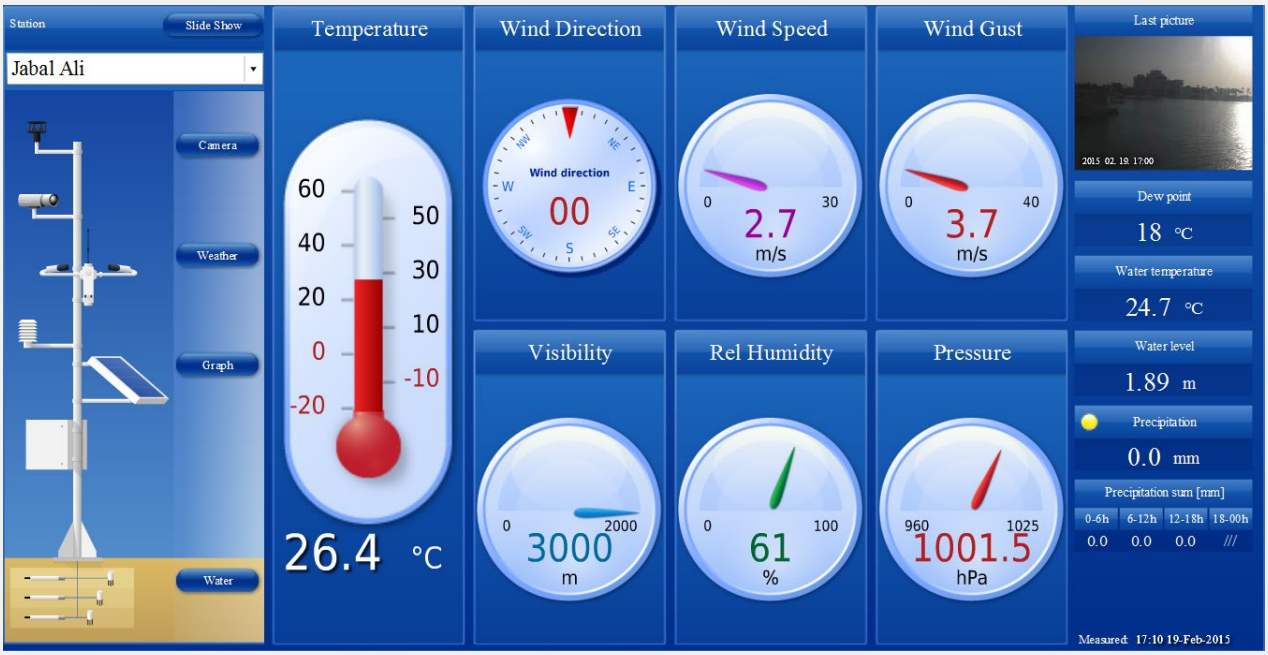
The system is using proven database based on WMO 1 recommended practices for climatological data processing (WMO Guide No. 100). It follows the WMO suggestion of an RDBMS. The great advantage of the database is its modular architecture, which gives the end-user the possibility of detailed customization. The end-user can specify additional non-standard input and output modules. Modules can be easily implemented and added to any existing or future installation. Integration of various data inputs is possible; AWS, radar, satellite, AHS, historical observations, buoy data, radiation, and air pollution monitoring, technical dam parameters, and more.



- *Original data - correct*
- *Suspect, but not erroneous data*
- *QC generated values*
- *Manually entered or overwritten data - correct*
- *Original data - not yet pass by QC*
- *Erroneous data*

The database can hold textual and numerical data, graphical information, and animations. It is capable of receiving, decoding, and storing the following data types from different data sources:

- data electronically imported from third party database systems;
- data manually entered or sent by SMS from manned stations with regular or irregular observing schedule;
- data from meteorological messages received via GTS2 or other distribution systems;
- data collected from automated weather stations (AWS); distributed in various formats;
- remote sensing data - radar and satellite images;
- model predictions (NWP outputs, hydrological model outputs);
- data from dam monitoring system (inclinometers, accelerometers, pressure meters, etc.);
- other numerical, textual, binary, or graphical data according to user requirements can be stored in CLDB after proper analysis.



