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A report from Swedenergy

Swedenergy's dam safety guidelines

RIDAS

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Foreword

Swedenergy takes dam safety issues very seriously.

Our dam safety activities are continuously evolving alongside our work developing dam safety guidelines and application guidance – RIDAS. With our activities in the area – including education, support for development projects, seminars and information days – Swedenergy aims to encourage good dam safety in all companies.

RIDAS was first published in 1997. It was created partly in order to refine the dam safety recommendations and guidance that existed at the time, making them more generally applicable and more comprehensive. New editions were published in 2002, 2008 and 2012.

Due to special dam safety rules that were introduced in the 2014 Environmental Code, chapters 1 – 3 were revised in the 2016 edition of RIDAS. The revisions primarily concerned the classification of dam facilities and safety management systems.

With the edition RIDAS 2019, the thorough revision that was initiated by RIDAS 2016 was completed. Some chapters were added, there were clearer links to the underlying legal requirements, and there were more references to relevant standards.

This edition is the result of a review undertaken after the application guidance work was completed in 2021, also taking into account the 2022 edition of the Swedish guidelines for design flood determination for dams.

From now on, the publication is called RIDAS, without year in the document's title. Revision month and year, which can be found on the cover page and in the header, denotes the edition.

Stockholm 25 April 2022

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CEO

Contents

1. Introduction

Hydropower activities are governed by various laws, ordinances, regulations and guidelines. The expectations of civil society and public acceptance affect how the activity is pursued. It is of major importance to prioritise *safety*[1].

Swedenergy and its *member companies* take *dam safety* issues very seriously. Swedenergy encourages good dam safety among the member companies by issuing RIDAS, the dam safety guidelines. The guidelines form the basis of good industry-practice dam safety activities for member companies covering working methods and technical solutions, and they can also be used to assist the authorities.

Dam safety activities develop over time, taking into account experience, research and development. The first edition of RIDAS was published in 1997. RIDAS was subsequently revised in 2002, 2008, 2012, 2016 and 2019.

Edition RIDAS 2019 entailed a comprehensive revision with an update of the main document and application guidance documents to reflect new legislation and relevant standards. The revision in May 2020 included a new section 4.7, the clean-up of concepts and corrections of footnotes, etc. In this revision, sections 4.3-4.5 and 5-5.1 have been updated in accordance with the application guidance for Chapters 4 and 5. In January 2025, RIDAS was published in a new layout. The content is the same. Minor corrections and adjustments have been made.

The introduction below presents Swedenergy's approach to dam safety and describes the responsibilities of a dam owner under the legislation, the roles of certain authorities, and the applicability and structure of the guidelines.

1.1 Dam safety

The prerequisites for high standards of dam safety are designing and constructing dams with reasonable safety margins; operating and maintaining them safely; and having *emergency arrangements* to address situations that arise.

The safety of a dam facility depends on the combined function of the technical systems, the organisation and the people responsible for operating the systems. Dam safety encompasses complex issues, and the *People, Technology and Organisation* (PTO) system perspective and information management are important starting points.

The focus of dam safety activities is to reduce not only the *likelihood* of *dam failure* occurring, but also the *consequences*.

Dam safety activities are planned on the basis of an analysis of operational risks and an assessment of safety. The analysis is based on knowledge of and an evaluation of

[1] The words in italics are described in application guidance document 1 - RIDAS Terminology.

the design, performance and condition of the dam facilities and the consequences in the event of failure.

There are uncertainties as to the nature of dam facilities and the loads to which they may be exposed. A cautious approach and safety margins should therefore generally be used in dam safety activities.

1.2 Responsibility of the dam owner under the environmental code and the civil protection act

1.2.1 Burden of proof, knowledge requirements, precautionary approach and technology[2]

Persons who pursue an activity or undertake measures must be able to demonstrate compliance with obligations under the Environmental Code. The general rules include requirements about knowledge, protection measures and precautions in the activity, as well as requirements about using the best possible technology. These requirements are weighed against the cost in an assessment of reasonableness.

1.2.2 Permission and maintenance obligation with strict liability in the event of failure[3]

Permission is required in order to carry on water operations, which include the construction, modification, repair and removal of dams. The owner of a water regulation *dam* is required to maintain it so that public or private interests are not harmed by a change in water conditions. The maintenance responsibility entails an obligation to pay compensation for damage due to *dam failure* (strict liability).

1.2.3 Self-regulation and supervision[4]

The *operator* must establish a defined and documented allocation of organizational responsibility. For all dams, the operator must continuously plan and monitor the activity in order to counteract or prevent any detriment to health or impact on the environment. Self-regulation must be documented, and the county administrative board must be informed promptly of any *operational disturbances* which might have adverse effects. At the request of the county administrative board, the operator must provide the information and documents necessary for *supervision*.

2 Miljöbalken (1998:808) 2 kap. 1–3 §§, 7 §.

3 Miljöbalken (1998:808) 11 kap. 9, 17–18 §§.

4 Miljöbalken (1998:808) 26 kap. 19 och 21 §§ och Förordning (1998:901) om verksamhetsutövares egenkontroll 4–6 §§.

1.2.4 Safety classification, safety management systems and reporting requirements[5]

A dam is assigned a *dam safety class* A, B or C if the damage caused by failure has more than minor significance for civil society. The dam owner carries out a *consequence assessment* and suggests a dam safety class, on which the county administrative board then bases its decision. If dams in dam safety class A, B or C are included in the activity, there are requirements concerning the safety management system, *overall assessments*, and annual dam safety reporting to the country administrative board.

1.2.5 Warnings, dangerous activity and notifications[6]

Anyone who discovers an accident such as a dam failure that presents a danger to human life or health or to the environment has an obligation to *warn* those in danger. If the county administrative board decides that a *facility* constitutes a *dangerous activity*, the owner is required to analyse the risks of accidents, to maintain or fund reasonable arrangements to undertake the necessary measures to prevent or limit serious damage. In the event of an accident or an imminent risk of accident, there are also obligations concerning warnings to the public and *notifications* and information to the municipality, the police, the county administrative board and the Swedish Civil Contingencies Agency (MSB).

1.3 Roles of certain authorities

The municipality determines how its land and water areas are used by formulating area regulations and detailed development plans. The municipality also draws up overview plans which set out the principles for the future use of land and water areas. The municipality strives for high-quality and safe living conditions and a living environment which is sustainable in the long term. The Planning and Building Act contains relevant provisions.[7]

The municipality is responsible for planning and running emergency services, for example dealing with high flows and floods potentially caused by precipitation or dam failure. If a flood or a dam failure occurs, the emergency services are responsible for preventing or limiting injury or damage to people, property and the environment. The municipality conducts *supervision* of operators in accordance with the Civil Protection Act.[8]

5 Miljöbalken (1998:808) 11 kap. 24–26 §§ och Förordning (SFS 2014:214) om dammsäkerhet.

6 Lagen (2003:778) om skydd mot olyckor 2 kap. 1, 4 och 5 §§ samt Förordning (1998:901) om verksamhetsutövares egenkontroll 6 §.

7 PBL – Plan och bygglag (2010:900).

8 Lagen (2003:778) om skydd mot olyckor.

The county administrative board is the supervisory authority for water operations and water structures involving dam safety. The *supervision* includes, to the extent necessary, verifying compliance with the Environmental Code, ordinances, regulations, water and environmental permits and other decisions issued in pursuance of the Environmental Code. The supervision also includes undertaking the necessary measures to correct deviations, for example by providing advice and information to operators and issuing injunctions.

The county administrative board may in certain situations also appoint an emergency commander and take responsibility for emergency services. The county administrative board is also responsible for coordinating emergency preparedness and provides a link between organisations at local, regional and national level.

The county administrative board reviews the municipality's decisions about detailed development plans in terms of health and safety and the risk of accidents.

Svenska kraftnät is the authority responsible for promoting dam safety. Its duties include providing supervisory guidance to county administrative boards on dam safety issues as described in Chapter 11 of the Environmental Code, issuing regulations and guidance documents concerning the Ordinance on dam safety[9], supporting the development of emergency management activities, and promoting research, development and knowledge sharing. Svenska kraftnät is also the national authority of power outage preparedness and safety protection in the supply of electricity.

The Swedish Civil Contingencies Agency (MSB) develops and supports society's preparedness against accidents and crises and is a driving force in the work with preventive and vulnerability-reducing measures. When a serious accident or crisis occurs, the MSB provides support to those responsible for managing the crisis. The MSB has a central supervisory responsibility under the Civil Protection Act and provides advice, support and guidance to all organisations affected by this legislation.

SMHI is responsible for meteorological and hydrological forecasting and warning services occasionally acting as the inspector verifying compliance with the water management regulations set out in water and environmental permits.

[9] Ordinance (2014:214) on dam safety.

1.4 Applicability and structure of the guidelines

The guidelines apply to all member companies engaged in hydropower activities. Classification of dams with regard to consequences in the event of a dam failure is a basis for the application of RIDAS.

Other methods, technical or organizational, then described in RIDAS today - can be applied provided that the same level of dam safety can be obtained. These deviations must be motivated and documented.

RIDAS comprises this main document with eleven chapters[10] and associated *application guidance* documents. The latest editions are available on the Swedenergy member portal.

Figure 1 illustrates the structure of RIDAS with chapters 2 to 11. The *risk management* structure for a particular facility is described in the inner box. General conditions and tasks, such as the dam safety assessment, are described around the box.

Chapter 2 contains the dam safety policy upon which the guidelines are based, supplemented by guiding principles. It also describes the concept of safety management and general rules governing the design of the company's *safety management system* in relation to dam safety.

