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Directive on the Safety of Water Retaining Facilities

Part D: Commissioning and operation

Commissioning - Maintenance - Surveillance

Note: This document is a preprint of Part D of the Directive on the Safety of Water Retaining Facilities (revised version, 2014-2015).
The Directive is addressed to the relevant supervisory authorities and the operators of water retaining facilities. It contains detailed information that is required for the application of the relevant articles of the Water Retaining Facilities Act (WRFA) and the Water Retaining Facilities Ordinance (WRFO). Deviations from the Directive are permissible as long as they facilitate the attainment of the specified safety objectives.

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Contents – Part D

1. Introduction

Part D of the Directive deals with the safety of water retaining facilities during commissioning and operation (Articles 7 and 8, WRFA and Chapter 2, Section 2, Articles 11 to 24, WRFO). It applies to water retaining facilities of all types, regardless of their dimensions, purpose and operator.

The implementation of the requirements specified in this part of the Directive must be adapted to the characteristics and to the surveillance needs of the facility considered within the scope of the legal provisions of WRFA and WRFO (principle of proportionality).[1]

2. Commissioning

2.1 Prerequisites

A licence from the relevant supervisory authority is required for the initial commissioning of a water retaining facility or its components (e.g. following a heightening of the dam). The same applies with respect to the recommissioning of a facility following a total or partial drawdown ordered by the relevant supervisory authority.

2.2 Commissioning licence (Article 7, WRFO)

An application for a commissioning licence must contain all the information that is required for carrying out a safety assessment in order to ensure that there is no threat to the safety of the population during the operation of the facility. As a rule, the required information is listed in the documents cited in Table D1 and, where necessary, in additional documents.

Documents	References	Comments
Acceptance report on construction work	Article 9, paragraph 3, WRFO	Compiled by the supervisory authority
Commissioning programme **Reservoir filling programme**	Article 12, paragraph 1, WRFO	Describes the foreseen commissioning modalities, including any reservoir filling stages if filling can be carried out in a controlled manner
Surveillance regulations during commissioning phase		Specifies the required visual inspections, measurements, function tests and assessments through to the normal operating stage
Gate regulations	Article 11, paragraph 1a, WRFO	cf. Part C2 of the Directive
Emergency regulations	Article 11, paragraph 1b, WRFO	cf. Part E of the Directive

Table D1: Documents which, as a rule, have to be submitted together with the licence application

1 Specific implementation guidelines for dams on the Upper Rhine and the Aare are available from the Supervision of Dams Section of the Swiss Federal Office of Energy (SFOE). Implementation guidelines for smaller water retaining facilities are available on the SFOE website.

The supervisory authority checks whether the safety requirements are met before it issues a commissioning licence. It may also request additional information and specify conditions governing commissioning.

Even if certain information still has to be provided, the supervisory authority may approve commissioning as long as there is no threat to public safety. In its approval, it specifies a deadline by which the missing information must be provided. The supervisory authority may also issue a licence for partial commissioning of the facility, for example if an acceptance report has only been compiled for a certain part of the construction work.

Commissioning licences issued by the supervisory authority comprise the following content in particular:

Documentation	Comments
List of documents on which the issue of the licence is based	In particular, documentation that was submitted together with the licence application, for example, reservoir filling programme and dam regulations
Criteria that must be met concerning the way in which commissioning is carried out	For example, adherence to the reservoir filling stages with prior approval by the supervisory authority when moving from one stage to the next; measurements to be carried out; required visual inspections and function tests.
List of documents and required information to be provided during and upon completion of commissioning	Including specification of the deadline for submitting the documentation and information
Facility-specific requirements	According to the special characteristics of the facility

Table D2: Content of commissioning licence

In accordance with the legislation governing water retaining facilities, the holder of the commissioning licence is deemed to be the operator of the facility (Article 1, paragraph 5, WRFO). When a commissioning licence is issued, the holder is not only authorised to use the facility in accordance with the provisions of the WRFA, but is also obliged to take responsibility for the safety of the facility in accordance with the provisions of the WRFA, the WRFO and the criteria specified in the licence. The licence is personal and non-transferable. In particular it may not be assigned to another company (even if the operating personnel remain unchanged).

2.3 Commissioning of a water retaining facility in which the filling of the reservoir can be carried out in a controlled manner

The operator is required to formulate a commissioning programme in which the way filling will be carried out (reservoir filling programme) is described, together with the surveillance in place (i.e. surveillance regulations during commissioning) until the commencement of normal operation. This commissioning programme must be submitted together with the licence application.

Reservoir filling programme

If the reservoir can be filled in a controlled manner (for example in the case of water retaining facilities equipped with discharge works that can be used for controlling the water level in the reservoir, or in which it is possible to limit or interrupt inflow), this is normally carried out in stages. The reservoir filling programme should contain the following information in particular:

- speed at which the water level rises and the levels of the interim filling stages, including their duration, as well as the conditions and procedures for maintaining the water level at each stage;
- deformations or other behavioural characteristics to be anticipated during filling;
- measurements, function tests and visual inspections that are to be carried out at each filling stage, together with the methods for evaluating the various measurements and inspections;
- way in which the rise in water level will be controlled in the event of a flood.

The choice of the number of filling stages and their reservoir levels is based on the following parameters:

- the geological conditions and status of knowledge about the underground;
- the dimensions of the dam and reservoir;
- the necessity to carry out function tests on the relief and outlet works at intermediate water levels;
- the results of the function tests, visual inspections and measurements in the initial filling stages, that could lead to modification of the original programme.

As a rule, the filling procedure is as follows:

i. Slow increase in water level up to the first filling stage. Frequent visual inspections are carried out while the reservoir is being filled, and the remotely transmitted measurement data are constantly evaluated. Periodical manual measurements are carried out in the absence of remote transmissions of data or in addition to the latter.
ii. Stabilisation of the water level and implementation of a complete measurement process (generally including geodetic surveys); function tests of the gated relief and outlet works.
iii. Evaluation of all measurements and observations, including comparison with anticipated values. The water level has to be maintained at the stage level until it is possible to deduce from the evaluation that the water retaining facility is behaving normally and a report or memo has been compiled for the attention of the supervisory authority. The supervisory authority may consent to a minor fluctuation of the water level during this phase.
iv. As long as the measurements and observations indicate that the facility can be operated safely, and subject to any necessary authorization from the supervisory authority, the next filling stage may be initiated on the basis of the same procedure.

As a rule, the emptying phase and successive load cycles do not have to be carried out in stages.

The supervisory authority decides whether or not it will be present in certain filling stages, and how it is to be represented. As a rule it attends on site during or upon completion of the main stages and on the occasion of the function test when the reservoir is full.

A water retaining facility does not have to be filled in stages if it does not attain the dimensions specified in Article 2, paragraph 1, WRFA. A single intermediate filling stage is generally sufficient if the water retaining facility is not classified as large in accordance with Article 3, paragraph 2, WRFA or if a sufficient number of measurements can be transmitted remotely and evaluated immediately.

Surveillance regulations during the commissioning phase

In terms of structure and content, these regulations are similar to those governing the operating phase (cf. section 4.1.5). They only differ through their constant development that results from ongoing observations, analyses and findings during the filling stage and during the subsequent phase of intensified surveillance, which as a rule continues for several years. The anticipated duration should be specified by the supervisory authority in its commissioning licence.

2.4 Commissioning of a water retaining facility in which the filling of the reservoir cannot be carried out in a controlled manner

If it is not possible to control the filling process (especially in the case of flood control reservoirs and sediment barriers or if the reservoir capacity is small in comparison with the catchment area), the supervisory authority issues the commissioning licence after it has approved the acceptance report in accordance with Article 9, paragraph 3, WRFO as well as the surveillance, gate and emergency regulations.

2.5 Commissioning report (Article 13, paragraph 1, WRFO)

2.5.1 Commissioning with controlled reservoir filling

Upon completion of the commissioning procedure, the operator is required to submit a commissioning report to the supervisory authority. This report must comprise the following items in particular:

- an overview of the way the initial filling of the reservoir;
- an analysis of the behaviour of the water retaining facility during the initial, resp. the various filling phases;
- the results of the function tests of the relief and outlet works;
- a summary of the inspections that have been carried out;
- a description of any notable events that may have occurred during this period and which could have had an influence on the progress of the commissioning procedure (floods, avalanches, landslides, mudslides, earthquakes, extraordinary meteorological conditions, etc.).