IMS4 enables visualization of data measurement | *Meteorological and hydrological, as well as data from other monitoring devices.*

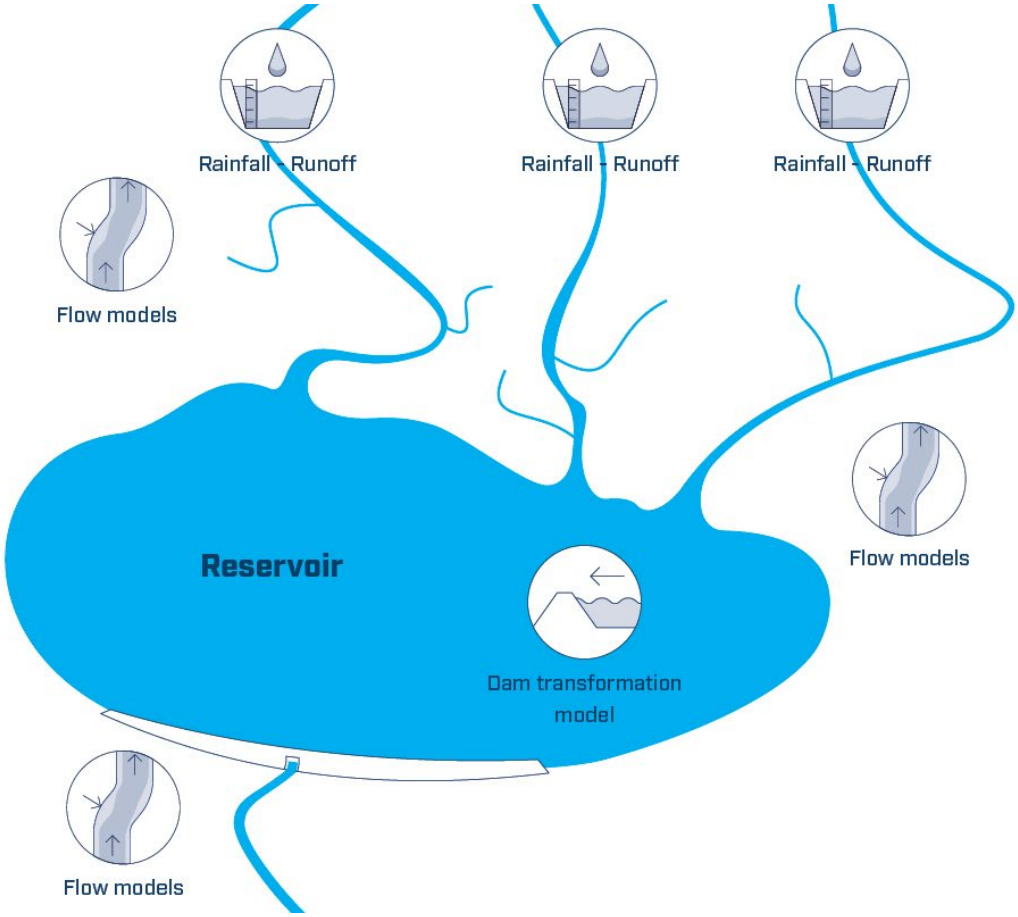
Forecasting System

The operator must have information about the upcoming conditions in the area of interest. The change of actual status of weather and hydrological conditions can influence the physical conditions of the dam object and physical conditions in the water reservoir. Strategic decisions have to be provided with the respect to this change of conditions.

Weather forecast is the prediction of the weather conditions for the area of the dam and for the area of interest (watershed of the dam). The weather forecast for the dam should include temperature, precipitation, humidity, atmospheric pressure, and wind parameters prediction. Weather radar data are welcome, but not necessary.