Chapter 3 describes how dams and *dam facilities* are classified, forming a basis for specifying requirements governing general dam safety activities among the member companies as well as requirements at the level of the facility.

Chapter 4 describes how a *dam safety assessment* is carried out at a dam facility and how it culminates in measures to address identified *risks*. This assessment is centred around the adverse events the consequences that the dam safety activities are intended to prevent and limit. Dam failure is the ultimate adverse event.

Chapters 5 to 10 describe the activities carried out at each dam facility according to existing practice or according to the dam safety assessment performed as described in Chapter 4. These tasks are classified as risk treatments and are contained within the large blue box in Figure 1. The chapters describe tasks which, to varying degrees, culminate in preventive measures that reduce the likelihood of adverse events, or in measures that limit their consequences.

Chapter 11 describes the activities undertaken by Swedenergy and the member companies with regard to follow-up, experience feedback, auditing and management review.

[10] References to a chapter refer to the main document as well as the accompanying application guidance document. References to a section refer specifically to the text in the section.

To support the application of RIDAS, a list of terms and their definitions has been created.[11]

Figure 1. RIDAS structure with risk treatments for a dam facility in the inner box, as well as general conditions, classification, dam safety assessment and follow-up.

[11] Application guidance document 1 - RIDAS Terminology.

2. Dam safety policy and safety management

It is a basic premise of dam safety activities that they are performed responsibly and with effective cooperation with authorities and other stakeholders.

The legislation – which is briefly described in section 1.2 – is the foundation for responsible dam safety activities. This foundation is supplemented by the member company's assessments and adopted policies, as well as systems for and application of *safety management*.

The *dam safety policy* developed by Swedenergy is presented below. Also described are safety management and the requirements governing the design of the company's safety management system in relation to dam safety.

2.1 Dam safety policy

Swedenergy has formulated the policy that underpins the guidelines in this document as follows:

> *The member companies' dam safety activities are aimed, as far as reasonably practicable, at protecting human life and health and preventing civil society being placed under severe strain, but also takes account of other protection needs.*
>
> *Dam safety is kept at a high international standard.*

On the basis of this policy and the relevant legislation, the following guiding principles are applied to a member company's dam safety activities.

- The consequences of a dam failure determine the dam safety requirements.
- Dam failure is prevented as far as reasonably practicable.
- A cautious approach is taken with regard to the degree of uncertainty.
- The consequences of dam failure are reduced with effective planning.
- Dam safety activities are planned and managed on the basis of an analysis of operational risks and an assessment of safety.
- The activities are carried out systematically to form a basis for standardised assessments.
- The activities are carried out with a long-term perspective and are aimed at continuous improvement.

2.2 Safety management

Safety management is concerned with how a member company manages its safety activities and covers dam safety as well as other safety-related areas. Such safety related areas may include protection of facilities, protection of the public, protection of information and IT systems, fire protection, electrical safety and the work environment. It may be useful to address all these issues in one *safety management system*.

The Environmental Code[12] and the Ordinance on self-regulation by operators[13] contain fundamental rules that a member company must apply to its dams regardless of the dam safety class.

A member company with dams in dam safety class A, B or C is subject to special rules on the safety management system according to the Environmental Code[14], the Ordinance on dam safety[15], Svenska kraftnät's checklist for safety management systems[16] and guidance on safety management systems[17]. The rules require a member company to establish and adhere to a safety management system, which must be described in a document in that also contains overall objectives and principles of action.

The safety management system must cover the methods, routines and instructions to be defined and applied under:

0 Overall control, documentation and information management.

1 Organisation, tasks, responsibilities and competence requirements.

2 Identification and assessment of the risk of serious accidents.

3 Operation, condition monitoring and maintenance.

4 Change management.

5 Planning for emergency situations.

6 Audit and review.

[12] Environmental Code (1998:808).

[13] Ordinance (1998:901) on self-regulation by operators.

[14] Environmental Code (1998:808) Chapter 11 Sections 24-26.

[15] Ordinance (2014:214) on dam safety Section 5.

[16] Checklist - Safety management systems and routines for self-regulation of dam safety (Svenska kraftnät 2018-06-12).

[17] Safety management system, overall safety assessment and annual dam safety reporting. A guidance from Affärsverket svenska kraftnät according to Sections 5-8 Ordinance (2014:214) on dam safety. Version 1.2, 2023-11-28.

RIDAS assists the member company in implementing the above requirements, and for a number of tasks it may be appropriate to refer directly to RIDAS.

The following clarifications of the points described above should be taken into account in the member company's safety management system for dam safety.

Regarding point 0, the member company draws up a register of all its dam facilities and dams with a dam safety class.

Regarding point 2 and requirements concerning the company-wide analysis of dam safety risks and vulnerabilities, note that this analysis is related to the risk and vulnerability analysis to be carried out by the owner of generating facilities with importance to the electricity supply according to the Electricity Preparedness Act[18]. Dam safety assessment is central for the identification of risks at dam facility level (see chapter 4).

Regarding point 3, the member company establishes routines for following up daily operation, maintenance activities and changes over time to maintain safe operation and take the necessary decisions on measures (cf. Chapter 4).

Point 4 involves the establishment of routines for changes concerning classification, acquisition, disposal and decommissioning of dam facilities.

The requirements mean all work carried out must be documented. This makes it possible to follow up how the system described is actually used and establishes a basis for experience feedback and continuous improvement of the safety management system as described in point 6 above (cf. Chapter 11).

The input of a member company's management team is essential in the development and application of the dam safety management system. This input includes knowledge of the legislation and the definition of objectives and guiding principles. It also includes the management team's access to up-to-date information and the ability to make decisions about measures to improve dam safety.

[18] Electricity Preparedness Act (1997:288) Section 4.

3. Classification

Dams and dam facilities are classified in terms of the following requirements:

- General dam safety requirements under the Environmental Code and RIDAS.
- Special emergency requirements under the Civil Protection Act.
- Special protection requirements under the Protection Act.

The above classification provides a basis on which requirements can be specified for general dam safety activities among the member companies, and also at the level of the dam facility.

3.1 Classification according to the environmental code and RIDAS

All dams owned by a member company are classified in terms of the potential consequences of dam failure. If a dam facility consists of several dams, they are each classified separately.

The classification determines planning, design, maintenance, instrumentation, surveillance, reporting to authorities, supervisory fees, and competence requirements for people performing tasks relating to dam safety, and it provides a basis on which decisions can be taken about dangerous activity and the need for protection.

The Environmental Code[19] and the Ordinance on dam safety[20] contain the basic provisions governing the dam classification. These are supplemented by Svenska kraftnät's regulations[21].

In summary:

- The dam owner must prepare a *consequence assessment* describing the potential *consequences* of dam failure and suggest a *dam safety class* to the county administrative board, which then makes a decision.
- The consequence assessment is updated as necessary and reviewed in the context of the *overall assessment* of dam safety. The same applies if there are permanent changes in the surroundings of the dam facility and also if notifiable repairs, modifications or other measures are undertaken that seriously alter the consequences for civil society.

[19] Environmental Code (1998:808) Chapter 11 Sections 24-26.

[20] Ordinance on dam safety (2014:214) Sections 2-4.

[21] Svenska kraftnät's regulations and general guidance on consequence assessments (SvKFS2014:1).

3.1.1 Dam safety classes

Dams are assigned to dam safety class A, B, or C under the Environmental Code following a decision by the county administrative board, or to dam safety class D or E under RIDAS following a decision by the member company.

The consequences of dam failure must be described in the following terms according to the Environmental Code[22]:

1. Loss of human life.
2. Destruction of national cultural heritage areas.
3. Disruption to the power supply.
4. Destruction of infrastructure.
5. Destruction of or disruption to socially important activities.
6. Environmental damage.
7. Financial damage.

The potential consequences of dam failure are examined in descending order from dam safety class A to E as shown below.

If the risk (likelihood) of loss of human life is not negligible, a dam is assigned to dam safety class A or B.

If the consequences in points 2 to 7 above are important to civil society, a dam is assigned to dam safety class A, B or C depending on the severity.

If the risk of loss of human life is negligible and the other consequences in points 2 to 7 above have minor importance to civil society, a dam is assigned to dam safety class D or E depending on the severity as described below.

The boundary between dam safety classes D and E is up to the member company to decide as it is the importance for the individual member company that is crucial.

[22] Environmental Code (1998:808) Chapter 11 Section 24.

Dam Safety Class A

Very major importance to civil society, with the potential for dam failure to cause:

- A national crisis affecting large numbers of people and large parts of civil society and threatening fundamental values and functions.
- Non-negligible risk of loss of human life.

Dam Safety Class B

Major importance to civil society, with the potential for dam failure to cause:

- Major regional and local consequences or disruption.
- Non-negligible risk of loss of human life.

Dam Safety Class C

Moderate importance to civil society, with the potential for dam failure to cause:

- Significant local consequences and disruption, but
- Negligible risk of loss of human life.

Dam Safety Class D

Minor importance to civil society but major importance to the member company, with the potential for dam failure to cause significant losses for the member company or private interests in terms of property and other assets.

Dam Safety Class E

Minor importance to civil society and for the member company, with no potential for dam failure to cause significant losses for the member company or private interests.

3.1.2 Consequence assessment

The classification must be based on an assessment of the potential consequences of dam failure. The consequence assessment is based on calculation methods and assumptions that are suitable for the purpose, such as those developed in the context of coordinated emergency planning.

A dam safety class should be proposed on the basis of the failure potentially causing the most serious consequences for civil society. Factors that influence the consequences of dam failure are the location of the dams, the design, the flow scenario, the development of the failure, the areas flooded and what may be affected.