2.5.2 Commissioning with reservoir filling that cannot be controlled

If it is not possible to control the filling of the reservoir, the supervisory authority normally requests a report on a detailed inspection after the event that gave rise to the initial filling. This report must include the results of the measurements and visual inspections called for in the commissioning licence (usually limited to deformation measurements and a visual inspection of the condition of the facility).

2.6 Transition to the operating phase

The operating phase commences as soon as the commissioning procedure has been completed.

The operating licence is implicitly an integral part of the start-up licence as long as the results of the initial filling or refilling indicate that the facility can be operated safely. The supervisory authority does not issue another licence.

The operating phase differs from the commissioning phase in terms of the organisation and extent of the surveillance activities that are governed by Articles 15 to 19 of the WRFO.

Every water retaining facility must be under surveillance. The organisation and extent of the surveillance are specified in the surveillance regulations, which have to be compiled or updated upon completion of the commissioning phase, while taking account of the findings recorded during this phase. The extent of the surveillance regulations depends on the properties of the water retaining facility, in particular its dimensions and complexity.

If an occurrence or condition should be detected that has influenced, or could influence, the safety of the facility, the operator is required to take the necessary measures to protect the population, even if this means partially or completely halting the operation of the facility. The operator must also notify the supervisory authority, which will order the implementation of further-reaching measures if it considers these to be necessary. It may also order the partial or complete drawdown of the reservoir.

3. Operation

The operation of the water retaining facility encompasses three tasks for which the operator is responsible:

1. The actual operation of the facility;
2. The maintenance of the facility;
3. The surveillance of the facility.

3.1. Operation

The actual operation of the water retaining facility consists in its utilisation in accordance with its declared purpose, including compliance with the surveillance regulations. The nature of the utilisation is decided by the operator and is not dealt with in this document.

3.2. Maintenance

The purpose of maintenance is to keep the facility in operational condition. Maintenance may be preventive or remedial.

The objectives are as follows:

(i) To prevent malfunctions of the installations relevant to safety and of measurement equipment through maintenance and scheduled servicing (preventive maintenance);

(ii) To repair any damage before it gives rise to a major deterioration (remedial maintenance).

Maintenance also encompasses ongoing servicing. This primarily concerns:

- the water retaining facility itself, including cleaning of drainage systems and shafts, upkeep of embankments, repair of various damages, etc.;
- the reservoir and relief equipment, especially removal of floating debris;
- hydromechanical installations, electricity supply installations, control and steering mechanisms, water alarm system;
- measurement equipment, especially the supports and the instruments themselves, clearing the geodetical survey lines, etc.;
- means of access.

The maintenance of the installations relevant to safety, for example the outlet and spillway gates, together with their control and drive mechanisms (including backup and emergency systems), plus measurement equipment for monitoring the water retaining facility, are dealt with in section 6.1. Maintenance that does not concern the safety of water retaining facilities is not dealt with in this document.

3.3. Surveillance

The surveillance of water retaining facilities is dealt with in detail in section 4.

4. Surveillance

4.1. Organisation and extent of surveillance activities

4.1.1 Objectives

The main objective of surveillance is to guarantee the safety of the facility.

Its purposes are as follows:

(i) To ensure that the condition and behaviour of the water retaining facility comply with the specified safety requirements;

(ii) To identify an anomalous behaviour of, or a specific damage to, the water retaining facility (retaining structure, appurtenant structure of relevance to safety, foundations, reservoir) or one of its safety systems, with the aim of taking the necessary countermeasures at the earliest possible juncture.

Through surveillance it is also possible to develop a measurements and observations database that is suitable for carrying out future analyses, especially in the event of an unexpected behaviour or a change in the condition of the water retaining facility.

Surveillance encompasses the following activities:

- Visual inspections of the condition of the water retaining facility (retaining structure, appurtenant structures of relevance to safety, foundations, reservoir);
- Carrying out measurements if the facility is equipped with the necessary devices, and evaluation of the results of these measurements – the aim of these measurements is to record the behaviour of the dam, its foundations and its surroundings;
- Checking the correct functioning of gated relief and outlet works.

Figure D1 presents a general overview of the surveillance activities and their associated processes, together with the defined objectives. It applies to all types of water retaining facilities, including those that are not equipped with measurement devices or which do not have any gated relief and outlet works.

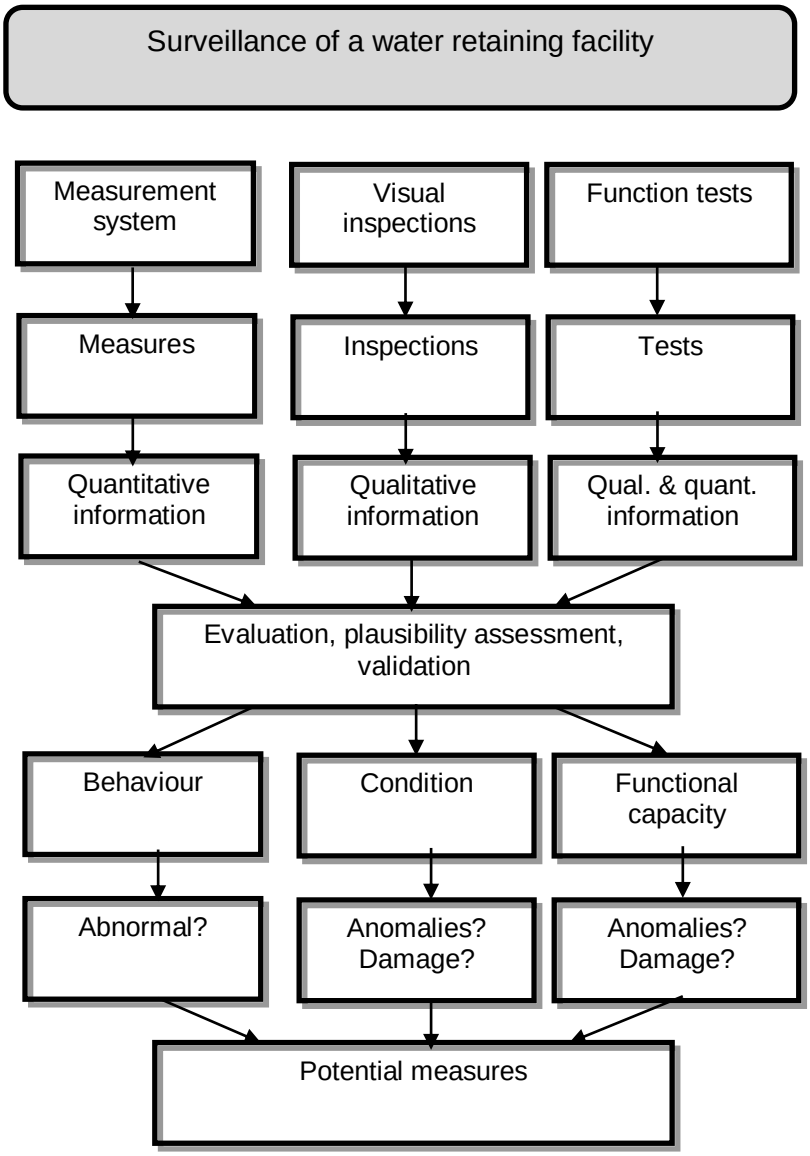

Figure D1: Surveillance of a water retaining facility

4.1.2 Organisation of monitoring activities

Monitoring is organised at several different levels (cf. Figure D2).

Figure D2: *Organisation of surveillance activities*
(level 3 only applies to facilities subject to Article 18, paragraphs 1 and 4, WRFO)

The organisation of levels 1 to 3 is the responsibility of the operator, and must be depicted in the surveillance regulations.

Level 1: The tasks allocated to level 1 are the responsibility of the dam warden and, if applicable, the geodetics specialist.

Dam warden

As a rule, the dam warden is an employee of the operator or of a company entrusted with this task by the operator. He/she carries out the tasks assigned to him/her by the operator in accordance with Article 16, WRFO.

These include visual inspections of the water retaining facility, carrying out measurements, verifying the correct functioning of gated relief and outlet works, and following maintenance tasks being carried out.

Geodetics specialist

The geodetics specialist is responsible for carrying out any required geodetic surveys on behalf of the operator.

Level 2: Tasks allocated to level 2 are carried out by the qualified professional in accordance with Article 17, paragraph 1, WRFO.

These include ongoing evaluations of visual observations, measurement results and results of functionality tests. He/she is required to carry out a visual inspection of the water retaining facility at least once a year. He/she is responsible for evaluating all information at disposal and for recording his/her findings and conclusions in an annual report.

Furthermore, his/her tasks include consulting with the operator on the surveillance of the facility and, where necessary, recommending the assistance of specialists (geologist, hydromechanics specialist, avalanche specialist, specialists in other natural hazards, etc.).