Weather forecast for the area of the watershed should include all parameters which are important for the hydrological prediction tools; mainly precipitation and temperature forecast.

The area of interest for the hydrological forecast is the watershed up to the profile of the dam. The inflow to the dam from the watershed can be forecasted with the use of the network of various hydrological models, especially rainfall–runoff models, flow models, and hydrodynamic (1D) models. These models are connected together for providing hydrological forecasts in real-time.



Rainfall-runoff models (HEC-HMS, HYPE, HBV) are transforming rainfall to a runoff a can be directly used for computing inflow to the dam. Models run in minute, hourly, or daily time steps, with the dependence on the needs of the dam operating authority.

Flow models (HEC-HMS) are usually included in one modeling packet with rainfall–runoff models. Almost all R-R models have some routines for computing of moving of outflow wave down the channel, at least lag method is used. HEC-HMS model includes several methods for flow computation, including kinematic wave, or Muskingum. These methods allow the computing of more actual spatial distribution of inflow to the dam and outflow from the dam.

Hydrodynamic models (HEC-HMS) are used for more accurate computation of flood wave transformation in the channel. Models can be used for the correct computation of the outflow from the dam. Their usage in daily operation is not very effective, but these models are very appropriate tools in the preparing phase of the dam for exact assessment of the processes downstream of the dam corresponding to a certain way of manipulation on the dam.

Dam transformation models (HEC-HMS, HEC-RAS, HEC-ResSim) are computing the transformation of outflow waves in the dam. The easiest solutions are using the relation curve of water level, or dam volume for releasing water from the reservoir. Models allow using of more sophisticated tools and relations for estimating the time schedule and amount of the water being released.

Connecting all above-mentioned models to one structure enables easy and accurate use of modeling tools for providing the most appropriate decisions for responsible operators of reservoirs.

MicroStep-MIS has 5 years of experience with proposing, set-up, calibration, and installing forecasting tools for hydrological bodies, including reservoirs.

