Appendix 4 - Checklist Of Details For Consideration When Undertaking A Surveillance Evaluation[16]

1. General Interpretation

All new data should be thoroughly examined in context with existing data.

Situation ''Normal''

Generally the latest set of observations can be quickly scanned as numbers in a table or points on a plot and be seen to be as expected. In simple cases such as settlement or horizontal deflection of fill or gravity dams the reading should be within a millimetre or two of expectation, for a well-planned observation schedule.

For high thin arch dams, reservoir water level and seasonal temperature variations can justify statistical regression checks, and the observation should be within a few millimetres of a well-organised prediction from regression.

Leakage and piezometric data, when notionally cleared of local runoff effects, should generally follow any significant reservoir head changes. Seasonal opening and closing of joints or cracks in concrete dams can be reflected in gallery or toe drain flows, but after allowing for such influences, there should be negligible long term change.

Anomalies - Real or Not?

Sometimes an isolated instrument reading, or a survey observation, will indicate some severe distress or a strain, deformation or pore pressure which, if valid, would represent a real threat to the dam.

Every effort should be made to urgently assess such a situation, with repeat readings, repair of blown fuses, or extra instruments, targets or reference pillar checks.

If the dam has not failed and the adjacent parts are not indicated as behaving abnormally, that instrument reading or survey observation must be taken as anomalous, however carefully it purports to have been checked "correct".

Typical Assessment of "Overall Picture"

In foundations with piezometers upstream and downstream of grout and drainage curtains, and flow measurement of drains or drainage adits, it is possible to develop a good picture of the water table.

Ideally the piezometers will continue to indicate a roughly linear head drop along the seepage path. Rises and falls can be expected to follow corresponding reservoir level changes.

If tightening of foundation joints by creep causes a slow reduction in the long-term mean leakage flow, the head pattern described above should still apply.

16 Taken from ANCOLD Dam Safety Management Guidelines (1994)

If pressures build up downstream of the drainage curtain in dry weather, consideration of some extra drainage drilling is indicated.

Emergency Action "Triggering"

The surveillance engineer should be familiar with the designs, recent performance and possible failure mechanisms of all dams for which the engineer has surveillance responsibility.

Immediate personal access should be available to senior management in a perceived Dam Safety emergency. Senior management should not usurp the authority of the Dams Safety Engineer unless they are appropriately qualified and experienced.

Staff at the dam should be sufficiently trained to recognise an emergency and have the authority to trigger emergency action in the event of a disruption in communication.

Dam owners, particularly in relation to initiating, testing or upgrading Emergency Action Plans should maintain close regular liaison with those responsible for emergency services.

2. Factors For Consideration

The evaluation of a dam's performance usually requires a close inspection of the dam and its appurtenances, examination of water pressures and seepage records and the various movements relative to the abutments or of differential movement within the dam. These data are then compared with design assumptions, predictions and historical behaviour patterns to fully evaluate the existing situation.

Seepage

Seepage through, around or under a dam is expected. The quantity and nature of seepage, the seepage paths, and the velocity of the seepage waters are issues to be considered when analysing the dams' structural behaviour.

The quantity and nature of seepage is important for several reasons:

- Leaching:
  seepage may dissolve some of the chemical constituents of the concrete, rock or soil. Leaching may provide an enlarged seepage path resulting in increasing seepage. Dams founded on limestone are subject to this problem. Evaluation of the composition of the seepage water (eg turbidity, dissolved salt content) can provide a further insight into dam behaviour.
- Weakening:
  seepage water may completely saturate soils and rock, and cause excessive uplift (pore pressures) as well as softening and weakening of soil and rock.
- Loss of Storage:
  excessive leakage may, in extreme cases, compromise the storage capability of the reservoir.
- Indication of Behaviour:
  increases in seepage quantity with time may indicate the onset of internal erosion, and decreases may indicate infilling of seepage paths, with build up of internal pressures in dams and their foundations.

The location of a seepage path is of concern because:

- Piping:
  if seepage is confined to a few discrete paths and the velocity becomes sufficiently high to move soil particles, progressive erosion may occur resulting in a "piping" failure.
- Leaching:
  seepage waters may result in concentrated dissolution.
- Drainage:
  if discrete seepage paths are present and are not intercepted by drains, then drains should be installed. Seepage (or pore) pressures if above design values may compromise the stability of a dam.