Level 3: Two experienced experts are responsible for the tasks allocated to level 3: a civil engineer and a geologist, in accordance with Article 18, paragraph 1, WRFO.

They are required to carry out a comprehensive safety assessment every five years, and to record their findings in their five-yearly reports.

They receive copies of each annual report and have to keep themselves up to date regarding the condition of the water retaining facility. At the request of the operator, they also support the qualified professional and advise the operator in the event of unexpected or extraordinary occurrences.

Level 3 only applies to water retaining facilities that meet the criteria specified in Article 18, paragraph 1, WRFO, or in accordance with a ruling by the supervisory authority based on Article 18, paragraph 4, WRFO.

Level 4: Level 4 is the responsibility of the supervisory authority (Articles 22 and 23, WRFA).

Here the supervisory authority has to ensure that the operator duly performs the assigned statutory tasks for maintaining the safety of the facility. It examines and validates submitted reports and inspects the facility on a periodical basis.

Performance of level 1 tasks by the qualified professional

In very small water retaining facilities in which the tasks at levels 1 and 2 are limited, the operator may allocate responsibility for monitoring activities at these two levels to the qualified professional. This is only permissible, however, if the person concerned meets the defined profile for level 2.

4.1.3. Monitoring system: Categories of measurement instruments

The measurement instruments for the monitoring system are divided into the following categories:

1) Measurement instruments for ongoing behaviour monitoring

This category encompasses instruments that are required for:

(a) detecting loadings on the structure, in particular due to:
- water level;
- temperatures outside and in the interior of the dam structure;
- precipitation;

(b) measurement of behaviour of the structure, especially:
- deformations;
- water pressure in the structure and its foundations;
- seepage.

Any modifications of these instruments and the respective measurement intervals require the prior consent of the supervisory authority. The operator is required to enter any such changes into the surveillance regulations and submit the revised regulations to the supervisory authority for approval.

Remotely transmitted measurement data in this category of instruments must be periodically verified through manual measurements on site (Article 16, paragraphs 2 and 3, WRFO).

The surveillance regulations must also describe in detail which measurements have to be carried out immediately in the event of an extraordinary occurrence (earthquake or flood).

2) Backup instruments for the measurements cited above or as replacements in the event of a malfunction.

   Any modifications of these instruments and the respective measurement intervals require the prior consent of the supervisory authority. The operator is required to enter any such changes into the surveillance regulations and submit the revised regulations to the supervisory authority for approval.

   Remotely transmitted measurement data must be periodically verified through manual measurements on site. In special circumstances, the frequency of these manual controls may deviate from the intervals specified in Article 16, paragraphs 2 and 3, WRFO.

3) Instruments that are only used to a minor extent for ongoing monitoring purposes, for example new instruments installed with the aim of testing their suitability in a dam.

   Modifications of these instruments and the respective measurement intervals do not require the prior consent of the supervisory authority. However, the operator is required to correspondingly update the surveillance regulations (without the need for prior approval) and notify the supervisory authority (Article 14, paragraph 3, WRFO).

4.1.4. Measurement system: instrumentation range

The measurement system must enable the qualified professional to assess the loads to which the water retaining facility is subjected, and the way the facility reacts to them. It usually covers one or several of the following elements:

- the loads that affect the condition and behaviour of the facility;
- uplift pressures / pore water pressures;
- quantities of seepage and drainage water;
- deformations;
- anchoring forces.

The range of instruments to be installed depends thus both on the type of dam and its dimensions, structure and age, as well as on the local conditions, especially with respect to the foundations.

In the case of dams intended to protect against natural hazards, the purpose of the monitoring system is to verify its serviceability.

General rules and principles for planning the instrumentation and defining the associated requirements can be found in [STK 2005a] and [ICOLD 2014]. [STK 2005a] also contains

descriptions of the characteristics of the various types of instruments and indication on their installation.

The operator must ensure that the instruments function correctly and are calibrated and checked as necessary [STK 2013b].

The measurement of the water level in the reservoir must always be carried out (with the exception of temporary retention basins).[2] In the case of large water retaining facilities for which five-yearly inspections are required in accordance with Article 18, paragraphs 1 and 4, WRFO, this measurement must be carried out redundantly.

4.1.5. Surveillance regulations (Article 14, paragraph 2, WRFO)

The surveillance regulations must be prepared by the operator and submitted to the supervisory authority for approval. They must contain a description of the organisation that the operator is setting-up to ensure the safe operation of the water retaining facility at all times.

They must especially describe the following:

- organisation, plus the duties and responsibilities assigned to the various involved persons;
- the requirements and the elements that have to be checked during periodical and annual visual inspections;
- the procedures for carrying out inspections and fucntional tests of the relief and outlet works in accordance with the description provided in Part C2 of the Directive;
- an overview (in table form) containing detailed information about the frequency or periodicity of the ongoing visual inspections, measurements and function tests of the gated relief and outlet works, and the on-site manual measurements to confirm the remotely transmitted measurement data – this table is to take the form of an appendix;
- the modalities and special characteristics of the measurements, the utilised tools and instruments, and the plausibility checks to be carried out during measurement;
- the procedure and periodicity for the forwarding of the results of the visual inspections, measurements and function tests of the relief and outlet works at the various surveillance levels;
- the preliminary verifications and analyses of the ongoing observations and measurements to be carried out by the qualified professional, including indication of the respective deadlines;
- the procedures for dealing with extraordinary occurrences, including:
  - an anomalous behaviour of the water retaining facility detected through measurements or visual inspections;
  - an identified change in the hydrogeological conditions (for example, appearance of a new water spring) or the condition of the rock massif;
  - an extraordinary or extreme flood event (indicating the applicable criterion, e.g. specified water level);
  - landslide, rockfall, avalanche;
  - earthquake (cf. enclosure 1 for additional information);

2 A gauge still has to be installed in temporary retention basins so that the water level can be determined in an emergency (cf. Directive, Part E).

- a malfunction of a safety-relevant system component (especially of a relief or outlet mechanism).

The supervisory authority determines whether the surveillance regulations submitted by the operator are complete, and whether the designated surveillance organisation meets the safety requirements in accordance with Article 14, paragraph 2, WRFO. It approves the regulations if they comply with the specified requirements.

The surveillance regulations must be kept up to date by the operator, and if any modifications are made it must again be submitted to the supervisory authority for approval.

The following amendments do not have to be approved, but the operator is nonetheless required to report them to the supervisory authority (Article 14, paragraph 3, WRFO):

- Coordinates of contact persons

  These changes have to be entered in the corresponding appendix to the surveillance regulations, and the update has to be noted on the front page. The operator is required to bring the amended appendix and front page to the attention of the supervisory authority and other addressees of the regulations.
- Amendments to other non-safety-relevant elements

  These changes have to be entered in the corresponding section of the surveillance regulations, and the update has to be noted on the front page. The operator is required to bring the amended sections and front page to the attention of the supervisory authority and other addressees of the regulations.
- Amendments that have been duly approved by the supervisory authority at a meeting or during an on-site inspection

  The operator is required to note these changes in the surveillance regulations, citing the corresponding minutes (date of meeting or inspection, applicable references), and to update the front page accordingly. The operator is then required to bring the amended sections and updated front page to the attention of the supervisory authority and other addressees of the regulations.

4.2. Level 1 surveillance

4.2.1. Introduction

Level 1 surveillance represents continual inspections as specified in Article 16, WRFO.

The aim of these inspections is to ensure that the water retaining facility is always in good condition and is behaving normally. They are carried out by one or more dam wardens, depending on the size of the facility.

Dam wardens are responsible for carrying out visual inspections of the water retaining facility, carrying out measurements, assisting with the verification of the correct functioning of gated relief and outlet works, and following maintenance tasks being carried out. The operator calls on the services of other specialised personnel for the performance of tasks that require special expertise (for example, for carrying out precise geodetic surveys).

Continual inspections must be carried out at the intervals specified in the surveillance regulations. In addition, immediate (visual) inspections and measurements (if the facility is equipped with measurement instruments) must be carried out in the event of extraordinary occurrences.

A temporary shortening of the inspection intervals and/or increase in the extent of inspections is required if the situation makes this necessary, for example if a malfunction of a system of relevance to safety should occur.

Measurements must be carried out in accordance with the provisions stipulated in the surveillance regulations. Dam wardens are required to perform a plausibility check of the results of the measurements and to repeat any measurements where necessary. The results of the measurements must be forwarded to the qualified professional in accordance with the intervals specified in the surveillance regulations (in the case of large water retaining facilities, at least once a month).