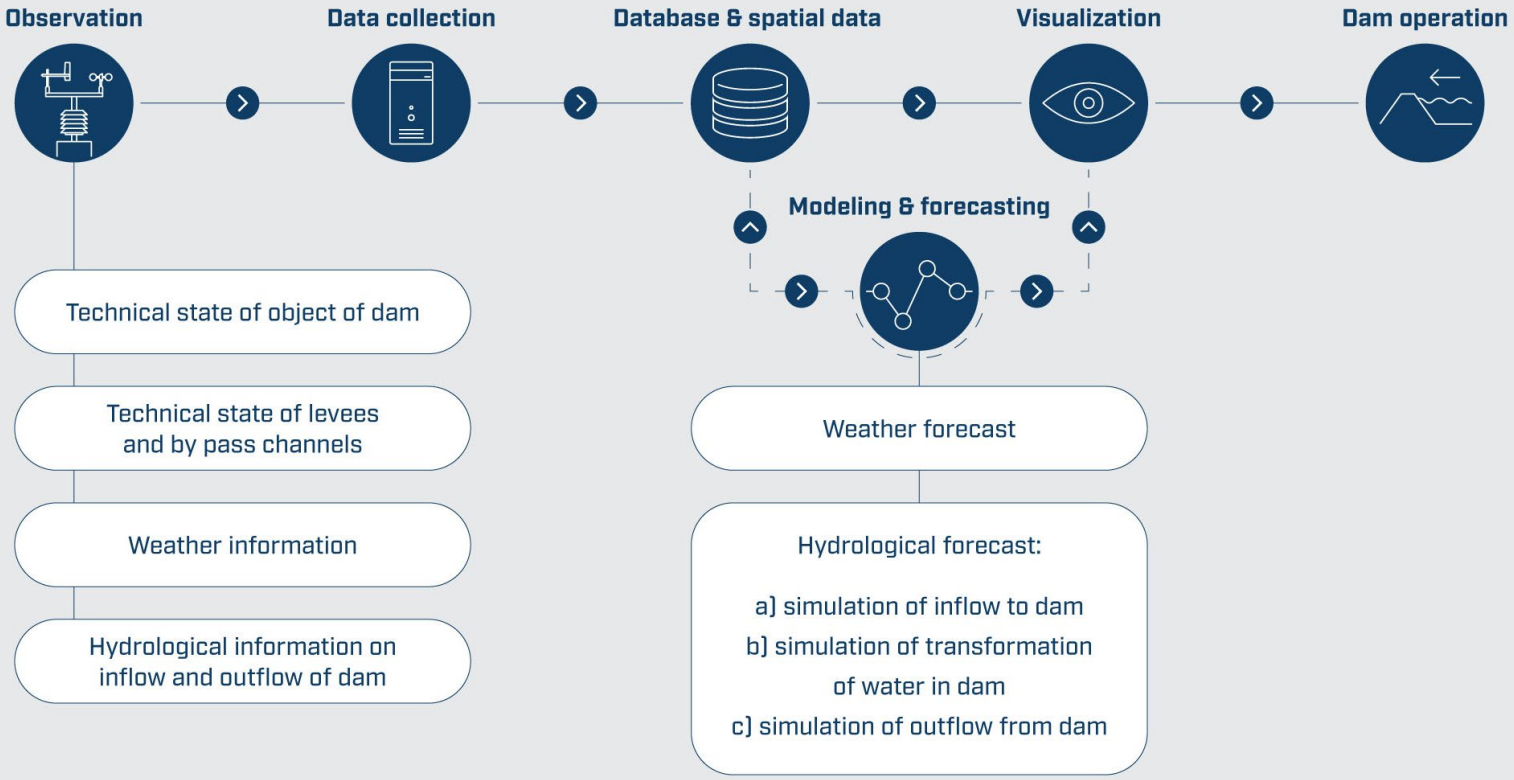
Decision Support System

Decision Support System (DSS) enables providing the right decisions at the right time. The operator should have all available data including safety data for monitoring of the actual status of the dam stability and safety, actual status of meteorological and hydrological conditions in the areas of interest, and a forecast of the future development of this

situation. All available data must be visualized in a user-friendly format in the form of graphs, tabs, and maps.

The operator has an overview of the actual and forecasted level of water in the reservoir, about the inflow and expected outflow. The system is giving him possibilities/advice, which actions should be taken with respect to all monitored conditions, including the state of the dam objects. The database is available and accessible all the time. Its archive enables usage of temporal analog / good practices approach. In the end, provided decisions are the best with the respect to:

- dam objects safety;
- population safety;
- optional usage of water stored in the reservoir – optional manipulation with water storage with the respect to all expected functions of the dam.