Movements

Some movement of all or part of a dam can be expected eg seasonal movements, changes in water level. Movements may be in the vertical plane, the axial plane (along the dam's axis), and the upstream-downstream plane, or rotational. It is common for more than one direction and mode of movement to be present in a dam.

Vertical movements occur as a result of consolidation of the foundations or the embankment. Such settlement is typically greater along the crest of the dam than along the heel or toe and is also usually greater near the centre of the dam than near the abutments. Such settlement can result in cracking. Minor upward vertical movement (heave) can also occur at the toe of an embankment dam due to fill creep or excess uplift pressures.

Vertical movement of the centre of a fill dam with respect to the abutments is generally associated with horizontal movement toward the centre of the dam. This axial movement results in tension, which can involve cracking of the core or face membrane.

Upstream-downstream movements are usually in the downstream direction and are due to hydrostatic forces acting on the upstream face of the dam. These movements can be horizontal or rotational. Upstream movements are usually of a rotational-type and may occur during "rapid drawdown". These rotational movements may be a deep-seated or a relatively shallow configuration. The slides may extend into the foundation, intersect at the dam's heel or toe, or may be entirely contained within the dam. The general cause of such movements is deficient shearing resistance along the often saturated failure surface associated with high uplift pressures and reduced effective stresses.

3. Typical Periods for Evaluation

During the life of a dam, from initial planning, through construction, reservoir filling, and operation, an evaluation may be necessary as follows:

Preconstruction

Evaluation of pre-construction conditions using various instruments can be valuable. During the initial planning and design stages several important considerations affecting dam safety should be investigated. They include:

- Normal ground-water levels:
  the existing ground-water level in the abutments, dam area, reservoir rim, and downstream of the dam and its seasonal variation should be determined.
- Quality of the ground-water:
  ground-water mineral composition can be compared with later seepage water mineral composition

to aid in determining if dissolution is occurring.

- Seepage at abutments:
  seepage due to natural ground-water at abutments prior to construction will affect the design of the dam and later evaluation of the dam's performance.
- Landslide scars/faults:
  old landslide scars and faults in the vicinity of the dam indicate the potential for additional sliding during reservoir construction and operation.
- Permeability of existing materials:
  for the foundation, abutments, and reservoir floor, treatments such as grouting cut-off walls and upstream blankets can reduce the effect of excessively permeable materials.
- Foundation consolidation:
  knowing the characteristics of foundation materials allows anticipated settlement of the dam to be estimated.
- Fill and foundation shear strength:
  the shear strengths of the relevant materials are needed to determine the stability of the dam.
- Seismic:
  the seismic risk at the dam site is used to design the dam to resist loading up to the Maximum Credible Earthquake. Preparations should also be made to assess the existence of reservoir-induced seismicity.
- Hydrologic:
  catchment conditions, flood potential and the likelihood of changing conditions affecting future flood magnitude are important in determining spillway capacity.

During Construction

Installation and observation of instrumentation begins during construction. Visual observation is also vital during this period.

- Instrument installation:
  many instruments are installed during dam construction. These include piezometers, pressure cells, strain gauges, settlement and movement measuring devices and thermometers. It is absolutely essential that proper care be taken during their installation otherwise no information of value will be obtained from them. Incorrect installation techniques produce information detrimental to interpretation. Instruments must be tested as they are installed. Continuous supervision by specialists with authority to require repair or replacement is vital in the rough construction environment.
- Settlement:
  consolidation of foundation and embankment materials result in settlement of the surface of the dam as it is constructed. Settlement measuring instrumentation (such as hydrostatic manometers and cross arms), installed during construction, record such settlement.
- Observation of excavations:
  during construction excavations for foundation and core trenches, should remove undesirable materials. Visual observations by experienced personnel during this phase are extremely valuable and should be carefully recorded. Based on these observations, there may be need for instruments to be relocated or added or for design changes. This information can be important in diagnosing subsequent anomalous behaviour.
- Increasing Pore Pressures:
  rapid construction of embankments, at high moisture contents, may cause excessive pore pressures, which would result in instability if not allowed to dissipate. Records of such pore pressures can be of long-term significance.
- Slide movements:
  slide movements due to high pore pressure building up during construction may be noted either

visually or by instrumentation.

- Temperature:
  excessive temperatures from cement hydration in concrete dams may cause subsequent thermal cracking if not controlled.
- Permeability:
  filter permeability should be checked as placement can compact a filter more than specified.