4.2.2. Job profile of dam warden

The duties of a dam warden are described in detail in [STK 2015]. He/she must be able to work independently and possess the necessary technical qualifications that enable him/her to:

- carry out measurements with the aid of the various instruments;
- carry out plausibility checks of the results of the measurements;
- perform, describe and keep records of visual inspections;
- identify new manifestations;
- assist with function tests;
- assist with the ongoing maintenance of installations and normal repair and renovation work.

The operator is responsible for ensuring that the dam warden possesses the necessary qualifications for performing all his/her assigned duties, and that he/she is able to attend further education courses. The operator must also ensure that the dam warden’s duties are described in a detailed manner. A sufficient number of personnel must be deployed in order to ensure that the duties of the dam warden can be performed as safely and precisely as possible.

4.2.3. Extent of surveillance activity

The extent of the surveillance activity designated by the operator depends on the characteristics of the water retaining facility. Corresponding information is available in several publications of the Swiss Committee on Dams [STK 1997a], [STK 1997b], [STK 2005a], [STK 2013a]. The measurement and inspection frequencies indicated in Table D3 are guidelines only. The supervisory authority may order shorter intervals or accept longer ones (or even waive measurements altogether), depending on the characteristics of the water retaining facility and in consideration of the risks to personnel when performing the tasks (for example, potential exposure to avalanches). In all circumstances it is the surveillance regulations approved by the supervisory authority that are binding. Visual inspections always have to be carried out.

All water retaining facilities designed to protect against natural hazards				
		Concrete structures	**Embankments**	**Comments**
Continual visual inspections		2 to 4 times a year	2 to 4 times a year	At least prior to the main season in which floods or avalanches occur, and after every significant event
Measurements to monitor the behaviour of the facility (Category 1, cf. section 4.1.3)	Deformations (with plumb lines or geodetic measurements)	1 to 4 times a year	Once a year to once every two years	
	Seepage and drainage water (turbidity)	1 to 4 times a year	1 to 4 times a year	
	Uplift and pore water pressure	1 to 4 times a year (interface between concrete-rock and foundations)	1 to 4 times a year (pore water pressure)	
Other measurements (Category 2, cf. section 4.1.3)		Once a year	Once a year	For measurements that ensure redundancy

Other small water retaining facilities				
		Concrete structures	**Embankments**	**Comments**
Continual visual inspections		2 to 4 times a year	2 to 4 times a year	
Measurements to monitor the behaviour of the facility (Category 1, cf. section 4.1.3)	Deformations (with plumb lines or geodetic measurements)	1 to 4 times a year	Once a year up to once every two years	
	Seepage and drainage water (turbidity)	1 to 4 times a year	1 to 4 times a year	
	Uplift and pore water pressure	1 to 4 times a year (interface between concrete-rock and foundations)	1 to 4 times a year (pore water pressure)	
Other measurements (Category 2, cf. section 4.1.3)		Once a year	Once a year	For measurements that ensure redundancy

Other large water retaining facilities without five-yearly inspections				
		Concrete structures	**Embankments**	**Comments**
Continual visual inspections		Once or twice a month	Once or twice a month	When the reservoir is been filled[3]
Measurements to monitor the behaviour of the facility (Category 1, cf. section 4.1.3)	Deformations (with plumb lines or geodetic measurements)	Once or twice a month	Once or twice a month	When the reservoir is filled
	Seepage and drainage water (turbidity)	Once or twice a month	Once or twice a month	When the reservoir is filled
	Uplift and pore water pressure	Once or twice a month (interface between concrete-rock and foundations)	Once or twice a month (pore water pressure)	When the reservoir is filled
Other measurements (Category 2, cf. section 4.1.3)		Once a month to once every two months	Once a month to once every two months	For measurements that ensure redundancy

3 A reservoir is deemed to be “filled” if the water level reaches the bottom outlet or water intake level, or the upstream foot of the dam if no outlets are available or are at a too high elevation.

Other large water retaining facilities with five-yearly inspections				
		Concrete structures	**Embankments**	**Comments**
Continual visual inspections		Largest facilities: weekly, limited to main components; once or twice a month for other components	weekly	When the reservoir is filled
Measurements to monitor the behaviour of the facility (Category 1, cf. section 4.1.3)	Deformations (with plumb lines or geodetic measurements)	weekly	weekly	When the reservoir is filled
	Seepage and drainage water (turbidity)	weekly	weekly	When the reservoir is filled
	Uplift and pore water pressure	Two to four times a month (interface between concrete-rock and foundations)	Two to four times a month (pore water pressure)	When the reservoir is filled
Other measurements (Category 2, cf. section 4.1.3)		Once a month	Once a month	For measurements that ensure redundancy

Table D3: Recommended frequencies for continual inspections

The respective measurement frequencies are deemed to be complied with if the measurements are carried out automatically and the data are transmitted electronically.

The recommended frequencies for ongoing visual inspections refer to the most important components from the point of view of safety, and to those components that are exposed to the highest loads. In the case of very large water retaining facilities, the visual inspections of other components may be carried out less frequently.

The cited frequencies apply to plausibility checks as well as to the initial evaluation to be carried out by the qualified professional (level 2). They also apply to the evaluation of electronically transmitted measurement data.

Natural hazards that could endanger the water retaining facility or influence its degree of stability have to be examined with the assistance of recognised specialists. This especially concerns issues relating to avalanches, mudslides, landslides, rockfalls and ice falls. Necessary monitoring has to be set-up.

4.2.4. Geodetic measurements

Geodetic measurements form an integral part of level 1 surveillance. Used in combination with other means for detecting deformation, these contribute towards:

- the determination of the behaviour of dams;
- rapid assessment in case of extraordinary situations or following an extraordinary occurrence;
- clarification of causes of anomalous behaviour that has been detected by other measurement instruments.

Continual geodetic measurements

This concerns geodetic measurements for the continual deformation measurements of the water retaining facility. They are carried out by dam wardens or other personnel appointed by the operator.

Precise geodetic measurements

This concerns geodetic measurements for the purpose of supporting the five-yearly inspections. These measurements may only be carried out by specialists who are able to demonstrate that they possess the necessary experience and expertise, as well as the required measurement equipment and evaluation software.

With the aid of precise geodetic measurements it is possible to put in an absolute reference frame the deformations that have been measured using other instruments such as plumb lines and extensometers.

[STK 2013a] contains recommendations for the implementation of these measurements.

Generally speaking, the geodetic network comprises an external reference system in the vicinity of the dam, plus in some cases an extended reference system.

- Geodetic network in the vicinity of the dam: The purpose of this network is to monitor absolute movements in the vicinity of the dam. These geodetic measurements are carried out at least every 5 years, namely in the calendar year that precedes the end of the five-year period. They are carried out at high water level in the reservoir – in the case of concrete structures, each measurement must be carried out at the same time of year.

  A reduced measurement network is generally identified within this network, in the close vicinity. It can be measured within a day and is able to deliver reliable results about the absolute movements of the dam (in some cases with limited precision) in an emergency situation.

  It is also recommended to carry out an additional geodetic measurement at low water level every 15 to 20 years.

- Extended geodetic network: The purpose of this network is to embed the absolute movements in the vicinity of the dam in a large-scale reference frame. It is generally measured less frequently, usually at intervals of 15 to 20 years. This measurement is carried out together with that of the network in the vicinity of the dam. An extended geodetic network is required if the occurrence of large-scale movements cannot reasonably be ruled out.

4.2.5. Inspection of relief and outlet works

The procedure for inspecting the relief and outlet works is dealt with in Part C2 of the Directive.

4.3. Level 2 surveillance

4.3.1. Introduction

Level 2 surveillance represents annual inspections as specified in Article 17, WRFO. These inspections of all water retaining facilities that are subject to the provisions of the WRFA must be carried out by a qualified professional. Here the objective is to verify the good condition and behaviour of the water retaining facility, also based on technical analyses and observations. It encompasses the following activities:

- an initial, continuous evaluation of the results of measurements and observations, together with the results of function checks of the relief and outlet works;
- a visual inspection of the water retaining facility at least once a year
- a detailed evaluation of all available data and written documentation of findings in an annual measurement and inspection report (annual report).

In areas requiring expertise that the qualified professional does not possess, the operator must call on specialists from other fields (geologists, forestry engineers, avalanche experts, etc.) in order to ensure that the inspection is carried out in full.

The qualified professional is also required to advise the operator upon the latter's request concerning issues relating to technical safety.

4.3.2. Profile of the qualified professional

The operator is responsible for choosing the qualified professional. This may be a natural person or a legal entity. The person concerned may be a member of the operator’s staff or a contractor.