When analysing *scenarios* involving extreme to very extreme flows, the consequences to be taken into account are the incremental damage caused by the failure compared to the normal flow without dam failure.

3.2 Classification/decision on special emergency requirements, etc.

Civil Protection Act[23] with accompanying ordinance[24] contains the rules governing *dangerous activity*.

The county administrative board consults with the municipality and decides which dam facilities constitute dangerous activity, in other words there is a risk that an accident will cause serious injury or damage to people or the environment.

Classification as dangerous activity entails obligations to analyse risks, to inform the authorities, to maintain reasonable emergency arrangements and to undertake measures to prevent and limit damage.

3.3 Classification/decision on special protection requirements

The Protection Act and the Protection Ordinance contain rules governing security protected assets. With the agreement of the owner[25], the county administrative board decides whether to designate a facility as a security-protected asset for electricity supply[26].

If a facility is designated as a security-protected asset, unauthorised persons are denied access and photography may be prohibited, etc.[27]

The owner of a security-protected asset is responsible for ensuring that the area is monitored and clearly signed.

[23] Civil Protection Act (2003:778) Chapter 2 Sections 4-5.

[24] Ordinance on Civil Protection (SFS 2003:789) Chapter 2 Sections 3-4.

[25] Protection Act (2010:305) Section 19 (2).

[26] Protection Ordinance (2010:523) Section 3.

[27] Protection Act (2010:305) Section 7.

4. Dam safety assessment

The *dam safety assessment* is carried out to provide an overall picture of the safety of the facility, with the associated risks and how they are addressed. With a comprehensive and systematic assessment of this kind, it is possible to:

- determine whether the dam facility has a satisfactory safety
- decide on necessary technical and organisational measures
- obtain data for external and internal reporting.

Dam safety assessment takes into account regulatory requirements regarding the analysis of risks related to dam safety, which include:

- *consequence assessment* and *overall assessment*[28]
- analysis of risks related to *dangerous activity*[29]
- investigation and analysis of health and environmental risks[30]
- risk and vulnerability analysis in the context of electricity supply preparedness[31]
- security protection analysis in respect of antagonistic threats.[32]

The methodology of the dam safety assessment is based on the risk management standard[33], *ICOLD* bulletins on management systems for dams in operation[34] and risk evaluation[35], and the publication on the operational safety of dams and reservoirs[36].

In general, the member company develops and applies routines to meet safety requirements and address risks for dam facilities. These routines include periodic follow-up and audit. The routines are proportionate to the extent of the activity and the potential consequences of dam failure.

The dam safety assessment is a central part of these routines.

The dam safety assessment is a continuous and iterative activity that can be carried out in stages and gradually assembled to form a whole. The member company's follow-up of daily operation and maintenance with surveillance, including identification of possible long-term trends, forms part of the information and empirical data on which the assessment is based (cf. section 2.2).

[28] Ordinance (2014:14) on dam safety Sections 2-4 and Section 7.

[29] Civil Protection Act (2003:778) Chapter 2 Section 4.

[30] Ordinance (1998:901) on self-regulation by operators Section 6.

[31] Electricity Preparedness Act (1997:288) Section 4.

[32] Security Protection Ordinance (2018:658) Chapter 2 Section 1.

[33] Risk management - Guidelines (ISO 31000:2018, IDT).

[34] Dam Safety Management: Operation Phase of Life Cycle (ICOLD Bulletin 154).

[35] Risk Assessment in Dam Safety Management (ICOLD Bulletin 130).

[36] Operational Safety of Dams and Reservoirs: Understanding the Reliability of Flow-control Systems (ICE Publishing, 2016).

Figure 2 describes the dam safety assessment within the grey area. It also describes the necessary preparations and the implementation of risk treatments that may result from the assessment.

The questions to clarify the *safety assessment* for which the member company is always responsible, are:

- Does the dam facility have a satisfactory *safety*?
- What *risks* need to be addressed?

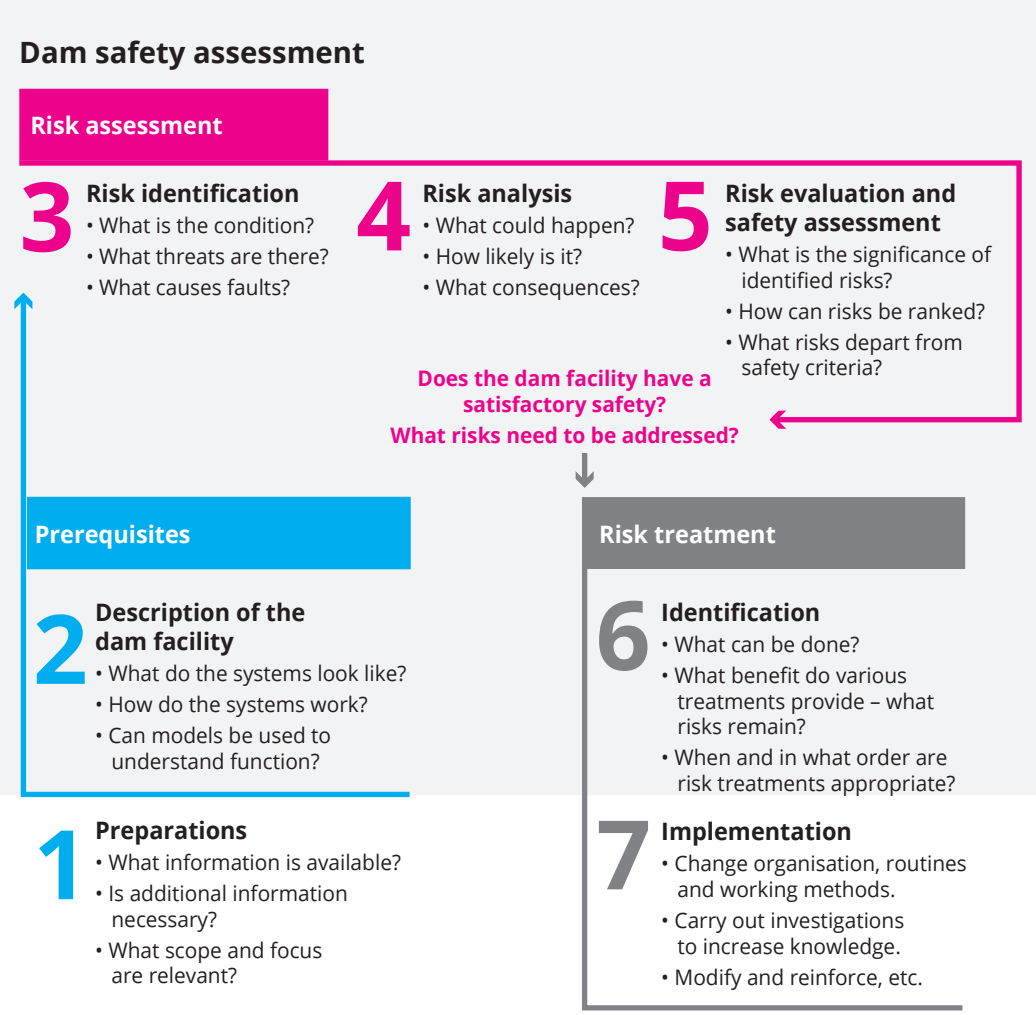

Figure 2. Dam safety assessment – stages and questions.

4.1 Preparations

The dam safety assessment must be prepared in various ways. *Facility information* is collected for the assessment. If any information is missing, additional investigations, calculations and analyses are carried out. The extent, focus and appropriate methods for the assessment are planned and a risk register is set up.

Internal and external resources are secured for implementation.

4.2 Description of the dam facility

The dam facility is described with the help of the questions in Figure 2: what do the systems look like, how do the systems work, and can models be used to understand the function?

In order to systematically identify risks for a dam facility, it is useful to describe the overall systems and the wider context of a dam facility, and also the system comprising the dam facility itself.

Description of links with overall systems forms basis for identifying *threats* and *risks* that they may pose to the dam facility. Knowledge of the overall systems can also form the basis for identifying the risks that the dam facility may expose the environment.

This is linked to the consequences assessment process, with modelling and evaluation of the consequences of dam failure as described in Chapter 3. The hierarchy: *watercourse – dam facility – dam*, is applicable in this context (cf. Section 6.2).

Description of the system of the dam facility provides an understanding of its structure and function. The hierarchy in this case is dam facility – dam – *part of dam*. The system must be described in greater detail in multiple steps regarding the water way, the *spillway gate*, the *hoisting equipment*, etc. until the scope and details are sufficient for the different elements and units of the system.

The three main categories of functions are water retaining, discharging and control (cf. Chapter 9). To understand how the dam facility works, it is helpful to use different types of models including models of water flow/leakage through a dam, dam stability and movements, hydraulic capacity of spillways and water ways, energy dissipation, spillway operation, *protection functions*, etc. The functions involved are described with their performance requirements (cf. *required function*).

The current risk management is described in a general way, taking into account the design and operational conditions of the dam facility, operational experience and the current organization.

4.3 Risk identification

The purpose of *risk identification* is to identify, understand and describe risks. Risk identification is carried out with the help of the questions in Figure 2 which include the condition of the dam facility, any threats, and the potential causes of faults.

Risk identification is based on knowledge of the properties/conditions, functions and deficiencies of the dam facility that entail vulnerabilities that, together with external or internal threats, may pose a risk. Known failure modes is also used in risk identification.

As regards the characteristics/conditions of different units, the identification of risks is initiated with data in reports from inspection and verification tests. *Deficiencies* in relation to the *requirements* set may be shown by reports from in-depth inspection or evaluations of dam safety.