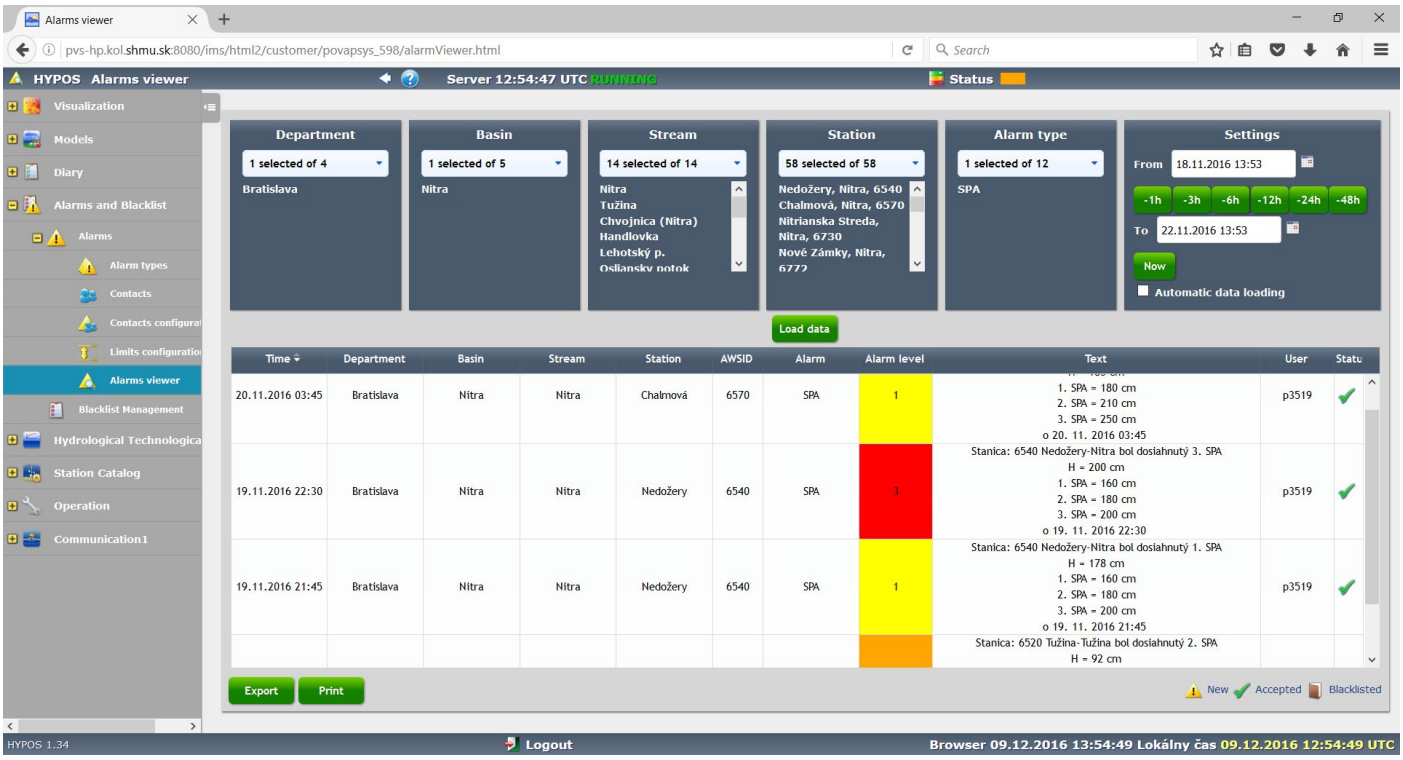
Warning System

The warning is one of the possible outputs of dam monitoring and the Dam Decisions Support System. Warning information can be:

- internal – for system operator;
- external – for the public.

The internal warning is the information for operator about:

- exceeding of the threshold for monitored safety parameters of the dam objects (stability of the dam);
- exceeding of the threshold for monitored safety parameters of the reservoir objects (stability of levees, level of groundwater);
- exceeding of the threshold for measured values of the water level in dam or/and inflow to the dam;
- exceeding of the threshold for measured values of weather parameters (wind-waves, precipitation, temperature);
- exceeding of the threshold for forecasted values of the water level in dam or/and inflow to the dam;
- exceeding of the threshold for forecasted values of weather parameters (wind-waves, precipitation, temperature);
- technical failure warning;
- other warnings (selected by the operator).



Internal warning appears in the visualization system for operator as a text message, or in the chosen graphical view.

External warnings are pre-defined by the user of the system. The most important is the information for the population, which is having their property and activities close to the water reservoirs and downstream of the reservoir. The most important warnings are for:

- high measured values of water level in the reservoir;
- high forecasted values of water level in the reservoir;
- high measured outflow from the reservoir;
- high predicted outflow from the reservoir;
- potential danger phenomena related to weather/ or water in reservoir area (waves, dangerous currents) - monitored or predicted;
- the danger of failure of the dam.

The warning can be delivered via different warning dissemination systems including sirens, SMS notifications, email notifications, TV or radio broadcast, and others.