The qualified professional must possess the necessary experience and know-how for carrying out the assigned tasks. The requirements may vary, depending on the properties of the water retaining facility (especially the type of dam or its dimensions and structural complexity, and special characteristics regarding its condition and behaviour).

As a rule, the requirements are as follows:

- technical qualifications to suit the properties of the water retaining facility:
  - for large water retaining facilities, education as a civil engineer at university level (Master’s degree from Swiss federal institute of technology or equivalent institution);
  - experience in construction of hydraulic works;
  - for embankment dams, experience in the field of geotechnology;
  - for concrete dams, experience in the field of structural calculations;
- sufficient language skills in order to be able to read and understand previous annual reports and other technical and safety-relevant relevant documents in their original language, as well as to communicate with dam wardens (level 1 surveillance);

- ability to compile reports in the language usually used in technical and safety relevant documents of the facility;
- between 5 and 10 years of experience in the above-mentioned fields in the case of water retaining facilities that are subject to five-yearly inspections in accordance with Article 18, paragraphs 2 and 4, WRFO.

If the position of qualified professional is held by a legal entity (e.g. an engineering bureau), at least one specifically named natural person must possess the qualifications cited above. A less experienced natural person may then be deployed to carry out surveillance level 2 tasks under the supervision of the specifically named natural person.

The operator is required to notify the supervisory authority of its choice of qualified professional. When making this choice, the operator must ensure that the long-term continuity of surveillance is duly secured. The supervisory authority may reject the proposed qualified professional if it has reasonable doubts about the latter's suitability (Article 19, paragraph 1, WRFO).

4.3.3. Annual visual inspection by the qualified professional

The qualified professional is required to carry out a complete and thorough visual inspection of the water retaining facility at least once a year and to subsequently compile an inspection report. The report must describe the conditions under which the inspection was carried out, plus all observations regarding the condition of the water retaining facility, its appurtenant installations (especially the relief and outlet works and the water alarm building or the water alarm observation post), and the various instruments.

As a rule, the inspection report should include photos to illustrate the observations that have been made.

Detailed information about the annual visual inspection must be provided in the surveillance regulations.

4.3.4. Continuous evaluation of measurement results

The operator is responsible for communicating the measurement results to the qualified professional, together with all special observations made by the surveillance level 1 personnel.

The qualified professional must then immediately evaluate the communicated data in order to rule out any potential threat arising from the water retaining facility. He/she must inform the operator about the action that needs to be taken in order to clarify the cause of any anomalous measurements (as a rule, repeat of the measurement concerned). In the event of a potential immediate threat, the qualified professional must immediately notify the operator and instruct the latter to inform the supervisory authority. The operator is responsible for taking the necessary measures to eliminate the threat.

The frequencies cited in Table D3 also apply to the initial evaluation by the qualified professional of the electronically transmitted measurement data.

The data to be analysed by the qualified professional also include the results of the function checks of the relief and outlet works.

4.3.5. Annual report

The qualified professional is required to compile an annual report that contains the following information in particular:

General information

- brief summary of the operation of the water retaining facility in the year under review: hydrological conditions, operation of the reservoir, performed maintenance and servicing tasks, operation of the relief and outlet works;
- precise details regarding any significant occurrences during the period under review that could have a direct or indirect impact on safety – floods, overflows, earthquakes, avalanches, rockfalls, unusually rapid increase or decrease of the water level in the reservoir, construction or other activities;
- comparison of the performed measurements and inspections with those required in accordance with the surveillance regulations - indicating the reasons why if any were not carried out;
- status report regarding recommendations by experienced experts in their five-yearly reports and by the qualified professionals in his/her previous annual reports, as well as measures agreed with the supervisory authority;
- conducted special studies;
- list of new documents to be incorporated into the water retaining facility archive.

Visual inspections

- any significant observations made by the surveillance level 1 personnel during their inspections (change in overall appearance of the water retaining facility, water leakage, signs of slope movements, etc.), including observations concerning the condition and functioning of the measurement instruments;
- any significant observations made by the qualified professional during his/her own inspections;
- a synthesis of the reported observations, plus recommendations concerning the need for additional inspections, maintenance work and other subsequently required action.

Results and evaluation of measurements

- detailed description of interventions in the measurement system (calibration, modifications, etc.);
- graphic depiction of measurement results;
- analysis of measurement results (with comments), with the aim of identifying tendencies or anomalies in the behaviour of the water retaining facility. In the case of large concrete dams, for a number of key points, monitoring of the behaviour has to be carried out with the aid of behaviour prediction model [STK 2003] and [BFE 2008];

- a synthesis of the measurement results and subsequently required action (additional inspections, calibration or modification of instruments, installation of additional instruments, increase in measurement frequency).

Results of testing of relief and outlet works

- results of function tests, with analysis;
- needs resulting from the analysis of function tests.

Overview

- summary and analysis of all observations, measurements and tests, with conclusions regarding the condition and behaviour of the facility, its surroundings (banks) and auxiliary installations – any deviations from standard behaviour or normal condition must be clearly emphasised;
- inclusion of already cited recommendations, where necessary with additions;
- overall safety assessment.

Enclosures

- plans and diagrams: key data relating to the water retaining facility and the relief and outlet works, list and brief description of measurement equipment (diagrams and extracts from plans), overview plans of the water retaining facility (reductions or extracts), overview of the most important levels, volumes, heights, capacities of the relief and outlet works;
- qualified professional's inspection report, including enclosures where applicable;
- reports of function tests of the relief and outlet works;
- minutes of meetings at which representatives of the supervisory authorities were in attendance;
- report on continual geodetic measurements if applicable.

4.3.6. Delivery of annual report and implementation of recommendations made by the qualified professional

The operator must submit the annual report to the relevant supervisory authority by the deadline specified in the surveillance regulations. If the water retaining facility is required to undergo five-yearly inspections, the report must also be submitted to the experienced experts and, where applicable, other involved specialists.

In each report or together with the report, the operator must also indicate how and when the recommendations by the qualified professional will be implemented.

4.4. Level 3 surveillance

4.4.1. Introduction

Level 3 surveillance represents the comprehensive (five-yearly) safety inspection as specified in Article 18, WRFO. It has to be carried out at large water retaining facilities that meet the size criteria as specified in Article 18, paragraph 1, WRFO, or if formally requested

by the supervisory authority. It must be carried out by an experienced structural engineering expert and an experienced expert in geology.

The objective of the five-yearly inspection is to verify the normal behaviour and good condition of the water retaining facility in depth and independently, taking account of the facility's long-term behaviour. The inspection must include:

- an in-depth analysis of the condition and behaviour of all components of the water retaining facility that influence its technical safety (including the facility's surroundings), taking account of the correlations between the visual observations and the measurements;
- a safety assessment of the facility reflecting the development of science and technology (especially with respect to extreme floods, earthquakes, materials);
- verification that the facility is still safe to operate;
- recommendations for the attention of the operator, especially regarding maintenance, structural measures, instruments or the performance of supplementary investigations or studies.

4.4.2. Profiles of the experienced experts

Experienced experts are natural persons who have been chosen by the operator and approved by the supervisory authority (Article 19, paragraphs 2 and 3, WRFO).

They must possess sufficient experience and know-how for carrying out the in-depth safety assessment. The requirements may vary, depending on the properties of the water retaining facility (especially the type of dam, its dimensions and structural complexity, and special characteristics regarding its condition and behaviour).

As a rule, the civil engineering expert has to meet the following requirements:

- hold a Master's degree in civil engineering from a Federal Institute of Technology or university;
- have 10 years of experience in planning, constructing or surveillance of dams;
- experience as for level 2;
- comprehensive theoretical knowledge and practical experience in those areas of relevance to the water retaining facility concerned, for example: rock mechanics, geotechnology, bituminous linings, concrete technology, structures, behaviour analyses, hydrology, hydraulics.

As a rule, the geology expert has to meet the following requirements:

- hold a Master's degree in geology or applied geology from a university;
- 10 years of experience in engineering geology or applied geology;
- comprehensive theoretical knowledge and practical experience in those areas of relevance to the water retaining facility concerned, for example: rock mechanics, geotechnology, hydrogeology, natural hazards;
- familiarity with the geology of the region concerned.