External threats affect the system from the outside and include meteorological, hydrological and seismic events, landslides, the influence of upstream facilities, antagonistic threats, etc. Checklists support their identification.

The internal threats originate in shortcomings from all activities that affect dam safety, namely design, construction, maintenance, operation, emergency planning, organisation, competence and documentation, etc. With well-designed routines, the member company can influence and control internal threats. Here, too, checklists support identification.

Knowledge of failure modes, i.e., the way in which the inability to perform the required function occurs, is available in checklists that can be supplemented by information about events and accidents that occur regarding dam safety.

The risks identified are entered in the risk register and assigned to one or more of the main functions of water retaining, discharge or control function.

Based on established descriptions of systems and functions, the processes and chains of events – cause and effect – that can lead to dam failure are analysed.

4.4 Risk analysis

The purpose of *risk analysis* is to understand the nature and characteristics of the risk and the risk level of the identified threat. The risk analysis is carried out with the help of the questions in Figure 2 which include what can happen, how likely *sequence of events* is, and what the consequences might be.

Dam failure is the most serious adverse event that can occur from the point of view of dam safety. The two main types of scenarios that can result in dam failure are *overflow* and *disintegration* of the dam and/or the foundation. A dam can overflow because the inflow to the reservoir exceeds the discharge capacity of the spillway, the spillway is unavailable, or the height of the dam is too low. Disintegration may be caused by problems with water tightness, stability and durability.

Vulnerabilities are analysed to determine the likelihood of occurrence and which functions could be affected. It is also important to analyse different combinations of vulnerabilities, which individually may have limited effects but together could have more serious consequences.

Scenarios are created by combining vulnerabilities with the expected loads of the dam facility, external threats for the dam facility considering its existing *condition* and functions. The likelihood that a particular *scenario* develops can be analysed in the light of events that have occurred, the failure rate of the constituent subsystems, as well as comparisons against technical requirements.

Different scenarios can also form the basis for an analysis of the potential consequences, which completes the risk analysis.

The risk analysis is forward-looking and includes possible changes in dam safety in terms of degradation, frequency of deficiencies and different external threats.

4.5 Risk evaluation and safety assessment

In the *risk evaluation*, the significance of the identified threats is analyzed and ranked and tested against the defined safety criteria (Figure 2). The risk evaluation covers both technical and organizational aspects.

The member company should define safety criteria relating to the functions and performance of the dam facility. The defined safety criteria should be based on the member company's guiding principles (cf. Section 2.1). Additional support is available from the requirements concerning functions and design set out in RIDAS Chapters 5- 10, from other regulations, and from the latest technical developments. The member company may choose to apply criteria other than those resulting from RIDAS, but differences must be justified and documented.

Identified deficiencies are ranked with the help of the risk analysis in terms of the likelihood of occurrence, the functions potentially affected, and whether they could lead to dam failure.

If a risk means that a defined safety criterion is not met, the assumption is that a *risk treatment* must be undertaken.

If a risk cannot be tested against a defined safety criterion, the ranking helps to determine the order in which it is best to undertake a risk treatment.

If there are a large number of identified deficiencies, this must be factored in so that the overall need for measures does not become overwhelming and difficult to manage.

Risks of very high significance may need to be addressed immediately. This may concern previously identified faults found in systems that are under more or less continuous load. The immediate measures may be temporary until permanent measures can be undertaken. However, the identified *deficiencies* are normally less significant and there is time to address them in normal planning routines.

In the light of the grading, ranking and evaluation of identified and analysed risks, *safety assessment* is carried out for the dam facility.

The safety assessment determines whether the dam facility has a satisfactory safety or if there are deficiencies that require measures (Figure 2). The outcome of the safety assessment may be that the dam:

- has satisfactory safety
- has conditional satisfactory safety
- does not have satisfactory safety.

4.6 Identification of risk treatment

If the risk evaluation and safety assessment show risks that require measures, it is necessary to investigate what can be done, what benefits various measures offer, and what risks remain after implementation (Figure 2). This investigation is a way of identifying appropriate measures and when and in what order it is best to implement them. The aim and extent of the actions are adjusted to the extent and size of the risks, as well as the dam safety class of the dam facility and other relevant conditions

In general, *risk treatment* requires a change in the current *risk management* for a dam facility according to Chapters 5 to 10 (cf. Figure 1). Proposed measures may involve a change in organization, personnel training, investigations to improve knowledge of the dam facility, modified routines for maintenance, operation and emergency management, repairs, modifications and reinforcements.

Compared to the risk management standard[37], the type of measures potentially relevant to dam safety are more restricted. For example, risks relating to dam safety cannot be excluded by use of contracts.

4.7 Implementation of risk treatment

The selection and decision to implement risk management measures are not part of the dam safety evaluation. In some cases, decisions on action may be simple, while in other cases extensive feasibility studies and investigations may be required before appropriate measures are ripe for decision-making and implementation.

[37] Risk management - Guidelines (ISO 31000:2018, IDT).

5. Organisation and competence

The member company ensures that the dam safety activities are properly organised, that the organisation is large enough, and that everyone working in the dam safety organisation has the necessary *competence*.

At a member company, many people work with dam safety. Some perform tasks that connect directly to the dam facilities, while others work with issues that may have an indirect impact on dam safety. It is important to create awareness of dam safety issues in the member company as a whole. Communication and information from management is an important part of this.

At a member company, the activities regarding dam safety can normally be divided into the four areas of safety management and dam safety evaluation, operation and preparedness, maintenance and projects.

5.1 Organisation

The member company is responsible for ensuring that personnel involved in dam safety have the necessary resources and powers for their duties. This is true regardless of whether the duties are performed by its own personnel or if outside personnel are engaged. The organisation and allocation of responsibilities and tasks relating to dam safety are defined and documented.

The organisation is designed to facilitate effective cooperation and dialogue between the individuals involved in dam safety.

When changes are made to the organisation of the member company, a dam safety assessment must be carried out.

For the mandatory roles of *dam safety accountable*, the *RIDAS manager* and the *dam engineering specialist* responsible persons appointed in the organisation who usually also act as contact persons for the authorities.

These three roles form the core of the field of safety management and dam safety assessment, with responsibility for the development of dam safety within a member company.

The three other areas of operation and preparedness, maintenance and projects include a number of roles and functions with regard to dust safety. For these areas, the member company can customize roles and functions that best suit the current conditions.

5.1.1 Dam safety accountable

The *dam safety accountable* is usually the most senior executive of the member company – the CEO or equivalent – and is always part of the company's own organisation.

The dam safety accountable is ultimately responsible for dam safety in the company and appoints the RIDAS manager and dam engineering specialist.

5.1.2 RIDAS manager

The *RIDAS manager* is familiar with RIDAS, has documented competence and is always part of the member company's own organisation.

He or she is responsible for application of RIDAS in the member company, for example by helping to develop the safety management system for dam safety. The RIDAS manager is normally the member company's dam safety contact person for Swedenergy.

5.1.3 Dam engineering specialist

The *dam engineering specialist* should be part of the member company's own organisation but the dam safety accountable may in exceptional cases appoint outside individuals.

The dam engineering specialist has documented competence in dam safety, dam design and construction. The dam engineering specialist has thorough knowledge of the dam facilities and the activities carried out there and is continuously active in dam safety.

The work involves providing the member company's organisation with the necessary technical expertise and contributing to the development of dam safety activities.

5.2 Competence

The member company is responsible for ensuring that personnel involved in dam safety have the necessary *competence* for their duties. This is true regardless of whether the duties are performed by its own personnel or if outside personnel are engaged. The employee's individual competence and the member company's collective competence are both important.

Competence is a combination of education and experience. Year of experience working with dams and dam safety can replace a certain amount of education. To a limited extent, the reverse may also be true. Well-developed work processes, support and competence sharing within the member company can to an extent replace the experience requirement at the individual level.

The member company is responsible for ensuring that personnel competence is up to date, and frequent competence development is an important part of this.

The member company is responsible for ensuring that the competence of its own staff is kept up to date through recurring competence development. For hired personnel, the member company sets competence requirements for procurement.

6. Facility information and reporting

In general, a member company is required to develop and apply routines and systems for managing *facility information* and for reporting which are proportionate to the potential consequences of dam failure and to the extent of the activity in general.

A member company ensures that every individual who performs tasks at a dam facility or who performs tasks which may otherwise affect dam safety has access to the necessary facility information.

The legislation sets out reporting requirements, in particular the Environmental Code, the Civil Protection Act, the Protection Act, the Safety Protection Act and the Electricity Preparedness Act.

Furthermore, a member company reports information on dam safety class, reports on events and measures with regard to design flood requirements to Swedenergy, as well as data to the joint dam liability insurance.

Facility information must be systematically managed in order to satisfy statutory reporting requirements and the regulations on *safety management systems*, even if there are no direct management requirements.

The member company appoints individuals with responsibility and establishes channels of communication for reporting, notifications and other communication with authorities relating to dams and dam safety.

Routines and systems for managing facility information and reporting are designed to provide appropriate protection against unauthorised access, distribution and destruction.

6.1 Facility information

Facility information comprises instructions, documentation, data, and plans for measures and changes affecting a dam facility.

Facility information can be grouped as follows:

- operating, maintenance and emergency instructions
- plans for measures and changes
- records, and other information and data.

The scope of facility information for a dam facility varies in terms of its size, age and history of events, investigations, maintenance measures, modifications to the facility, etc.

6.2 Management of facility information

In general, facility information for a dam facility is collected, catalogued and made accessible to meet any needs that may arise.

This can be organised in different ways: a physical location (archive space), an electronic system or combinations of the two may be appropriate depending on the circumstances of the member company.