During First Reservoir Filling

The first filling of a reservoir is normally a critical event for a dam. At that time, the first true analysis of the behaviour of a dam with reservoir loading can be made. Instrumentation readings and visual observations are conducted very frequently during this period.

- Seepage:
  as the water level in the reservoir rises, it is especially important to watch both the dam and abutments for increases in seepage quantities, changes in seepage clarity, new seepage locations and the functioning of drains.
- Pore pressure:
  at this time frequent readings should be taken to monitor pore pressure changes and patterns.
- Dam movements:
  the increasing load from the reservoir water will cause movements of the dam, particularly in the downstream direction. These require close monitoring, ideally including correlation with movement controlling factors.

During Normal Operations

Dam owners generally aim to have trouble free operation of a dam for many years. The water level in many reservoirs fluctuates each year resulting in seepage quantity and pore pressure fluctuations on a regular, somewhat predictable basis. It is therefore important to establish a regular instrumentation monitoring schedule and a regular visual inspection of the facility and to summarise the findings in regular surveillance reports on the dam. Any significant unusual changes noted should be an immediate cause for further investigation.

During Rapid Drawdown

Occasionally, the reservoir level is lowered rather quickly for some reason. The term "rapid" depends on the type of material in the dam and abutments. In some relatively permeable materials, "rapid" may mean hours or days, while in low permeability materials, a "rapid drawdown" might cover a period of weeks. During drawdown the external reservoir water pressure is removed but the internal pore pressures in the dam and abutments remain, to dissipate more slowly in impermeable materials. This creates a condition where slides may occur in the upstream face of an embankment, the abutments, or anywhere along the reservoir rim. Surface movements and pore pressures in the upstream shoulders require special monitoring at this time.

4. Interpretation Of Data

Data Presentation

The use of graphical presentation of instrumentation data should be undertaken for the evaluation of dams. Graphical presentation by computers is simple and rapid and reduces the chance of plotting errors and enables ancillary computations and data variation checks to be performed.

Data presentation, when properly done, is of very significant value, but incorrect data plotting may cause errors in interpretation. The characteristics of incorrect plotting include:

- Improper scale:
  proper and consistent scales must be used. Movements should not normally be shown larger than full-scale (1:1).
- Excessive data:
  in general, each plot should contain only two variables: (eg water level and time). There may, however, be a large amount of data points on a single instrument or even a number of instruments. The number of instruments shown on a single sheet of plotting is a matter of common sense. Plot lines should not repeatedly cross each other and distinctly different line symbols should be used for each plot.
- Coloured lines:
  distinguishing plots by colour should be avoided due to the use of black and white photocopying (eg when "quoting" plots in subsequent communications).

Detection of Errors

Data errors can usually be detected either in the field at the time of reading or in the office during processing or reviewing. Often, it has been found that if the instrument reader knows what the previous reading on an instrument was, they can re-check the current reading if it differs significantly. (The risk that the reader will report a reading close to the previous one without actually making an observation, or even where a different reading is actually obtained, has to be considered.)

Normal and Abnormal Conditions

Application of the terms "normal" and "abnormal" depends on the particular characteristics of a dam in question. The behaviour of pressures, strains, movements, and seepage, should be compared to the behaviour anticipated during the design of the dam and any preconstruction data gathered from the dam site. It is important for designers to state acceptable "ranges" in design reports and operating instructions. For dams with limited design data, historical behaviour patterns should be developed.

Correlation of Inspection/Monitoring Data

The recommendation for major remedial works on a dam should not depend on uncorroborated evidence. Ideally any visible anomaly should be confirmed by anomalies recorded on associated instruments.

It is important to compare measured aspects of a dam's behaviour over identical date ranges. Since observations cannot always be made concurrently, response factors, such as regression coefficients, should be used to determine the most probable values on the chosen comparison date, for movements, which could not be observed on the date.

Reservoir water level, ambient temperature, and age since construction should be included amongst the controlling variables in these studies. In comparing the designer's predictions and the prototype's performance, regression can be an important tool in separating the effects of temperature, water load and creep, so that each may be compared in turn.

In general, those responsible for interpreting monitoring results should endeavour to make all possible logical linkages throughout the range of dam data obtained from observations and inspections and be vigilant in the detection of errors and false alarms. Familiarity with the reliability of installations and observers is a great advantage in making a judgement as to whether an "alarm" is false or real as a result of a genuine excessive change in the value of the entity being monitored. In this regard close liaison between operators and surveillance personnel is critical.