In addition, both experts must meet the following requirements:

- in the case of water retaining facilities of particularly high importance or those that display particularly complex behaviour or characteristics, the experts must possess clearly demonstrated experience at surveillance level 3 in other water retaining facilities (five-yearly inspections), and in exceptional cases at surveillance level 2.
- sufficient language skills in order to be able to read and understand annual reports and other technical and safety-relevant documents relating to the water retaining facility in their original language, as well as to communicate with the qualified professional (surveillance level 2) and the dam wardens (surveillance level 1).
- ability to compile their reports in one of Switzerland's official languages (preferably in the language used for the preparation of technical and safety-relevant documentation) - in English only by way of exception.

The experienced experts must also be independent of the qualified professionals, the operator and the owner, in order to ensure that an independent safety assessment of the water retaining facility is carried out with reference to the other ongoing analyses ("four-eyes" principle). Their independence also ensures that an effective or apparent conflict of interests with the other involved players can be avoided (Article 19, paragraph 3, WRFO). Experts are inadmissible if they are closely related to, subordinated to or economically dependent on the owner of the water retaining facility, the qualified professional or a member of the operational management, or generally speaking if any forms of conflict of interests should exist. The supervisory authority is responsible for verifying the necessary independence. Any changes concerning these criteria must be reported to the supervisory authority.

4.4.3. Five-yearly site inspection

At the end of each five-year reporting period, the operator has to organise a site inspection of the water retaining facility. The objective here is to secure an exchange of findings regarding the condition and behaviour of the facility between the operator, the dam wardens, the qualified professional, the geodetics specialist, the experienced experts and the supervisory authority, as well as to identify special action to be included by the experts in their reports. The extent of a five-yearly site inspection and the topics to be discussed at the experts' meeting are described in enclosure 2.

A five-yearly site inspection does not take the form of a detailed technical control. It does not replace either the annual visual inspection or continual visual inspections.

As a rule, the geology expert carries out his/her detailed inspection prior to the five-yearly site inspection, and passes on his/her observations to those involved either before or during the five-yearly inspection.

4.4.4. Five-yearly report

The operator is responsible for granting the experts access to the facility where necessary and for providing them with the documentation they require for carrying out their in-depth safety assessment and compiling their five-yearly report. This includes:

- the surveillance, gates and emergency regulations;
- annual reports;
- reports on precise geodetic measurements;
- other studies and reports of relevance to safety.

In their comprehensive safety inspections, civil engineering experts have to:

a) address the condition of the water retaining facility and its appurtenant installations;

b) analyse the behaviour of the dam, its foundations (rock deformation, leaks, quantities of drainage water, uplift and pore water pressure) and their condition, including the condition of the grout curtain during the five-year period, comparison with the long-term behaviour of the water retaining facility and analysis of specific measurements (movements, leaks, pressure measurements);

c) evaluate the measurement equipment and, where necessary, propose improvements for measurements and the associated programme;

d) assess the degree of safety of the water retaining facility to extraordinary events (especially floods, earthquakes, landslides);

e) make recommendations regarding additional studies to be carried out (e.g. with respect to hydrology, flood safety, earthquake safety), or the need for structural or operational measures.

In their comprehensive safety inspections, geology experts have to:

a) analyse the behaviour of the subsurface structure of the dam during the five-year period, compare the long-term behaviour of the water retaining facility and analyse specific measurements (rock deformation, leaks, quantities of drainage water, various pressures), analyse the condition of the dam foundations, including the condition of the grout curtain;

b) examine the stability of the valley slopes in the vicinity of the reservoir and dam, including an analysis of the risks that could arise and result in mass flows into the reservoir which could block access to the discharge systems or prevent them from functioning correctly;

c) assess the safety measures of the rock surfaces and the maintenance of the galleries in the rock mass, and where necessary make recommendations regarding work that needs to be carried out, or concerning more effective organisational measures;

d) analyse the regional seismic activity during the period under review;

e) evaluate the measurement equipment for the dam foundations and valley slopes in the vicinity of the reservoir, and where necessary make recommendations for improvements or regarding the measurement programme;

f) recommend studies to be carried out (for example, regarding the presence of permafrost, the risk of impulse waves caused by masses falling into the reservoir), or the need for structural or operational measures.

If the operator so desires, or if a decision is taken at the site inspection meeting, the experts may be required to supplement their reports with special analyses.

4.4.5. Precise geodetic measurements

As a rule, a precise geodetic measurement is carried out in the year prior to the five-yearly site inspection. The corresponding geodetic report is then handed over to the participants before the commencement of the inspection.

4.4.6. Delivery of five-yearly reports and implementation of recommendations made by the experienced experts

The operator must submit the five-yearly reports of the structural engineering expert and geology expert by the deadline specified in the surveillance regulations. A copy must also be submitted to the qualified professional.

The operator must include a memo with each report stating how and when the experts' recommendations are to be implemented.

4.5. Level 4 surveillance

4.5.1. Introduction

The supervisory authority represents the level 4 surveillance. Its duty is to ensure that the operator complies with the applicable safety regulations. In particular:

- it checks and approves the surveillance, gates and emergency regulations;
- it ensures that the continual, annual and five-yearly inspections, as well as the function tests of the relief and outlet works, are carried out in accordance with the provisions of the surveillance regulations;
- it ensures that the measurements and visual inspections, as well as the function tests of the relief and outlet works, are carried out professionally in accordance with the latest status of science and technology;
- it verifies the plausibility of the measurements and observations and their analysis and interpretation, as well as the conclusions drawn from the annual and five-yearly reports;
- it ensures that the operator keeps the facility archive up to date;
- it assesses the condition and behaviour of the water retaining facility based on the safety reports, and validates the findings of these reports by carrying out on-site inspections and participating from time to time in function tests of the relief and outlet works;
- it orders the implementation of structural or operational measures and special studies if this is deemed necessary for safety reasons;
- it maintains regular contact with the facility's operator and personnel, as well as its designated contractors, and supports them where necessary.

4.5.2. Examination of the annual report

In its examination of the facility's annual report, the supervisory authority ensures that the aspects cited in section 4.3.5 have been dealt with clearly and comprehensively.

It pays special attention to the development of the condition of the water retaining facility and to any extraordinary occurrences that had to be dealt with by the safety management personnel.

It assesses the recommendations included in the annual report, together with the responses on the part of the operator. Where necessary it orders the implementation of measures that have been recommended by the qualified professional, or other measures it deems necessary.

It determines whether the operator has complied with the provisions of the surveillance regulations, both during normal operation of the facility and in the wake of extraordinary occurrences. It ensures that the operator has taken any necessary corrective measures. And it ensures that the legal provisions governing the safety of the water retaining facility have been duly complied with.

4.5.3. Examination of five-yearly reports

In its examination of the facility's five-yearly reports, the supervisory authority ensures in particular that the aspects cited in section 4.4.4 have been dealt with clearly and comprehensively.

It pays special attention to the development of the condition and behaviour of the water retaining facility, and to declarations and substantiations cited in the reports.

It assesses the recommendations included in the reports together with the responses on the part of the operator. Where necessary it orders the implementation of measures that have been recommended by the experienced experts, or other measures it deems necessary. And it ensures that the legal provisions governing the safety of the water retaining facility have been duly complied with.

4.5.4. Inspections by the supervisory authority

During its inspections, which have to be carried out at the intervals specified in Article 23, WRFO, the supervisory authority examines the central components of the dam and its safety-relevant appurtenant installations. In particular it inspects the most important measurement instruments and those components with special status or behaviour (including the abutments and banks that indicate special characteristics).

Visual inspections may be carried out during the annual inspection by the qualified professional or at another time. In the former case, the responsible representative of the supervisory authority carries out his/her own inspection (possibly the same path as the qualified professional).

It is recommended that the supervisory authority should participate in the function tests of the relief and outlet works of large facilities at least once every five years.

5. Archive

5.1. Content

The operator is required to maintain and constantly update an archive pertaining to the water retaining facility and to ensure that it can be accessed without delay when necessary. The

content of this archive is specified in Article 22, paragraph 2, WRFO and described in enclosure 3 (see also [STK 2005]).

The supervisory authority is responsible for deciding whether the subsequent inclusion of missing documentation in the archive may be waived, for example in favour of the creation of a dam monograph.

5.2. Location of the archive

The archive must be created and kept by the operator. Its content may be in paper and/or electronic form.

The documentation does not necessarily have to be kept or stored at a single location, but a complete overview must always be available (detailed register of documents in the archive).

6. Notifications to the supervisory authority

6.1. Notification regarding maintenance/renovation work

Extensive maintenance operations (in terms of duration or size) or the replacement of components of the water retaining facility are classified as renovation work. The operator is obliged to notify the supervisory authority by a reasonable deadline about renovation work involving components for ensuring technical safety so that the latter can examine the documentation where necessary, request additional information and/or intervene prior to commencement of the work concerned. This concerns work relating to category 1 instruments (in accordance with section 4.1.3), the relief and outlet works and the water alarm system which falls within the scope of responsibility of the supervisory authority (cf. Part E of the Directive).