Facility information is structured and described systematically with reference to the concepts of watercourse, dam facility, dam and part of dam (cf. Section 4.2).

6.2.1 Operating, maintenance and emergency instructions

The member company will formulate the operating, maintenance and emergency instructions that are necessary for the safe management of the dam facility. It is beneficial to have standardised instructions for all dam facilities, including spillway gates and other equipment. Instructions can be grouped into:

- Operating instructions – including surveillance of operation and measurement.
- Maintenance instructions – including inspection and condition monitoring.
- Emergency instructions – including emergency management.

The availability of operating, maintenance and emergency instructions must be guaranteed by providing multiple ways to access them.

6.2.2 Plans for measures and changes

Plans for measures and changes to be applied to a dam facility are documented and managed systematically. Plans should include the risk treatments that result from the dam safety assessment described in Chapter 4.

Planning is preferably based on the needs of an individual dam facility while also taking account of the needs of all the dam facilities involved in the activity.

6.2.3 Records, and other information and data

Records, and other information and data, vary in size between different dam facilities and exist both as electronic data files and as paper documents. They may include correspondence, drawings, calculations, images, descriptions, lists, data and models.

The best way to manage electronic data files is to use a systematic folder structure on a disk space with backup routines. If there is access to an electronic document management system with search functions, it is advisable to manage documents relating to dam safety there as well.

The member company develops a standardised way of describing its dam facilities and documenting work done on them.

Information that may be required at short notice to deal with emerging situations should ideally be made physically accessible at the facility or nearby.

6.3 Reporting

A member company notifies the county administrative board of operational disturbances[38] and, at the request of the county administrative board, submits the information and documents necessary for supervision[39]. If necessary, the member company provides notification in advance of a change to an electricity generating facility[40]. The member company usually also submits a consequence assessment[41] for its dam facilities to the county administrative board. Certain data and events for statistics and feedback are reported to Swedenergy.

In addition to that stated in the above paragraph, member companies with dam facilities in dam safety class C according to the Environmental Code submit a dam safety report every year[42] and, every ten years, an *overall assessment*[43] of the safety of their dam facilities to the county administrative board. The overall assessment is essentially based on the dam safety assessment described in Chapter 4.

In addition to that stated in the above paragraphs, member companies with dam facilities in dam safety class A or B according to the Environmental Code submit an analysis of risks[44] and provide *notification* of serious accidents[45] if the facility constitutes a *dangerous activity*.

Most member companies use *dam owners' liability insurance* for their dam facilities. Dam facilities with dams in dam safety classes A, B and C are covered. Every year, the insurance providers are given information about the dam safety class, etc. for the dam facilities covered.

[38] Ordinance (1998:901) on self-regulation by operators Section 6.
[39] Environmental Code (1998:808) Chapter 26 Section 21.
[40] Electricity Preparedness Act (1997:288) Section 6.
[41] Ordinance (2014:214) on dam safety Section 2.
[42] Ordinance (2014:214) on dam safety Section 8.
[43] Ordinance (2014:214) on dam safety Section 7.
[44] Civil Protection Act (2003:778) Chapter 2 Section 4.
[45] Civil Protection Act (2003:778) Chapter 2 Section 5.

7. Operations and emergency management

In general, a member company is required to develop operational and emergency routines and systems that are in proportion to the potential consequences of dam failure, the characteristics and functions of the dam facility, and current deficiencies.

Operation of a dam facility includes operational measures by remote control or local control, surveillance for operational purposes and activation of personnel for emergency purposes.

Emergency management relating to dam safety is based on well-executed planning and encompasses organisation, resources, plans, routines, collaboration and emergency drills.

As part of operation and emergency arrangements, the authorities are notified of operational disturbances and serious accidents (cf. Section 6.3).

Operational measures, data collected through surveillance, events that have occurred, notifications to authorities and completed checklists for emergencies are documented and archived in accordance with the routines used by the company (Section 6.2). This information forms the basis for subsequent analyses (Chapter 4), reporting (Section 6.3) and experience feedback (Chapter 11).

7.1 Operation and operational measures

Operations are undertaken by the normal organisation with operating personnel and the operations' centre function, including the personnel required for necessary operating measures outside normal working hours.

The member company dimensions its organisation for operation according to the need for operational measures with remote control or local control. For local control, account is taken of the distance to the dam facilities and the operational and safety-related *response time* requirements.

For an *operations centre function*, operational measures include:

- surveillance of water levels
- remote operation of spillway gates
- surveillance of alarms
- deployment of personnel for operational measures and immediate corrective maintenance
- activation/deployment of personnel for emergency response
- surveillance of deployed personnel
- feedback from deployed personnel.

For operating personnel, operational measures include:

- local operation of spillway gates
- manual handling of spillway devices
- local handling of alarms after activation of on-call duty
- feedback to the operations centre function for decisions about:
  - immediate corrective maintenance
  - activation/deployment of personnel for emergency response.

The member company establishes the operating instructions required for the safe operation of the dam facility. Operating instructions cover *routine operation* and *nonroutine operation* and should describe the transition between them in terms of criteria, decision-making and internal information. Non-routine operations mean situations that depart from the norm, such as high flows, severe weather conditions, spillway gate faults, generator breakdown, loss of protection functions, loss of remote monitoring and control, and implementation of certain maintenance measures and changes to the facility.

Non-routine operations may entail operational restrictions, the need to deploy personnel at the dam facility, more frequent operational inspection intervals, extended inspection, etc. Non-routine operations are managed by the normal organisation with the resources that are usually available as well as additional resources if the situation demands it.

7.2 Operational surveillance

Operational surveillance collects the information needed for the operation and management of a dam facility for functional and safety-related purposes. A dam facility is often operated by remote control, so operational surveillance is usually automated and equipped with alarm functions. Operational surveillance is often coordinated with surveillance of power stations and undertaken by the operations centre function.

Operational surveillance relating to dam safety may cover *reservoir levels, leakage* through the dam, spillway gates and fault indications, fire and intruder alarms, and the loss of *protection functions*, remote surveillance and remote control.

The information collected through operational surveillance is compared to defined limit values and planned operations in order to make decisions about operational measures, taking into account the changes that have taken place and can be expected over time.

7.3 Emergency management and planning

Emergency management is generally understood to mean the capacity to respond to *emergencies* and to mitigate their consequences. With regard to dam safety, emergency management also includes the ability to carry out actions to prevent a *sequence of events* from developing into a dam failure.

The emergency management can vary widely depending on how different sequences of events develop.

The emergency response aims to establish and maintain the ability to:

- prevent the development of harmful situations
- issue *alarms* and *public warnings*
- limit damage
- limit consequences in general.

Well-executed emergency planning improves the capacity to undertake measures. The results of emergency planning by a member company include:

- instructions for special functions and roles
- facility-specific information and routines for emergencies
- a *dam safety organisation* designed to meet emergency requirements
- plans for emergency drills, review of emergency plans and routines
- plans for collaboration and emergency drills with outside organisations.

Emergency planning should be coordinated with other emergency and crisis management planning within the member company.

Emergency planning for special roles or functions on constant standby include personnel for the *operations centre function*, the *engineer on duty* and the *operating technician on duty / machine operator*. The engineer on duty may be part of the operations centre function or provide assistance to it. Emergency plans should preferably be designed as checklists.

Facility-specific information and routines for *emergency situations* are developed according to the needs identified in the dam safety assessment described in Chapter 4, or in previously conducted situational analysis.

Plans for emergency drills and routines for regular review of emergency plans following emergency drills or when otherwise necessary are developed and implemented in the activity. Personnel occupying roles and functions on constant

standby should undergo regular emergency drills between everyone and three years depending on the extent and focus of the emergency drills.

For other functions potentially involved in an emergency situation, emergency drills should be planned and undertaken in the activity accordingly.

Responsibility for performing internal emergency drills for personnel should be linked to the line organisation, which implies a responsibility for the immediate superior.

Cooperation with outside organisations may include organisations operating in the watercourse as well as regional and national stakeholders. Continuous cooperation is important in gaining information and knowledge about the activity and its potential consequences. Relevant organisations are other dam owners, the water regulation companies (VRF), county administrative boards, the Swedish Transport Administration, the emergency services, police, military and others.

One forum for such cooperation is the *river group* (älvgruppen) for the particular watercourse, which is organised by the county administrative board. On occasion, the county administrative board initiates regional collaborative exercises. The member companies should help to plan and participate in these exercises.

The member company develops plans for cooperation with outside organisations taking account of the potential consequences of failure of the dam facilities and their geographical location.

National routines for issuing alarms and warnings have been developed by Svenska kraftnät[46]. The member companies are required to adapt their internal routines so that the national routines can be applied.

[46] Larmning och varning vid dammhaveri – Nationella rutiner – Utgåva 2022, Svenska kraftnät 2021-11-15

8. Maintenance

The basic legal requirements governing maintenance are set out in the Environmental Code[47] and in the Ordinance on self-regulation by operators[48].

RIDAS uses and builds upon the standard for maintenance terminology[49]. The content of this chapter clarifies and supplements the standard where necessary with regard to the maintenance of dam facilities.

The member company maintains the facilities forming part of the activity with the aim of minimising any risk of damage to public or private interests. To this end, the member company has routines to verify that equipment for the operation and condition monitoring of facilities is kept in good condition.

The frequency and scope of maintenance are based on the dam safety assessment described in Chapter 4. If a dam safety assessment has not yet been carried out for a facility, the existing scope is used as the basis, with the frequencies set out in the relevant sections below.

Personnel involved in Maintenance are subject to competence requirements, cf. Chapter 5.