If such work would alter the functionality of a safety-relevant system (including the interpretation of measurements), the operator must obtain the prior approval of the supervisory authority.

The operator must ensure that the technical safety of the facility is also assured during renovation work. In the course of renovation work on the relief and outlet works the operator must ensure sufficient flood safety and that the option of lowering the water level in the reservoir in the case of an impending threat can be rapidly reinstated.

6.2. Notification regarding malfunctions and operating anomalies

All malfunctions and operating anomalies of relevance to safety must be reported to the supervisory authority so that it can carry out its own inspection where necessary and thus make sure that the water retaining facility can continue to be operated safely, or that it is able to answer any questions that may be posed by politics and the media.

The operator must notify the supervisory authority by the following deadlines (subject to other emergency regulations):

- **Immediate** notification in the event of major malfunctions and operating anomalies (severe damage to the water retaining facility or third-party property, or resulting or anticipated severe or fatal injuries).
- Notification **within 24 hours** in the event of serious malfunctions and operating anomalies (significant damage to the water retaining facility or third-party property, or the risk of, or resulting or anticipated, minor injuries).
- Notification **within 5 days** in the event of minor malfunctions and operating anomalies (minor damage to the water retaining facility or third-party property has occurred or is anticipated, without the risk of injuries).

Natural and other occurrences that could influence the safety of the facility (for example, signs of a landslide that could form a natural dam above the reservoir, or the threat of an ice fall) must also be reported according to the scheme above.

6.3. Other notifications

The operator is obliged to notify the supervisory authority about all other activities of relevance to safety, or which could influence its stability. This includes the dates when testing the relief and outlet works, the annual and five-yearly inspections of the facility, and an emptying of the reservoir.

These activities must be reported to the supervisory authority sufficiently in advance to allow its representative to participate in them if deemed necessary.

7. References

Abbreviation	References
ICOLD 2014	Bulletin 158: Dam supervision guide
STK 1997a	Zustandsüberwachung von Stauanlagen und Checklisten für die visuellen Kontrollen, Arbeitsgruppe Talsperrenbeobachtung, 1997
STK 1997b	Geodätische und photogrammetrische Deformationsmessung für die Überwachung der Stauanlagen, Arbeitsgruppe Talsperrenbeobachtung (French / Englisch) 1997 German version in: “wasser energie luft” 85. 1993, issue no. 9, pp. 181 to 242
STK 2001	Talsperrenmonographie - Empfehlungen für die Redaktion, Arbeitsgruppe Talsperrenbeobachtung, 2001
STK 2003	Analysemethoden für die Vorhersage und Kontrolle des Verhaltens von Talsperren, Arbeitsgruppe numerische Methoden in der Analyse des Verhaltens von Talsperren, 2003
STK 2005a	Messanlagen zur Talsperrenüberwachung: Konzept, Zuverlässigkeit und Redundanz, Arbeitsgruppe Talsperrenbeobachtung, April 2005 (Teil 1: Messkonzept; Teil 2: Messanlagen und Messmethoden; Teil 3: Kommentarblätter)
STK 2005b	Aktensammlung über die Stauanlage, Arbeitsgruppe Talsperrenbeobachtung, Mai 2005
STK 2013a	Geodäsie für die Überwachung von Stauanlagen, Arbeitsgruppe Talsperrenbeobachtung, 2013
STK 2013b	Messgeräte – Kontrollieren und Kalibrieren, Arbeitsgruppe Talsperrenbeobachtung, 2013
STK 2015	Role and duties of Dam Warden, Working Group on Dam Surveillance, 2015
Swiss Federal Office of Energy 2008	DamReg: User manual & software application. B. Weber, 2008 (SFOE website)

Enclosure 1: inspections following an earthquake

1. Principles

The aim of inspections following an earthquake is to be able to take any required immediate action to protect people and property. This means that any damage or changes in behaviour of the facility have to be identified as quickly as possible. The urgency and degree of detail of the necessary inspections depend on the intensity of the earthquake at the location of the water retaining facility. The following three levels of intervention have been defined and are described in greater detail in section 3:

Intervention level 1: continual inspections, at latest within 2 weeks.

A complete visual inspection of the dam and its surroundings has to be carried out as part of the next continual inspection, within 2 weeks following the earthquake. The supervisory authority must be notified about the occurrence and any measures that may have been taken.

Intervention level 2: on-site inspection within 24 hours.

The qualified professional, experienced experts (in the case of water retaining facilities required to carry out five-yearly inspections) and the supervisory authority must be immediately notified about the occurrence and any measures that may have been taken.

Intervention level 3: immediate on-site inspection.

The qualified professional assists the operator on site at his request. The experienced experts (in the case of water retaining facilities required to carry out five-yearly inspections) and the supervisory authority must be immediately notified about the occurrence, the results of the inspection and any measures that may have been taken.

2. Intervention level thresholds

Different thresholds apply with respect to the way in which the intensity of the earthquake on site is determined. The thresholds are lower if the intensity had to be estimated than if it was obtained using accelerographs at the dam site so as to take uncertainties into account.

2.1. Dams equipped with accelerographs

The thresholds indicated in this section apply to dams that are equipped with at least three accelerographs that are permanently connected to an internal on-call or similar service. The peak accelerations measured at the dam site serve as the basis for deciding on allocation to one of the three intervention levels. The corresponding threshold is considered to have been reached if at least two of the accelerographs display peak readings above the levels shown in the table below[4]:

4 Highest reading of the 3 orthogonal directions

Intervention level	Peak acceleration measured in rock (abutment or free-field)	Peak acceleration measured in or on dam
1	> 10% a_h	> 20% a_h
2	> 25% a_h	> 50% a_h
3	> 50% a_h	> 100% a_h

a_h = peak ground acceleration for which the verification of earthquake safety of the dam in accordance with Part C3 of the Directive was satisfactorily carried out.

2.2. Dams without accelerographs

The following thresholds apply to dams that are not equipped with accelerographs or are equipped with less than three, or are not permanently connected to an internal on-call or similar service. These levels are based on movements perceived on site at the dam and in its immediate vicinity in accordance with the intensities defined by Medwedew, Sponheur and Kamik (MSK),

Intervention level	MSK intensity on site	Description of intensity
1	IV	Normally felt by people in buildings, interruption to sleep. Rattling windows.
2	V – VI	Normally felt by people outdoors, may cause alarm. Damage to plaster on buildings, possible damage to chimneys, oscillation of suspended objects, pictures dislodged.
3	≥ VII	Large numbers of people flee from buildings, general alarm or panic. Moderate to severe damage to buildings.

If the operator receives a report from the supervisory authority concerning the intensity of an earthquake at the site of the dam, the applicable intensity is the one that indicates the higher of the levels ascertained by the supervisory authority and estimated on site based on the ground tremors.

2.3. Exceptions

If the requirements for earthquake safety of a water retaining facility are not totally satisfied, the thresholds are then reduced upon consultation with the supervisory authority.

2.4. Damage and anomalous behaviour

If damage or anomalous behaviour should become apparent, the operator must immediately notify the qualified professional. An immediate on-site inspection then has to be carried out in accordance with the criteria for intervention level 3.

3. Extent of post-earthquake inspections

The extent of inspections to be carried out after an earthquake must be specified in the surveillance regulations. These inspections are based on the following principles.

3.1. Inspections for intervention level 1

At this level, damage to the dam is unlikely. The purpose of the inspection is to identify any changes in the condition and behaviour of the dam and its immediate surroundings. It takes the form of a visual inspection of the dam, its foundations and the banks of the reservoir, plus an interpretation of the main results of the behaviour measurements (displacements in relevant cross-sections, uplift pressure, seepage). Any existing electronically transmitted measurement data must be analysed immediately after the event, while data that are not electronically transmitted have to be analysed as soon as they are available.

3.2. Inspections for intervention level 2

Damage to the dam which could threaten the safety of the facility is unlikely, but cannot be entirely ruled out. Limited damage is also possible that does not affect the stability of the dam but which could hamper a rapid response in an emergency (for example, power supply, access to machinery).

Here the main objective is to detect any change in the behaviour of the dam and its immediate surroundings, or any signs of a gradual change in behaviour. The inspections take the form of a comprehensive visual inspection of the dam, its foundations, the banks of the reservoir, the appurtenant installations, the equipment and instruments required in case of emergencies, and an interpretation of the results of measurements of category 1 and 2 instruments in accordance with section 4.1.3 of the Directive.