Resources are secured to manage and carry out planned and unplanned maintenance activities.

Maintenance is documented, followed up and reported in a form which is suitable for the particular activity so that it can be used as a basis for planning, the dam safety assessment (Chapter 4), and follow-up and experience feedback (Chapter 7).

This chapter concerns maintenance during routine operation. The criteria for and the need for different maintenance in non-routine operation, such as extended surveillance, are described in Chapter 7.

8.1 Types of maintenance

Maintenance can be devided into preventive and corrective maintenance. *Preventive maintenance* is subdivided into *predetermined maintenance* and *condition-based maintenance*. *Corrective maintenance* is subdivided into *immediate* and *deferred corrective maintenance*.

The member company uses preventive maintenance to proactively reduce the likelihood of degradation of critical parts of the dam facility. Preventive maintenance is the basis on which facilities are kept in good condition.

[47] Environmental Code (1998:808) Chapter 11 Section 17.

[48] Ordinance (1998:901) on self-regulation by operators Section 5.

[49] Maintenance – Terminology SS-EN 13306:2017.

Condition monitoring, inspection or compliance tests are carried out as predetermined maintenance at established intervals and are supplemented with condition-based maintenance if necessary.

The facility owner has a defined process to assess the severity of a fault and the urgency with which corrective maintenance must be carried out.

8.2 Maintenance planning

The maintenance requirement for a dam facility depends on the dam safety class, the current *condition* and function of the facility and other safety-related requirements.

When maintenance measures are planned, a risk evaluation is carried out if the measure could potentially reduce the availability of units critical for dam safety.

Maintenance is planned, undertaken and followed up systematically, preferably aided by *maintenance plans* (cf. Section 6.2.2). Maintenance plans are updated as necessary and are always reviewed when changes are made to the facility.

8.3 Maintenance activities

In dam facilities, different types of inspections and other *maintenance activities* are carried out with varying purposes, scopes and frequencies as follows, (the five first activities are included in the generic term surveillance):

- operational inspection
- inspection
- in-depth inspection
- condition monitoring
- compliance test
- function check-out
- routine maintenance.

Instructions for these activities may be specific to a single facility or general and applicable to multiple facilities.

8.3.1 Operational inspection

The purpose of the *operational inspection* is to detect changes and identify faults or conditions that may affect the safety and operation of the dam facility.

The operational inspection is a visual check of the parts of the facility, often concentrating on those parts which are particularly important from a safety point of view.

The operational inspection is carried out according to instructions describing the scope and focus. It is normally documented using a checklist covering the checks that are performed.

The operational inspection is normally carried out at between weekly and monthly depending on the dam safety class and other factors.

8.3.2 Inspection

The purpose of the *inspection* is to identify and evaluate faults and degraded states.

The inspection includes a visual check of the parts of the facility that are important from the point of view of dam safety, preferably in combination with the compliance tests. The scope of the inspection depends on the particular facility and the dam safety class of the dams contained in it. The inspection compares the current condition to the originally intended design and function, taking into account any changes that have subsequently been made.

The inspection is usually carried out according to instructions describing the scope and focus. The inspection includes a review of documentation from the operational inspection and the compliance tests.

The inspection is normally carried out at least once a year. For facilities which operate under different conditions over the year, such as reservoirs with a large *operating range*, it is advisable to conduct inspections at both low and high *reservoir levels*.

8.3.3 In-depth inspection

The purpose of the *in-depth inspection* is to obtain an overall expert assessment of relevant information and an assessment of dam safety based on a comparison of the existing situation with the currently applicable requirements.

A detailed visual check identifies faults and degraded states. The interaction between faults and degraded states, results from dam measurements and the changes expected over time are analysed and evaluated.

The in-depth inspection covers all parts, units and functions in the facility that are important to dam safety.

The in-depth inspection is usually carried out according to instructions describing the scope and focus. The in-depth inspection includes an analysis of operational experience and results from other inspections, compliance tests and condition monitoring.

The in-depth inspection is carried out at least once per five-year period for facilities in dam safety classes A and B, and at least once per ten-year period for dam safety classes C and D.

8.3.4 Condition monitoring

Condition monitoring consists of dam measurements to analyze the condition and function of the dam facility. Conditioning monitoring also includes operational surveillance as described in Section 7.2.

Measured data is collected for the purpose of tracking and evaluating any changes and forming a basis for a long-term assessment of the condition of the facility.

There are no clear boundaries between condition monitoring with dam measurements, operational surveillance and the operational inspection. Operational surveillance also includes the surveillance necessary for the perimeter security of a facility.

The need for condition monitoring of a dam facility is determined in a facility-specific analysis, normally in the context of the dam safety assessment described in Chapter 4.

8.3.5 Compliance test

The *compliance test* is carried out on all mechanical and electrical systems necessary for operation and condition monitoring of the dam facility, for the purpose of verifying and maintaining high standards of safety/functionality. Apart from discharging and ice prevention systems, this also includes water level measurement and systems for dam measurements, condition monitoring, alarms and communication, etc. Auxiliary civil structures with importance to dam safety are also covered. Examples include drainage, water level pipes and post-tensioning tendons.

Facility-specific instructions/checklists are created for compliance tests.

Compliance testing of the discharging systems is preferably carried out once at least annually during a period of normal flow.

8.3.6 Function check-out

The *function check-out* is a technical check that the component and/or system still works as required after work has been done or a modification has been made.

The function check-out is always carried out after measures have been undertaken and covers the parts and units in the facility that may have been affected by the measures.

8.3.7 Routine maintenance

To maintain high standards of dam safety, it is important to carry out *routine maintenance* for recurring needs. Routine maintenance is a prerequisite for a well-functioning facility.

9. Construction and design

This chapter applies to existing dam facilities, dams undergoing modifications, and the construction of new dams. Assessment of the safety of existing dam facilities is carried out in accordance with Chapter 4 with the related application guidance.

A dam facility is a system containing water retaining, discharging and control functions. The safety of the facility is dependent on the different functions and particular emphasis is given to the function's safety and their relationship during construction and design of the facility.

The purpose of the water retaining function is to store the water and create generating head and consists of elements such as the foundation and different types of dam structures.

The purpose of the discharge function is to pass water from the reservoir to the watercourse or the downstream reservoir. This is normally done using spillway gates and water ways with energy dissipators. Spillway gates and power stations with intake gates have both a water retaining and a discharge function.

The control function consists of various technical systems that usually require an operator to control and monitor the dam facility. The People, Technology and Organisation (PTO) perspective is of great importance in construction and design.

Dam facilities are usually located one after another along a watercourse, requiring coordinated water regulation. A system-wide perspective for the watercourse with tributaries is therefore often necessary in construction and design.

The dam facility and its essential components should be designed and constructed to be accessible in all operating situations.

The facility has perimeter security to prevent unauthorised access, in accordance with the requirements and the general needs of the member company.

9.1 Loads and design assumptions

A dam facility is designed and constructed so that in any given situation, there is a technically and financially reasonable level of safety against dam failure. The more serious the potential consequences of dam failure, the higher the level of safety required. Design assumptions and technical solutions can therefore be differentiated according to the dam safety class.

The *loads* considered are permanent loads, variable loads and accident loads. The construction is designed so that the serviceability limit state and ultimate limit state are not exceeded. The dam facility is designed and dimensioned to withstand combinations of loads and conditions.

The *design flood* of a dam facility is determined on the basis of the consequences that a failure could entail in connection with high to very extreme flows, in addition to the consequences that these flows themselves entail (marginal damage), using the methodology in the current guidelines[50].

Account is taken of aging phenomena, changes in climate, and new knowledge in different fields that may alter the design assumptions.

9.2 Water retaining function

The purpose of the *water retaining function* is to store water and create a head, and is performed by a number of subsystems:

- reservoir bottom and banks
- foundation
- embankment dams
- concrete dams
- other dams
- abutments
- spillway and intake gates
- power station/intake.

9.2.1 Reservoir bottom and banks

The *reservoir bottom* and banks are investigated for the desired degree of water tightness and stability to limit *leakage* from and landslides in the reservoir.

9.2.2 Foundation

The *foundation* of the dam facility consists of rock or soil with sufficient water tightness, evenness, stability and carrying capacity to support the dam body and the relevant loads.

The foundation is laid on a cleared and prepared surface. Steps are taken if necessary to achieve sufficient water tightness, to address uplift and leakage, and to avoid instability and internal erosion.

[50] Guidelines for the determination of design floods for dam facilities, 2022, Svenska kraftnät, Energiföretagen och SveMin.

9.2.3 Embankment dams

An embankment dam is a dam consisting primarily of a packed filling of earth or fragmented rocks. An *earth-filled dam* usually consists primarily of the natural earth, and a *rockfill dam* usually consists primarily of fragmented rocks.

Embankment dams are normally divided into zones with different characteristics and functions:

- An impermeable zone, often a compacted earth core, which limits leakage through the dam.
- Filter zones, which prevent fine material being carried away and drain the water from the impermeable zone.
- Support fill, which gives the dam stability.
- Erosion protection, which protects against the effects of waves, ice and precipitation.

The impermeable zone may consist of materials other than earth, such as concrete, bitumen, steel or wood. It can be located inside the dam or on the upstream side.

If necessary, a toe berm is created to improve stability and safety in the event of a large leak. The need for a toe berm is considered primarily for dams in dam safety classes A and B.

9.2.4 Concrete dams

A *concrete dam* is a dam consisting mainly of concrete. The spillway system and power station are often parts of the water retaining function and are normally made of concrete.

Concrete dams can be subdivided into gravity dams and *arch dams*.

There are many different designs of gravity dams, and they are mainly stabilised by their own weight. The most common types are:

- *Solid gravity dam*, which is a dam with a uniformly solid cross-section.
- *Buttress dam*, which normally consists of a front slab supported by buttresses or supports.

Gravity dams also include *RCC dams* (roller compacted concrete), a solid gravity dam type made of concrete with low cement and water content, placed and compacted with earthmoving equipment.

Arch dams are supported by their *abutments* on rock or other concrete structures and are found in various designs, for example single-curvature and double-curvature.

9.2.5 Other dams

Apart from embankment dams and concrete dams, there are also the following dams, which differ in terms of design and function:

- Masonry dams
- Wooden dams
- Sheet pile dams
- Fuse plugs
- Cofferdams.

Masonry dams are made of bricks or stones which are laid with or without mortar, possibly with a watertight concrete layer on the upstream side or within the structure.

Wooden dams are mainly built as wooden box dams which are filled with rocks for stability, or wooden trestle dams usually with a watertight wooden layer on the upstream side.

Sheet pile dams are made of single wall or double wall steel or wooden sheet piles. Sheet pile dams are widely used as temporary structures.

Fuse plugs are designed to withstand a water load up to a certain level, above which they are washed away to discharge the water. They may consist of an erodable embankment dam or concrete blocks for example.

Cofferdams are temporary dams built to allow construction or other work to be done in dry conditions. They are typically embankment dams or sheet pile dams, or combinations of the two.

9.2.6 Abutments

The different characteristics of embankment dams and concrete dams mean that special attention must be paid to *abutments* between them to guarantee safe function. Abutments are designed to optimise integration and water tightness.

Abutments onto the ground can be contrasted with abutments between different dam types and require special designs, especially abutments onto steep slopes.

9.2.7 Spillway and intake gates and other stoplogs

Spillway and *intake gates* and *stoplogs* such as *needle beams* and *valves* form part of the water retaining function when they are closed or partially open.

9.2.8 Power station with intake

As well as being a passage for water for power generation, the *power station* with its intake frequently forms part of the water retaining function.

9.3 Discharge function

The purpose of the discharge function is to pass water, ice and debris from the reservoir to the watercourse or the downstream reservoir.

The *discharge function* is performed by these subsystems:

- Spillway and intake gates with handling system
- Water ways with energy dissipators
- Access routes and spillway bridge
- Power supply
- Heating and ice prevention systems
- Backup and emergency handling systems.

Hydraulic control structures and equipment are designed with reference to safety requirements, operating conditions, water regulation conditions, environmental requirements, etc. There are different categories of hydraulic control structures and equipment that are classified according to:

- Location in the facility (*surface spillway, bottom outlet*).
- Operating type (*primary spillway, secondary spillway*).
- Means of controlling/regulating the flow (active or passive regulation).

Active regulation means regulation with hydraulic control structures and equipment that can be operated, whereas passive regulation refers to self-regulating spillways such as overflow spillways, siphon spillways and fuse plugs.

Spillways with active regulation are equipped with some kind of regulating device to control the discharge. Such devices can consist of anything from manually operated to automatic spillway gates. There are a number of different types of spillway gates, mainly categorised by the construction type of the gates. The most common are *bulkhead gates* and *segment gates*. Other common types of spillway devices are *stop*

logs, needle beams, flap gates, trapezoidal gates, sector gates, roller drum gates and *cradle gates*.

The discharge function of the dam facility must have adequate discharging capacity and must be safe, reliable and accessible when necessary. It must be robust and designed and constructed to meet the applicable dam safety requirements for the particular facility and for the relevant dam safety class.

9.3.1 Spillway and intake gates with maneuvering system

Spillway gates must be able to withstand the design *loads* with satisfactory safety. Intake gates in the closed position are part of the water retaining function and, in this respect, must be able to withstand the design loads with satisfactory safety.

It must be possible to operate spillway and intake gates locally at the dam facility. To operate gates, *hoisting equipment* of various kinds is used, which usually work mechanically or hydraulically and with *redundancy* if necessary. Hoisting equipment must be able to withstand the design loads with satisfactory safety.

9.3.2 Water ways and energy dissipators

The *water way* is the path taken by the water as it passes through or past the facility from the intake to the outlet. Water ways have different purposes, for example generation, discharge, fish migration and locking operations. A discharging water way might consist of an intake, spillway crest, weir, *energy dissipators*, spillway channel and outlet.

Water ways should ideally be designed and constructed with upstream and downstream stoplogs to allow the flow to be stopped temporarily for maintenance and repair.

Energy dissipators are available in different types and are selected according to the flow characteristics. The most common types are stilling basins and obstacles of various kinds including blocks, deflectors and sills.

Fish ladders, wildlife passages, etc. must be designed and constructed in such a way that they do not impair dam safety.

9.3.3 Access routes and spillway bridge

Hydraulic control structures and equipment must be accessible when necessary. *Access routes* to the hydraulic control structures and equipment, for example ladders and walkways, must be safe for personnel and positioned so as not to obstruct gate operation.

The function of the *spillway bridge* is primarily to allow access to the dam, the hydraulic control structures and equipment and the power station. The distance between the bottom of the bridge and the surface of the water must be large enough that the spillway opening is not blocked by debris. Bridges are designed to be wide and strong enough to meet the maintenance requirements

9.3.4 Power supply

The electrical equipment involved in the discharging and control functions of a dam facility must be designed with satisfactory safety for the applicable loads and if necessary, the system must contain *redundancy*.

A backup power facility is an important component of the *power supply system* and is designed with reference to functional and performance requirements.

9.3.5 Heating and ice prevention systems

Hydraulic control structures and equipment that must be operated in winter must be equipped with the necessary heating and *ice prevention systems* if there is a risk of freezing or other effects of the cold.

9.3.6 Backup and emergency maneuver systems

Spillway gates are usually operated with normal handling systems and, if necessary, *backup operating systems* and/or *emergency handling systems*.

Backup operating systems are designed with reference to the functional and performance requirements (speed, lifting power, etc.) for safe discharging, and generally provide the same performance as normal handling systems.

Emergency handling systems usually provide lower performance compared to normal handling systems. Mobile generators may be adequate if there is sufficient time to acquire, transport, connect and bring the equipment into operation in all possible use cases.

9.4 Control function

The *control function* comprises operations centre functions, *control systems* and associated measurement, management and regulation systems.

The water retaining and discharge functions have instrumentation, and the condition monitoring of the dam facility is designed with reference to the identified *failure modes*, condition, design and dam safety class.

9.4.1 Operations' centre function

The *operations' centre function* forms part of the control function and its purpose is to monitor and operate facilities remotely. The operations' centre function is usually centralised, and operates and monitors several facilities, but it can also be decentralised.

In most cases, remote control (operational surveillance and operation) is enabled with a system consisting of computers, communication equipment, peripherals and graphical user interfaces.

The operations' centre function has relevant user interfaces for the instrumentation system of the facility, including a clear presentation of operational indicators, alarm levels and alarm functions. The system is designed so that the operator can easily monitor the operation and condition of the facility in real time in terms of dam safety, for example leakage, groundwater level, movements, temperature and gate position.

The system is designed to provide adequate security against intrusion and cyber- attacks.

9.4.2 Control system

Control system is a generic term for equipment and functions intended to operate, monitor and protect the facility and its electrical and mechanical systems. The control system generally manages a number of systems in the power-generating, water retaining and discharge functions.

The control system is intended to monitor and protect the water retaining function.

The control system is designed for adequate reliability, robustness and security against intrusion, and is designed to facilitate the standardisation of technical solutions.

9.4.3 Water level measurement

The *water level measurement system* consists of gauges upstream and downstream of the dam facility. They are designed and positioned so that the correct level is measured in relation to the water resources management regulations and the location of the spillway. Water level measurement is designed with *redundancy* unless there are special reasons otherwise.

9.4.4 Condition monitoring

The dam facility is equipped with instrumentation suitable for all possible use cases, failure modes and dam safety classes. Measurement software and suitable intervals for evaluation are specified in the context of construction and design.

For water retaining components, for example, the instrumentation may include the measurement of leakage, pore pressure, uplift and movement.

For hydraulic control structures and equipment, for example, the instrumentation may include the measurement of gate position, motor currents and temperature. Gate control systems are equipped with functions for operation and indication, and also protection and locking functions.

Remotely operated discharging systems are equipped with devices to ensure that the part of the facility being operated does not exceed its limit state.

9.4.5 Dam Overtopping Protection System (DOPS)

DOPS is a local *protection system* that is independent of the normal control functions and is activated when the normal operation of spillway gates does not work. The protection automatically opens one or more spillway gates at defined water levels. The protection is designed with effective security to prevent unintended activation.

DOPS is installed with reference to the critical fill time, the circumstances in upstream and downstream facilities, and the dam safety class. Reservoirs with a long critical fill time do not normally require DOPS.

10. Execution of projects

In general, member companies will develop and apply routines for their projects that are proportionate to the potential consequences of dam failure, the size of the project, and the exposure to risk during execution. For project activities in general it is assumed that the member companies have defined routines for project initiation, planning, design, execution, and completion.

When modifications to the facility and other measures with importance to safe dam operation are executed, special attention must be paid to dam safety. This applies to all stages from planning through design/construction to physical execution and the subsequent function check-out. Cooperation between everyone involved is a key factor in guaranteeing the best possible result in terms of dam safety.

This guideline also applies to the construction of new dam facilities. Requirements and routines for executing projects are described below.

10.1 Planning with reference to risks in execution

The choice of method for work affecting dam facilities may have an impact on dam safety in the execution stage.