It has to be decided on a case by case basis whether a check of the functions of the gated relief and outlet works needs to be carried out.

For embankment dams, the inspections have to be repeated over a period of time that has to be defined by the qualified professional, the experienced experts (for dams with five-yearly inspections) or the supervisory authority.

3.3. Inspections for intervention level 3

Damage that could threaten the safety of the facility in the short term is unlikely, but cannot be ruled out, especially if an extreme earthquake has occurred. Here it is necessary to carefully determine the extent to which the long-term stability of the dam may be affected.

An earthquake that corresponds to level 3 is an extreme loading to which the structure has probably never been exposed. This means that the corresponding behaviour of the dam is entirely unknown. It is therefore essential to carry out a careful, complete and immediate inspection.

The extent of the inspections is the same as the extent described for level 2. The results of all available measurements have to be taken into account.

As a rule, an inspection of the relief and outlet works has to be carried out in order to ensure that they are still functioning correctly.

All inspections must be carried out immediately and repeated over a timeframe to be specified by the supervisory authority, the qualified professional or the experienced experts (for water retaining facilities with five-yearly inspections).

4. Checklist for post-earthquake inspections

A checklist of the aspects to be taken into account when compiling programmes for post-earthquake inspections is available in ICOLD/CIGB Bulletin 62 (post-earthquake inspection of dams – recommendations) [ICOLD 1988]. The main elements are cited below.

4.1. Structural damage

<u>Embankment dams</u>

- thorough inspection of embankments and their slope protections;
- search for any signs of landslides, cracks, subsidence, uplifts or slippage, presence of sink holes;
- recording of signs of surface or internal erosion, an increase or decrease in pore water pressure or seepage and drainage water, increase in the turbidity of the seepage and drainage water;
- recording of water springs or moist zones, deposits of materials;
- inspection of the abutments (observation of any landslides or rockfalls, new water sources and seepage).

Concrete dams

- thorough inspection of the dam faces;
- search for new cracks (at the surface and in the galleries) and relative movements of joints;
- recording of an increase or decrease in uplift pressure or quantities of seepage and drainage water, increase in the turbidity of seepage and drainage water;
- inspection of the abutments (observation of any landslides or rockfalls, new water sources and seepage).

Spillway and outlet works

- inspection of the condition of the rock faces above the run-off channel of the spillway;
- recording of cracks formation, search for signs of movement of structures or parts thereof (guide walls, channel beds, bridges, dividing piers, overflow threshold, outlets);
- inspection of the stilling basin of shafts, galleries and channels of the discharge facilities;
- inspection of the condition of appurtenant installations, water catchments, grates, outlets, thresholds, metal pipelines, pumps, motors, valve chambers, standing and mobile cranes, steering equipment, lighting, ventilation. Functional tests under dry conditions of the gates and hydromechanical equipment (if present);

Movements on active faults

- inspection of outcrops of active faults and in galleries and caverns.

Instability of banks

- inspection of the banks of the reservoir in order to detect any potential landslides, rockfalls, etc);

Access ways

- inspection of access ways to the dam and galleries.

4.2. Damage to installations

Electricity supply

- inspection of the main power supply and the operating status of the backup generators, plus the internal electricity supply lines;
- inspection of the lighting systems in the premises required for the safe operation of the facility.

Communication, electronic transmission and remote control equipment

- verification of the availability of communication equipment;
- verification of the operating status of the electronic transmission system for measurement instruments that are required for making an immediate behaviour assessment;
- inspection of the operating status of remote control equipment for safety installations (especially outlets).

4.3. Evaluation of measurements

If damage has been detected or if unusual behaviour of the dam is suspected, a complete series of measurements has to be carried out, regardless of the intensity of the earthquake felt on site. The condition of each instrument has to be checked in order to ensure that the performed measurement is accurate. Measurements must be verified as soon as possible (preferably on site) and immediately evaluated in order to make an initial assessment of the dam's behaviour.

If possible, a subsequent analysis of the water surface movements should be carried out in order to assess the degree of wave generation in the reservoir during or immediately after the earthquake.

4.4. General condition of measurement equipment

During the visual inspection it is also necessary to check the measurement equipment, even if it is not required to perform measurements.

Enclosure 2: Five-yearly site inspection

As a rule, the five-yearly site inspection encompasses the following activities:

- visual inspection of the most important components of the facility from the point of view of technical safety, plus the components that display a special status or special behaviour and those that have been (or are to be) the focus of maintenance or other work;
- inspection of the premises for the operation of the outlets;
- inspection of the water alarm centre and/or the water alarm observation site;
- inspection of potentially unstable zones around the reservoir.

During the inspection, the geology expert has to summarise the geological features of the water retaining facility.

During the inspection, the geodetic specialist has to explain the installed geodetic network and the most significant results.

The topics to be discussed during the meeting of the five-yearly site inspection include:

- documents and reports: documents that the operator has submitted to the supervisory authority [supervisory authority];
- special occurrences: special operational occurrences, performed works, significant natural occurrences [operator and qualified professional];
- recommendations of the experts regarding the previous five-year period: recall of the recommendations formulated in the previous five-yearly reports, including indication from the operator regarding on how they have been addressed [experts and operator];
- geology [geology expert];
- condition of the dam [qualified professional and civil engineering expert];
- function tests of the relief and outlet works (qualified professional);
- geodetic measurements [geodesy specialist];
- behaviour of the dam [qualified professional and civil engineering expert]
- instruments and measurement frequency [dam warden, qualified professional, experienced experts, supervisory authority];
- earthquake safety;
- flood safety;
- other special studies;
- planned work [operator];
- deadlines for submission of reports [supervisory authority].Enclosure 3: details regarding content of archive

See also [STK 2005b] – Aktensammlung über die Stauanlage, Arbeitsgruppe Talsperrenbeobachtung, Mai 2005.

Enclosure 3: Detailed content of dam's archive

a) The main drawings of the facility as-built and details relating to the construction

At least a situation plan of the water retaining facility, descriptive cross-sections of the various components of the facility, views and cross-sections of the outlets and spillways, a detailed description of the monitoring system, an overview plan of the reservoir and in general all necessary plans for providing a complete description of the facility.

Alterations to the water retaining facility have to be reflected in the existing or supplementary plans.

The details relating to the construction of the facility have to encompass the encountered conditions for the foundations, the utilised materials, construction schedule and in general all documents relating to the construction phase that are necessary for providing a complete description of the facility.

b) The agreement between the owner and the project developer concerning the planned utilisation (utilisation agreement)

If available, utilisation agreement in accordance with SIA standard 260 (2013 version) or equivalent.

c) Description of the practical implementation of the utilisation agreement (project basis)

A document summarising the bases of the project: the applicable loads for static and dynamic analyses, the mechanical properties of the foundations, the material properties, flood hydrographs, etc.

d) Structural, hydrological and hydraulic calculations and reports

Structural calculations and reports, especially calculation assumptions, applied calculation methods and the obtained results. Analyses concerning the verification of earthquake safety and all subsequent structural examinations, whether of a general nature or specific to an alteration of the structure, form an integral part of the archive.

Hydrological analyses during the planning of the water retaining facility, and all subsequent hydrological studies.

Hydraulic verifications: calculations of the capacity of the relief and discharge systems, flood routing, sedimentation studies, hydraulic model tests, etc.

e) Geological reports

Geological reports from the planning and construction phases, including the corresponding geological plans and cross-sections, plus subsequent geological studies of the abutments and foundations, banks and reservoir.

f) Commissioning report

The report submitted to the supervisory authority, plus other commissioning reports following alterations to the water retaining facility.

All correspondence relating to the commissioning licence and the approval of various documents and regulations requiring the approval of the supervisory authority form an integral part of this section of the archive.

g) Annual reports, and reports on geodetic deformation measurements

Annual reports since commissioning, as described in section 4.3.5.

Reports on geodetic measurements carried out since the initial reference measurement.

h) Five-yearly reports

For water retaining facilities required to carry out five-yearly inspections, reports from the civil engineering and geology experts, plus accompanying memos from the operator as described in section 4.4.4.

i) Reports on malfunctions and operating anomalies

Reports concerning malfunctions and anomalous behaviour that are of relevance to technical safety and have been submitted to the supervisory authority. If preferred, these documents may also be incorporated into the annual reports.

j) Surveillance, gates and emergency regulations

All versions of these three documents: the currently valid version must be clearly designated as such.

k) Dam monograph [STK 2001]

If a dam monograph was compiled (summary of the main plans, characteristics of the facility, reports on its condition and behaviour).