Projects that reduce the discharging capacity of a dam for a certain period are planned with reference to the hydrological conditions in the watercourse. Both before and during execution, cooperation and information sharing is necessary with other dam owners in the watercourse and water regulation companies concerning downtime planning and reservoir release capacity constraints.

The planning should favour execution during periods when there is a low likelihood of flows exceeding the available discharging capacity. Even so, plans are developed to handle a flow exceeding the available discharging capacity by means of measures prepared in advance.

Where projects cause hydraulic control structures and equipment that are normally used for water level regulation or as DOPS to be unavailable, special measures are required in the form of operational planning and non-routine operation.

10.2 Organisation, inspection and monitoring

A coherent organisation is advisable, encompassing all stages from planning to handover of the facility and documentation on project completion. The member company appoints a technical expert with good competence in dam safety to be responsible for the technical review and ensuring that the facility is compliant to RIDAS after the project is completed. The technical expert and the dam engineering specialist have a close collaboration during the project if these are not the same person/resource.

The person responsible for undertaking changes to the facility and other measures, for example the project manager, reports issues with importance to dam safety to the above individual during the project and after completion. Any deviation from RIDAS is documented and included in this reporting.

For projects that may have an impact on dam safety, there are competence requirements for the responsible planners/designers and project managers or equivalent, see Chapter 5. For projects with a substantial impact on dam safety, the member company is justified in specifying competence requirements for other parties, for example, consultants, suppliers and contractors.

Planned measures and facilities are evaluated from a dam safety perspective during the feasibility and design phase. The basis which the decision to proceed with execution is made on must include a report on dam safety aspects based on the results from an expert review. During project execution, working documents and similar items are subject to continuous review before they are used for production, assembly and construction.

Inspectors are appointed to perform continuous monitoring of production, assembly and construction. This monitoring guarantees that materials, work execution and the end result are in accordance with the production documents and working documents.

The measures and facilities that are necessary for project execution, such as operational changes, reconfigurations, cofferdams and other provisional arrangements, are examined before the decision to proceed and before execution, in the same way as the project to which the execution relates. Monitoring of calculations, materials and work execution must also be the same as for the project.

10.3 Cofferdams and other provisional arrangements

A *cofferdam* is a temporary dam structure or construction that allows a site to be drained to enable work to be done on the permanent dam structure or construction.

Where the cofferdam replaces a normal dam, the consequences of a failure are similar to the consequences of a failure of the normal dam. Such cofferdams are subject to the same work execution and monitoring requirements as a permanent dam structure during the construction period. During the operational stage they are also subject to inspection and condition monitoring requirements such as leakage, movement measurements, etc.

Where the cofferdam does not replace a normal dam, a failure will cause the work site to be flooded but there will be no further consequences. The requirements for such cofferdams are based on assessments of the work environment risks and the risk of financial loss.

When cofferdams are designed, it may be permissible to assess the likelihood of flooding and other events in consideration of the fact that the dam will be used for a limited period. For example, this means that less stringent requirements may be applicable when the discharging capacity is designed. Some other design requirements may also be relaxed.

When projects are executed, it may be necessary to replace the normal functions of the facility with temporary equipment and solutions, known as provisional arrangements. This may involve the power supply, surveillance, communication, access roads, etc. Provisional arrangements are designed to have the smallest possible impact on the functions of the facility. For particularly important functions, plans must be made to use backup functions. Procurement of equipment and resources in advance should be considered for backup functions.

Dewatering is carried out with pump conduits made of pipes positioned so that there is no erosion of embankment dams and no impact on other parts of the dam if the conduit breaks.

10.4 Emergency arrangements, condition monitoring and inspections during execution

Before project execution, an emergency plan is created to manage abnormal events and risks that are specific to the project. This emergency plan is communicated to the companies operating at the facility during project execution, with the requirement that all personnel must be informed of events and risks that might have an impact on dam safety. The plan is also communicated to internal personnel who are not directly involved in project execution but who may be involved if an abnormal event occurs. If necessary, the emergency plan is notified to the relevant authorities such as the emergency services and the county administrative board.

Project-specific emergency plans are updated as the project proceeds and briefings are held with affected organisations as necessary.

During project execution, special *condition monitoring* may be necessary. This could include upstream and downstream water levels, leakage flow and movements in cofferdams, dewatering, etc. Condition monitoring can be manual or automated and equipped with alarms. It may be appropriate to increase the frequency of inspections.

While personnel are present in a work area that might be affected by a dam failure or other flood risks, visible and audible alarms may be required to initiate evacuation in abnormal conditions.

10.5 Function check-out

After a modification is made to the facility, a *function check-out* is carried out, see Chapter 8.

The purpose of the function check-out is to ensure that the component and/or system works as required after work has been done or a modification has been made.

The function check-out is always carried out after measures have been undertaken and covers the parts and units in the facility that may have been affected by the measures.

The function check-out tests all functions – both normal and redundant functions. It is particularly important to thoroughly test all safety functions and alarm sequences. The function check-out is headed by a designated function check-out manager.

The function check-out is performed according to a program established in advance and approved by the member company. The function check-out is documented and when the facility can be returned to routine operation, the function check-out manager creates a written report. The report is submitted to the member company, or the individual appointed to be responsible for ensuring that the facility is RIDAS compliant after the project is completed, and to the dam engineering specialist (DS) of the facility.

10.6 Documentation and as-built documents

Modifications to the facility are documented using drawings, reports, images, etc. Operating instructions and maintenance manuals are revised and updated for new or modified parts of the facility.

All documentation about the change to the facility is catalogued and submitted to the member company after the function check-out for archiving in accordance with the applicable routines.

When new documentation is archived, it is also advisable to review the existing documentation and make a record of or mark those parts that are out of date.

For guidelines on *facility information*, see Chapter 6.

11. Follow-up and improvement

The purpose of follow-up, experience feedback, audit and management review is the continuous improvement of dam safety activities within a member company. Audits are carried out by auditors from an organisation which is independent of the company, whereas the other three activities are carried out internally within the company.

The member company usually develops and applies follow-up, experience feedback, audit and management review routines that are proportionate to the potential consequences of dam failure and the extent of the activity in general.

Follow-up in this context is focused on the follow-up that forms part of or is closely related to the operational tasks performed.

Experience feedback is a general process that a member company can apply as part of its systematic improvement activities. Experience feedback includes evaluation of the follow-up that has been carried out.

Swedenergy performs RIDAS audits to ascertain how a member company applies RIDAS in its dam safety activities. A member company may also arrange for audits and reviews to be carried out using specially commissioned experts with international experience or specific technical knowledge.

Management review involves an assessment of opportunities for improvement and the need for changes to the management system for dam safety, including changes in policy and objectives for dam safety activities.

11.1 Follow-up

Based on records from operation, maintenance, emergency arrangements, emergency drills, changes, etc. (cf. Section 6.2), a member company conducts *follow-up* to determine whether the tasks have been performed as planned and in accordance with applicable routines, or whether there are *deficiencies* in these two areas. Each organizational unit that performs duties regarding dam safety carries out annual follow-up of these. Follow-ups relating to an individual dam facility are used as a basis for dam safety assessment in accordance with Chapter 4. Follow-up is documented and reported according to defined routines within the member company.

11.2 Experience feedback

A member company with dams in dam safety class A, B or C develops and applies routines to systematically collect and share the experience gained from follow-ups and events in the activity concerning operation, maintenance, emergency arrangements, emergency drills, changes, etc.

Experience feedback takes place continuously and is compiled every year to build up a record. This is the responsibility of the RIDAS manager, or a person appointed by him or her.

Member companies contribute to experience feedback within the Swedenergy.

11.3 RIDAS audit

The *RIDAS audit* takes place under the direction of Swedenergy and assesses how the member company applies RIDAS and its application guidance documents in its dam safety activities. The audit is an important starting point for developing the dam safety activities of the member company.

The RIDAS audit relates to all activities relating to dam safety. For member companies with dams in dam safety classes A, B and C, the audit assesses the application of the guidelines on safety management, compliance with defined objectives and the general quality of dam safety activities.

For member companies the audits are normally carried out every 7 years.

11.4 Other reviews and audits

A member company may conduct other *audits* with specially engaged expertise with special expertise and international experience. The aim may be to investigate or test the dam safety activities against international practice in general or for any other particular purpose, or for review and consultation in connection with major or qualified modifications to a dam facility. Such audits are carried out as necessary and may be relevant mainly for member companies with dams in dam safety classes A and B.

11.5 Management review

A member company with dams in dam safety class A, B or C develops and applies routines for *management review of dam safety*. Reviews take place at least once a year by the member company's management team, with one individual responsible for planning, execution and documentation.

In the management review, the organisation's management system relating to dam safety is evaluated to ensure that it remains appropriate, sufficient and effective. The evaluation involves an assessment of opportunities for improvement and the need for changes to the management system for dam safety, including changes to the policy and objectives for dam safety activities. Section 2 describes the general requirements concerning safety management. The management review is based on the results of completed external and internal audits of dam safety and for other purposes.

For Swedenergy and its member companies, dam safety is important. Swedenergy works for good dam safety at its member companies by publishing Swedenergy's guidelines for dam safety, RIDAS. The guidelines form the basis for dam safety work according to good practice for member companies in terms of working methods and technical solutions and can also provide support for authorities, consultants and contractors.

The guidelines apply to all member companies in the hydropower industry. RIDAS consists of a main document and associated application guidance documents. The main document describes the dam owner's overall dam safety management. The application guidance documents are more comprehensive descriptions and support the actual dam safety activities. The documents are reviewed and updated regularly to ensure that they are up-to-date and relevant.

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